ADAMS'
COMMON SENSE INSTRUCTION
ON
GAS TRACTOR OPERATION

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A BOOK FOR TRACTOR OPERATORS
WHO DESIRE TO KNOW THE MOST EFFICIENT
METHODS OF MAINTAINING A TRACTOR
AT ITS HIGHEST WORKING POWER

BY
HARRY W. ADAMS

WITH CONTRIBUTIONS FROM MANY OF THE
LEADING TRACTOR AND ACCESSORY
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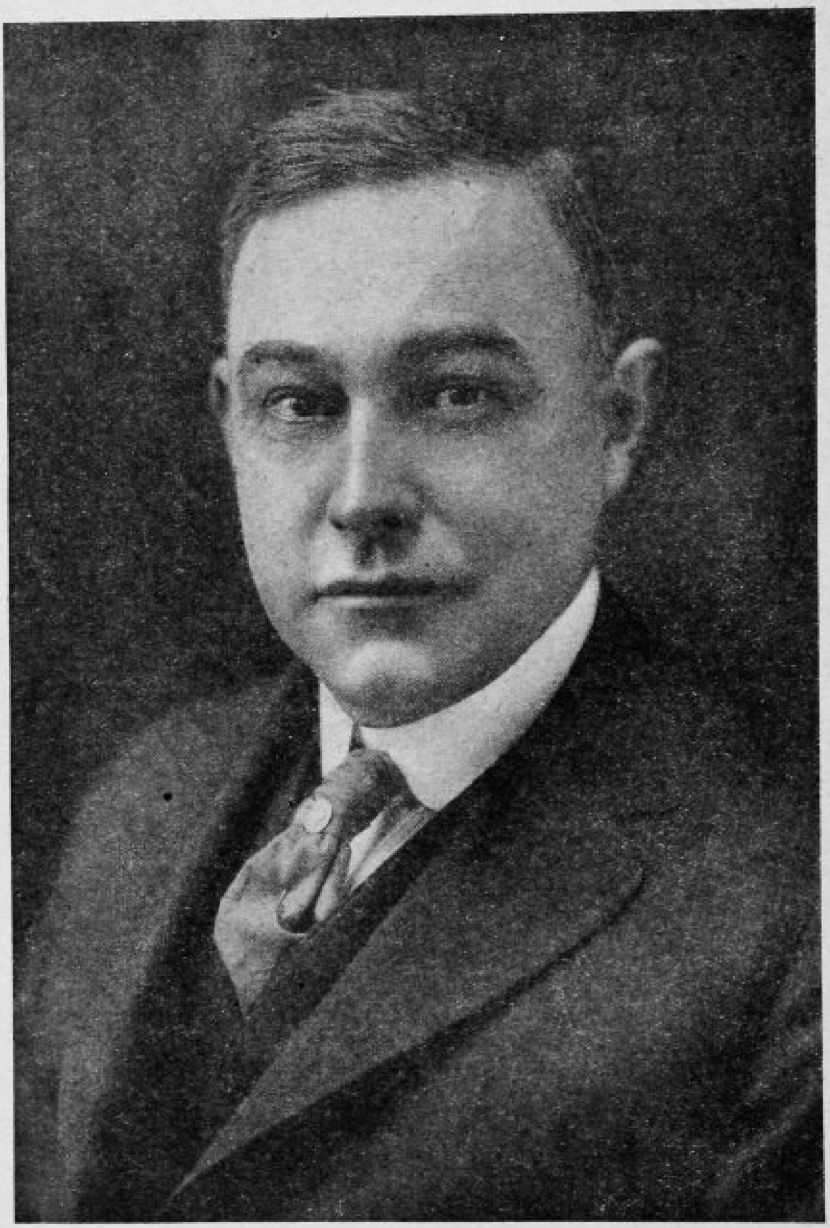

H W Adams

PREFACE

The discovery of the expansive power of steam and the development of the practical steam engine by Watt, was the inception of the era of supremacy of mechanical power, and the decline of animal energy in the mechanical arts. The first steam engine was devised to draw water out of mines with greater celerity than prevailed with animal power, such as wind or falling water; and though crude in form, it was not long before it had conclusively demonstrated its superiority as a prime mover, and was generally used to replace animal power in the industrial establishments and workshops of the day.

When the steam engine had been developed still further, other inventors sought to apply it to the wide field of transportation. Early in the nineteenth century the steamboat contrived by Robert Fulton proved without question that navigation by mechanical power was possible; and a little later, road vehicles were devised that ran without horses. The opposition of the ignorant public prevented further development; and some countries, notably England, passed laws excluding such self-propelling vehicles from the highways. Ignorance has always been a bar to progress; and thus the antipathy of an uneducated populace delayed the development of the modern automobile by over half a century.

While the steam engine and other forms of prime movers soon displaced horse and human power in the field of mechanical engineering and general manufacturing, animal power has remained for years supreme in the oldest and most important industry of mankind, agriculture. In most countries it is the horse. Agriculture is the basis of any country's prosperity. It is the most important of the occupations of man because it furnishes the majority of the foodstuffs that sustain life. A country that cannot grow enough food for its population is always in grave danger; and no matter how large its other resources may be, it is always at the mercy of those states that are able to feed their people.

The increased cost of living, the high prices for the bare necessities of life, and the scarcity of farm labor, demand careful consideration and scientific application of principles in order that the farmer's efficiency may be increased. It is extremely important that the cost of producing the food of man shall be reduced. It is due to this that the farmer's attention has been called to a mechanical power that will increase his efficiency.

The horse has become unprofitable. He is too costly to buy and too costly to keep.

His price has increased 143 per cent in the last 10 years. The cost of his feed, his harness, his barn, his hostlers, has increased. Nothing that concerns the horse has remained the same except his power. He is not one pound stronger today than he was 30 years ago.

Our annual horse cost has grown until it is now equal to our railroad cost. Our 25,000,000 horses and mules consumed food in one year to the value of $2,000,000,000, or as much as the total operating cost of the 250,000 miles of railroad in the United States.

As Edison has said: "A horse is the poorest motor ever built." He eats 10 pounds of hay for every hour he works. He eats 12,000 pounds of food a year. He eats the whole output of five acres, and yet his thermal efficiency is only two per cent.

If a horse were made of steel, like a gas engine, he would not need to be larger than a waste basket or a soap box. Being a hay motor and hay being an exceedingly wasteful fuel, he had to be made enourmously large in proportion to his power. This fact about the horse, that he burns hay for fuel, makes him enourmously expensive.

The laws of business are as inevitable as the laws of nature. Business swings towards lowest cost, as inevitably as the waters fall over the cliff of Niagara. No matter what our theories may be, the horse is going out and the engine is the more fit to survive.

The thermo efficiency of the best steam tractor is only about three per cent, while the thermo efficiency of the gas tractor is about twelve per cent. It is due to this great economy that the gas tractor has become so popular as a mechanical power on the farm. If we expect to substitute this power for the horse, we must understand it as perfectly as the horse. We all know that the horse demanded constant care and attention. He had to be fed, watered, curried, and shod, and often given medical attention. The harness, the bit, the bridle and the wagon required adjustments and repairs.

The efficient farmer understood foods, medicines, and the care and treatment of horses. And he understood just what type of harness bit, and bridle would aid in producing the highest efficiency in the horse. The power which serves us best is that which we best understand.

In order that one may efficiently and economically operate the gas tractor, he must understand the following subjects:

The fundamental principles of the internal combustion motor which are compression, explosive pressure, average pressure, indicated and mechanical horse-power, thermal and mechanical efficiency, oils, fuels, and their combustion.

Laying out flywheels, setting camshafts, timing valves, grinding valves, fitting pistons and piston rings, alignment, babbitting and adjustment of bearings.

Carburetors, elementary electricity, ignition, starting and lighting, magnetos, their timing and wiring, firing order, tractor construction and design,—and distribution of weights, sizes, and ratings.

Clutches, gears, transmissions, shafts, bearings, belts, power transmitted by same, torque on crankshaft, and transmission shafts, sizes and speeds of pulleys, governors, cooling systems, oiling systems.

Having had twenty-five years of practical experience, both in factory and field, with the external, and internal combustion motor, and ten years as instructor in tractor schools.

I have formulated simple rules concerning the operation of the gas tractor, and have devised ways and means for its care and up-keep, which place a practical knowledge of the tractor within the reach of the average operator of today, without the assistance of a technical education.

The aim of this book is to raise the standard of the tractor operator so that he of his own knowledge, will be able to maintain his tractor at its highest working power, thus greatly reducing the cost of production of foodstuffs.—**This Spells Efficiency.**

HARRY W. ADAMS

ANNOUNCEMENT

The writer wishes to acknowledge his appreciation for the valuable assistance, co-operation, and material furnished by the following leading manufacturers, whose product has done so much towards increasing crop production, and reducing the cost of foodstuffs.

Advance-Rumley Thresher Co., La Porte, Ind.
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
The Aultman & Taylor Machinery Co., Mansfield, Ohio
Avery Co., Peoria, Ill.
J. I. Case Threshing Machine Co., Racine, Wis.
John Deere Co., Moline, Ill.
Electric Wheel Co., Quincy, Ill.
Emerson-Brantingham Co., Rockford, Ill.
Gray Tractor Co., Minneapolis, Minn.
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Minneapolis Threshing Machine Co., Hopkins, Minn.
Parrett Tractor Co., Chicago, Ill.

CHAPTER I

FUNDAMENTAL PRINCIPLES OF THE INTERNAL COMBUSTION MOTOR--CARE AND OPERATION

1. The External Combustion Motor. An external combustion motor is one where the heat units contained in the fuel used are consumed outside of the motor itself—like the steam engine, where the heat acts upon an enclosed vessel and vaporates water and forms a pressure that works upon a piston in a cylinder and transforms heat into mechanical energy.

2. Internal Combustion Motor. The internal combustion motor, like the steam engine, is a heat motor, but the B. T. U.'s contained in the fuels act directly upon a reciprocating piston through the pressure formed by the expansion of the burning gases while confined within the cylinder walls or combustion chamber.

These motors are divided into two types: the four-stroke cycle, which is universally used on gas tractors and automobiles today, and the two-stroke cycle which is used mostly for marine work and to a small degree on tractors and automobiles. But this type of motor for various reasons is not very popular. although recently several improvements have been made that appear promising. Therefore we will treat on the former cycle only in these lessons.

Before the student can hope to understand an internal combustion motor, he should familiarize himself with the names and functions of the essential parts of an internal combustion motor, which are:

1. The Cylinder.
2. The Crank Case, to which the cylinder or cylinders are bolted.
3. The Piston, which works in the Cylinder with a reciprocating motion.
4. The Crank Shaft, which is held in position by bearings in the crank case.
5. The Connecting Rod, which forms a link between the reciprocating piston and the rotating crank shaft.
6. The Valves, which regulate the admission of fresh fuel in the form of gas and the escape of exhaust or burned gases.
7. The Cam Shaft, which operates the valves.
8. Cams.
9. The Flywheel, which is rigidly bolted or keyed to the crank shaft and serves the purpose of preserving an approximately uniform motion of the crank shaft under the varying impulses received from the pistons.

3. The Cylinder. The construction of a four-stroke cycle gas motor cylinder in its elementary form is very simple. Such a cylinder merely consists of a single iron casting, open at one end and closed at the other with the exception of two valve openings; one of the openings being the **intake,** and the other the **exhaust** valve opening.

Around this cylindrical vessel, and usually formed in the same single casting, there is a space provided, known as the water jacket, in which water is kept in circulation to conduct the heat of the burning gases away from the cylinder at such a rate that the inside walls are held at a temperature low enough to prevent pre-ignition (which we study later in our lessons), and to insure proper lubrication with which high temperatures seriously interfere.

4. The Piston. This is a device for receiving the pressure of a fluid operating within a cylindrical tube. It usually consists of a cylinder a trifle longer than the stroke of the piston, and fitting within a cylindrical vessel, along which it moves back and forth. It is the essential part of a reciprocating motor; a metal barrel-like cup working in the cylinder in connection with the cranked rotating shaft, whereby the power is usefully applied.

5. Piston Ring. In mechanical engineering, a ramsbottom, or snap ring, fitting into a groove in the circumference of the piston to prevent leakage of gas or other pressures.

6. Connecting Rod. A vibrating link employed to connect a crank or similar rotating part with a reciprocating portion of the mechanism; particularly, the rod which connects the piston pin or wrist pin and crank pin of the direct acting motor and assists in converting a reciprocating motion into a rotary motion.

7. Crank Pin. The cylindrical stud or pin at the extremity of a crank, opposite to the shaft and parallel with it, which affords attachment for the connecting rod by which the crank is turned.

8. Crank Shaft. The main shaft of a motor in which are formed the cranks for converting the reciprocating motion of the piston into the rotary motion of the shafting. The cranks should be located so as to balance the motor both explosively and mechanically.

9. Cam Shaft. A cam shaft is a shaft on which cams are formed for operating the inlet and exhaust valves on a four-stroke cycle motor. This shaft runs half the speed of the crank shaft owing to the fact that we want each valve to open once and close once during a cycle of two complete revolutions of the crank shaft.

10. Cam. A cam is an eccentric with two abrupt sides for opening and closing the valves quickly.

11. Crank Case. The crank case is a housing surrounding the crank shaft and cam shaft. This forms a dust-proof housing, and also prevents the oil from escaping from the motor bearings. It also furnishes support for the crank shaft bearing, and all bearing points inside the crank case housing, to which is also secured the cylinders.

12. Oil Pan. The lower portion of the housing is called the oil pan. This portion furnishes an oil reservoir to furnish the motor with the splash oiling system.

13. Hand Plates. Hand plates or inspection plates are placed on the side of the housing, that makes it very easy to inspect all the bearings within the crank case housing. Under each crank throw just below the oil pan there are sediment pockets where all waste matter in the oil may settle, and they also answer as inspection plates, which may be readily taken off when taking up connecting rod bearing.

14. The Flywheel. The function of the flywheel is to insure to the crank shaft the continuance of an approximately uniform rotation not only through the period of explosion but also through the period that elapses between the completion of one explosion and the commencement of another. It is during this time that the several operations of exhaust, suction, and compression are performed.

15. It would be well for the student at this point to become familiar with the following definitions:

1. Piston Stroke. A piston stroke is the movement in a cylinder of a piston from an in-center to an out-center or vice versa. Let us suppose, for instance, the piston is at zero degree in the cylinder. In order to perform a complete piston stroke it will be necessary for the piston to travel to out-center in the cylinder. The crank will then have traveled one-half of a circle, which will be 180 degrees. A piston stroke is, therefore, 180 degrees travel of the crank pin or one-fourth of a cycle.

It takes four of these strokes, two revolutions of the flywheel, 720 degrees travel of the crank pin, to complete a cycle.

2. Degrees. A degree ($^\circ$) is 1-360 part of a circle, each degree is divided into 60 equal parts called minutes and each minute is divided into 60 equal parts called seconds.

In order to determine the length of one degree on the flywheel it will be necessary to multiply the diameter of the flywheel in inches by 3.1416. This will give the circumference of the flywheel in inches. Dividing this product by 360 will give the length of one degree. Multiplying the number of degrees in each event by the length of one degree will give the length of each event in inches.

Every flywheel has 360° regardless of the diameter.

3. Diameter. The diameter is the distance across a circle or flywheel at the extreme circumference.

4. Circumference. The circumference of a circle or flywheel is the distance around same, and is found by multiplying the diameter in inches by 3.1416. This would equal the circumference of the flywheel in inches. Dividing this product by 360 would give the length of one degree in inches or fractional part thereof.

5. Cycle. A cycle is a series of events. A day is a cycle of 24 hours, a year of 365 days. A cycle is the time that elapses between the repetition of events. In a four stroke cycle motor a cycle is from zero degrees dead center to zero degrees dead center, 720° travel of the flywheel, two complete revolutions of the flywheel or four strokes of the piston.

6. Pressure in Cylinders. In performing the different strokes of the cycle, three pressures are obtained in the combustion chambers, viz.: Normal, Positive and Negative.

   Normal pressure is that pressure which is equal to that of the atmosphere, 14.70 pounds at sea level. Zero pounds gauge normal pressure.

   Positive pressure is pressure higher than atmosphere.

   Negative pressure is lower or less than atmosphere.

A negative pressure is measured in inches, which means inches of mercury in a "U" tube. For example: If we have five inches of negative pressure, or vacuum as it is commonly called, it would mean that there is five inches difference in the levels of the mercury in the "U" tube.

Mercury is 12 times heavier than water; therefore, for each inch of negative pressure or vacuum we would raise water 12 inches. A perfect vacuum equals 30 inches at sea level.

16. The Four-stroke Cycle Motor. The motors used on the majority of tractors today operate on the four-stroke cycle principle, therefrom deriving the name, "four-stroke cycle motors." Our lessons treat on motors of this principle only. The four strokes are:

(a) Firing, power or ignition stroke, 0° to 180°

(b) Cleansing or exhaust stroke, 180° to 360°

(c) Suction or intake stroke, 360° to 540°

(d) Compression stroke, 540° to 720°

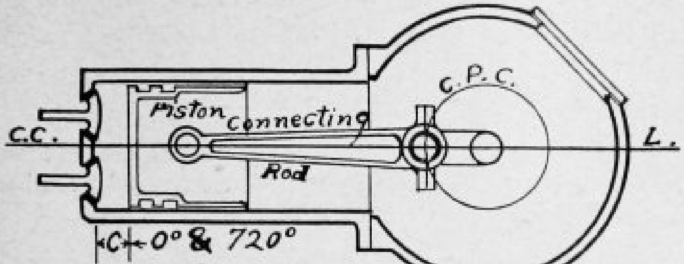


Fig 1

CYCLE STROKES

17. The Power Stroke. It must be understood that the internal combustion motor is not a self-starting motor, and to start same in motion it is first necessary to crank the motor through its cycle until one piston at least has reached 720⁰ (see fig-

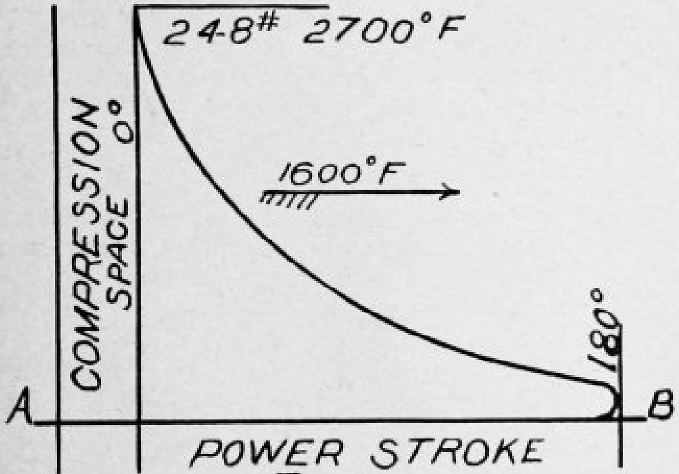


Fig 2

ure 1), which is zero degrees or the beginning of the next cycle. At this point ignition takes place and ignites the charge in the gas motor cylinder which

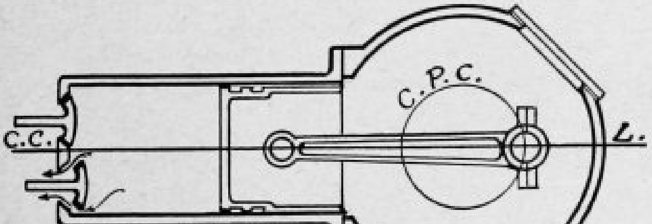


Fig 3

has been previously compressed. The pressure rises to approximately 250 lbs. and a temperature of 2,700 degrees F. At this point the piston starts on its first outward or power stroke, while the pressure gradually drops to near atmospheric pressure at B as shown in Figure 2. The line A-B represents atmospheric pressure or 14.7 lbs. The distance from zero degrees to 180 degrees represents the piston stroke and one-half revolution of the flywheel. The crank is then at the first out center or 180⁰ in the cycle.

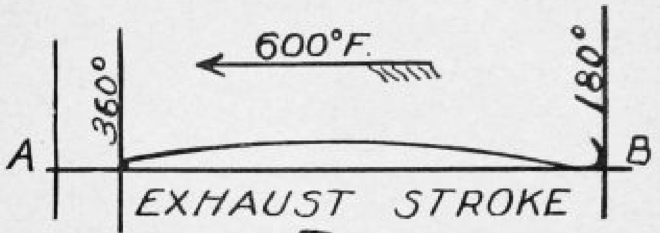


Fig 4

18. The Exhaust Stroke. At this point the exhaust valve opens as shown in Figure 3 and the piston starts on its second or exhaust stroke, the crank traveling

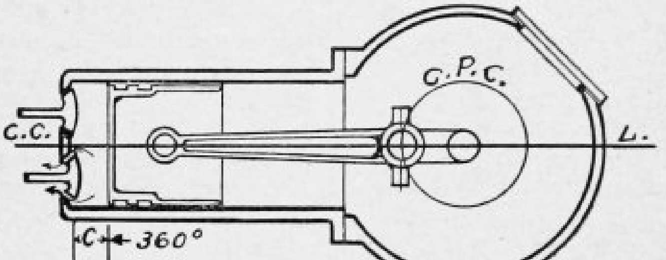


Fig 5

from 180⁰ to in center at 360⁰. This is the exhaust stroke (see Figure 5.) The pressures in the cylinder are shown by Figure 4. At 360⁰ or soon after the

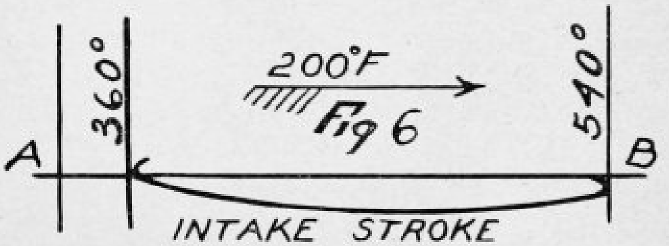


Fig 6

exhaust valve closes, the piston starts on the third or intake stroke.

19. The Intake Stroke. The pressure in the cylinder drops slightly below atmospheric as shown in Figure 6. During this stroke a new charge of gas enters the cylinder and continues to enter until the piston has reached the second out center, 540⁰ (see Figure 7).

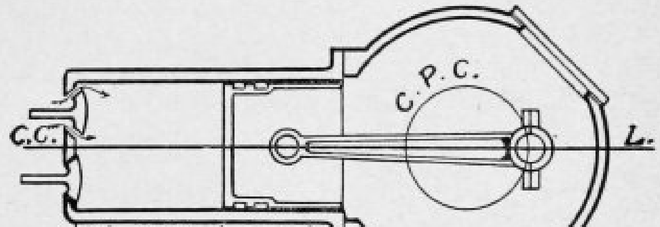
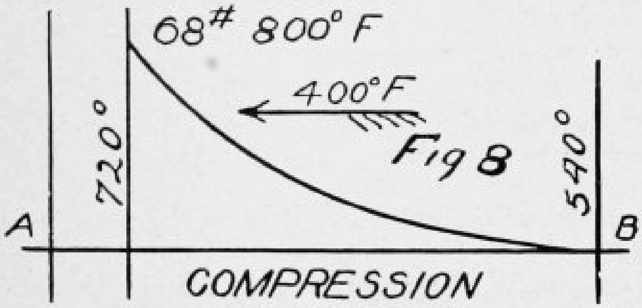


Fig 7

20. Compression Stroke. The intake valve closes soon after the piston starts on its fourth or compression stroke and the charge of fresh gas is compressed to perhaps 68 lbs. pressure. See Figure 8.

At the end of this fourth or compression stroke



the piston again reaches 720° or zero degree, dead center, as shown in Figure 1, and the cycle is renewed second and third time, and so on, continued indefinitely.

21. Referring to Figure 2, it will be noticed that the pressure in the cylinder at the beginning of the power stroke is approximately 250 lbs., and at a temperature of 2,700° F. As the piston travels outward on the power stroke, the pressure drops rapidly to approximately 15 lbs. at 180° in the cycle.

22. Referring again to Figure 4, where the piston starts on the first inward or exhaust stroke, the pressure in the cylinder is slightly positive. The temperature in the cylinder during the stroke is approximately 600° F. (From 180° to 360° in the cycle.)

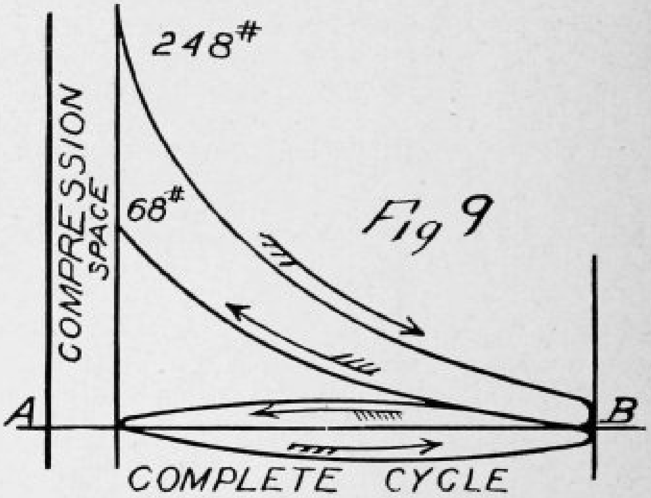
23. In Figure 6 we see the piston is now traveling from 360° to 540° on its third or intake stroke. During this stroke the pressure in the cylinder drops to possibly two inches below atmospheric pressure. The temperature in the cylinder during this stroke is approximately 200° F.

24. Figure 8 shows that the piston is now traveling from 540°, the second out center, to 720° or dead center, on the fourth or compression stroke. The pressure gradually increases until dead center is reached. This pressure depends entirelv upon the relation between the cubical contents of the combustion chamber and the volume sweep of the piston, which will be taken up later.

25. If 68 lbs. compression is carried, the temperature at 720° will be approximately 750° F. Ignition takes place here, and the burning gases generate a high temperature, reaching approximately 2,700° F., with 248 lbs. pressure.

26. Figure 9 represents a complete theoretical indicator diagram combining Figures 2, 4, 6, and 8. These diagrams are taken by what is known as the Gas Engine Indicator, which is a device having a piston and cylinder connected to the combustion chamber of the motor and a drum on which a piece of paper is placed. The drum is connected to the crank shaft in order to revolve it back and forth and keep pace with the piston in that particular cylinder. The pressures act upon the indicator piston, which are counteracted by a spring which is caliberated so as to indicate the pressures in the cylinder at all times. This indicator card is approximately 2½ inches long and 2 inches high when taken on the motor. By the use of this indicator we know at all times the pressures in the cylinder during the different strokes, and by obtaining the pressures the temperatures are also easily calculated.

27. In diagrams 4 and 6, No. 4 shows positive pressure in the cylinder during the exhaust stroke, and No. 6 shows negative pressure during the intake stroke.



Owing to the rapidity of the movement of the piston it is impossible to have the exhaust valves or intake valves large enough to prevent this positive and negative pressure, but on a poorly designed motor we have more positive pressure during the exhaust stroke and more negative pressure during the intake stroke. The greater these curved lines vary from the straight line A-B, the greater the loss in power during these strokes and the less efficient the motor.

In order to lay out flywheels, set cam-shaft, and time the valves, it is necessary to become familiar with certain mechanical terms, as follows:

28. **Cylinder Center Line.** This is an imaginary line running through the cylinder which forms the axis of the cylinder bore and which is equidistant from the cylinder walls at all points, is called the cylinder center line.

29. **Crank Path Circle.** This is an imaginary circle generated by a point at the center of the crank pin as it rotates about the center line of the main crank shaft.

30. **In Center.** The point where the center of the crank pin on crank path circle intersects the cylinder center line nearest the cylinders is called the in-center. The crank is at 360° in its cycle at its highest point in the cylinder.

By studying the diagram showing the imaginary lines of the cylinder and crank-path circle, it will be convenient for the student to familiarize himself with such lines and intersections. See Fig. 10, No. 32 and 33.

31. **Out Center.** The point where the center of the crank pin on the crank-path circle intersects the cylinder center lines farthest from the cylinder is called out center. When the crank pin is out center, the piston is at its lowest point in the cylinder. There are two out centers; first out center is at 180°, second at 540°.

32. **Dead Center.** The point where the center of crank pin on crank-path circle intersects the cylinder center line nearest the cylinders is called D. C. The crank is at 0° in its cycle. At that position the power applied to the piston can have no rotating effect upon the crank shaft.

In the various adjustments of valves, timing of ignition, etc., which will be taken up later, it is necessary to be able to determine how to place the various parts of the motor in certain known positions.

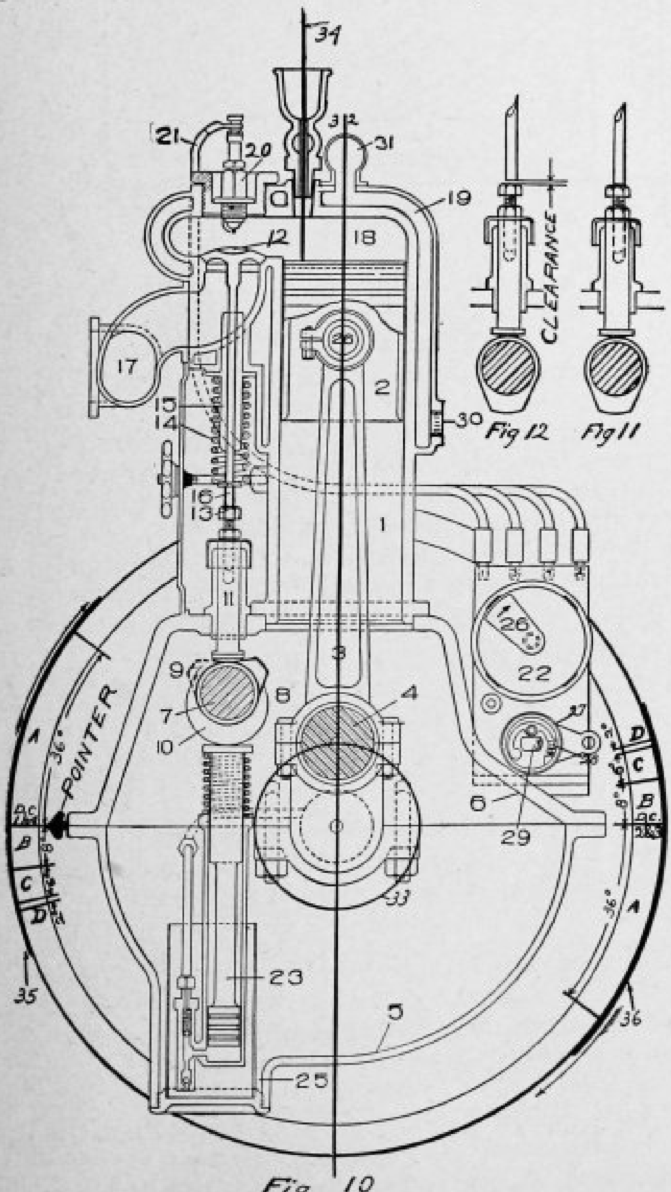


Fig 12 Fig 11

Fig 10

Since the position of D. C. in the motor marks a convenient starting point from which to calculate the time of the occurrence of various phenomena in the operation of a motor, it is necessary to become familiar with rules for determining the position of this point.

33. **The Pointer.** A pointer is a mark conveniently located on a motor which corresponds with marks on the flywheel for determining the position of the piston in the cylinder and the location of the crank on the crank-path circle.

34. **The Pointer Location.** The pointer can be located at any convenient position, but on most motors it is in line with the imaginary cylinder center line. On some gas tractors it is not always convenient to place the pointer at the above position. In such cases it is usually 90° from the cylinder center line, and in line with the division in the crank case in line with the planed surface where the lower portion of the crank case bolts to the main housing. (See Fig. 10.) It is to be remembered that the pointer can be located at any convenient point.

Sometimes a tram, consisting of a piece of heavy wire with the ends sharpened and bent at right angles to the main wire, is used to locate this point. Make a center punch mark at any convenient point on the motor or tractor frame. Have the main portion of the wire long enough to reach to a convenient place on the face of flywheel which may be used as a pointer.

To Find Dead Center on a Flywheel with Marks

35. Rule I. (1) Revolve crank shaft while watching inlet valve of cylinder to be brought to center or zero degrees.

(2) When valve closes, revolve crank shaft one-third revolution farther.

(3) Examine flywheel for center mark, which should now be approximately under pointer.

(4) Move flywheel forward or backward until mark comes directly under the pointer.

36. Rule II. (1) Open priming cock upon cylinder which you desire to bring to dead center or zero degree.

(2) Revolve crank shaft until compression has finished issuing from said stop cock.

(3) Examine flywheel for center mark, which should be approximately under pointer.

(4) Move flywheel forward or backward until mark comes directly under pointer.

37. **To Find Dead Center on a Flywheel without Marks.**

Rule III. Place a straight piece of wire down through the priming cock of the cylinder to be brought to center. Turn flywheel until this wire has traveled up to its highest point in the cylinder. Now revolve flywheel until the piston returns downward again about one inch. Put mark on wire at the top of priming cock and also mark flywheel under pointer. Again revolve flywheel until wire moves upwards and returns downward again until the mark on the wire is level with the priming cock. Then mark flywheel under the pointer, and divide the distance between the marks on the flywheel, which will be dead center. (See 34, Fig. 10.)

To Find Dead Center Mark of a Four-Cylinder Motor

Place wire down through priming cock of cylinder number one, as stated above. The marks obtained would be D. C. for (1 and 4). Repeat the same operation on cylinder number 2 to obtain D. C. for (2 and 3). Sometimes on a horizontal motor you cannot get a wire or stick through the cylinder head. Then it is necessary to work from the opposite or crank end by placing a stick against the end of the piston through the inspection plates and revolving the flywheel until the stick or wire comes to the extreme outward position and travels back about one inch. Mark stick in line with the face of the inspection opening and mark flywheel under pointer. Then revolve flywheel until stick comes out as far as it will go and back to the mark again.

Mark flywheel under pointer. Divide the distance between these marks and the center mark will be out-center for cylinder No. 1, and D. C. for cylinder No. 2. Repeat the same operation on cylinder No. 2, and mark it D. C. number 1. Remember that D. C. number 1 is also dead center for number four, and dea center No. 2 is also dead center No. 3, on a four cylinder motor.

There are 360° between them. If No. 1 is on dead center, No. 4 will be at in-center 360° in its cycle.

If the mark D. C. (2 and 3) is under the pointer, one of them will be on dead center 0°, and the other 360° in its cycle.

Dead center marks on a four cylinder motor are sometimes marked C. C. instead of D. C., meaning center-center, that is dead-center and in-center, both of which are represented by the same marks.

38. Usual Flywheel Marks on a Four Cylinder Motor

1. D. C. 1-4	6. I. C. 1-4
2. D. C. 2-3	7. E. O. 2-3
3. E. O. 1-4	8. E. C. 2-3
4. E. C. 1-4	9. I. O. 2-3
5. I. O. 1-4	10. I. C. 2-3

39. **Cycle Events.** While the piston travels in strokes, the valve operation is laid out in events, and on most tractor motors which travel at 800 piston feet or 9,600 inches per minute, the valve timing has five events. These are (A), (B), (C), (D), and (E), and are termed cycle events. The actual duration of the events are somewhat different in length. For example, the intake event is a trifle more than one-half revolution of the flywheel, and the exhaust is always considerably more.

In speaking of valve timing we always express ourselves in events; in speaking of the movement of a piston we express ourselves in strokes.

Events

(a) Power event..........144 deg. of crank turning effort to 144
(b) Exhaust event........224 deg. of crank turning effort to 368
(c) Internal event........ 6 deg. of crank turning effort to 374
(d) Intake event.........182 deg. of crank turning effort to 556
(e) Compression event.....164 deg. of crank turning effort to 720

(See Fig. 15 and 16.)

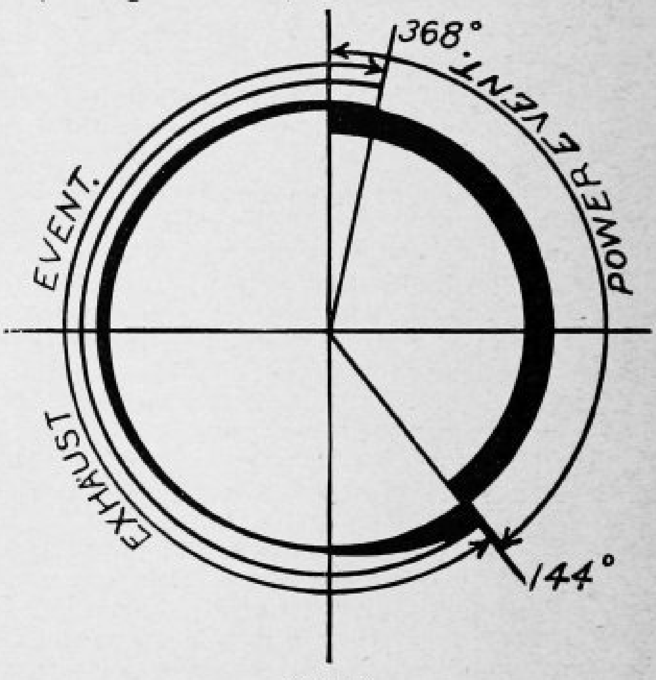


FIG. 15

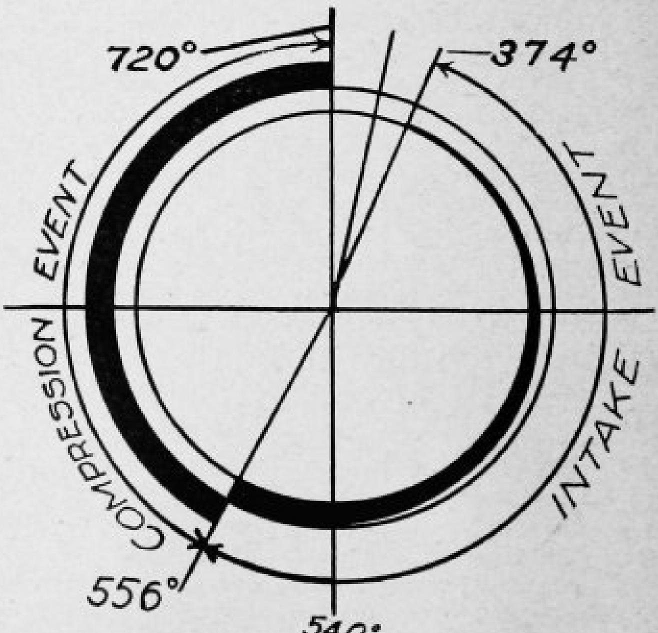


FIG. 16

Adding these five events will give you seven hundred and twenty degrees (720).

See Figures 15 and 16, which show the position of the crank when the valves open and close. The gases in the cylinder during each event are represented by the heavy lines.

40. **The Power Event.** This is the first, and naturally the most important, cycle event; and in most motors it is the shortest of the five. For the present we will consider this as starting when the crank pin passes 0°, D. C., and continuing through 144° of crank turning effort. Nominally one would think that this event should be 180° in length, or be continued until first out center was reached; but note, by the time the crank pin has reached 144°—

(a) The crank throw stands at such an angle that the connecting rod can no longer turn upon it to advantage.

(b) The piston has already moved approximately 11/12 the first stroke, and will not move an appreciable distance as the crank moves the final 36°.

(c) At the beginning of the power event the pressure is very great, sometimes 248 pounds positive; but as this giant pressure moves the piston outward, the chamber above it increases, allowing the pressure to expand. At 144° this pressure has decreased to approximately 25 pounds positive.

Therefore the exhaust valve is opened at 144°, and is permitted an opportune unloading of all pressure upon the piston by the time the crank pin has reached 188°. Then the piston starts on its first inward stroke.

From 188° to 360°, the piston travels inward, and any positive pressure remaining upon it tends to retard its inward movement, causing a consequent loss of power. (See Fig. 15. The heavy black lines represent positive pressure.)

41. **The Exhaust Event.** It has been stated that the exhaust event commenced at 144° in the cycle or 36° early of out-center. From 180° to 360° the piston moves so rapidly that at 360° it has slightly congested the gases ahead of it, although the exhaust valve has been wide open. As long as the pressure is slightly positive in the combustion chamber, more stale gas can be induced to pass out; therefore the exhaust valve remains open even after 360° and even after the piston has **actually started downward.** The closing is supposed to occur upon a normal pressure, or 8° after in center, or at 368°.

42. **The Interval.** A new gas will not pass into the cylinder upon a positive or normal pressure; therefore, there is no need for the admission valve to open immediately upon the exhaust closing. Most up-to-date motors allow an interval of 6° in which the piston moves downward slightly and creates a mild negative pressure. This prevents any **flutterings** or **backfires** in the intake manifold.

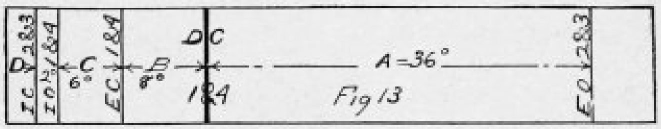
43. **The Intake Event.** Note that when the admission valve opens, the crank pin is 14° after in center, and the piston has already started downward. It moves with such velocity during the major portion of this outward stroke that by the time the crank pin reaches 540° second out center, there is an appreciable negative pressure in the cylinder. As long as there is such a negative pressure new gas can still be induced to enter; but the combined result of leaving the admission valve open after center, and the slight return of the piston, produces a normal pressure at approximately 556°. At this point the intake valve closes.

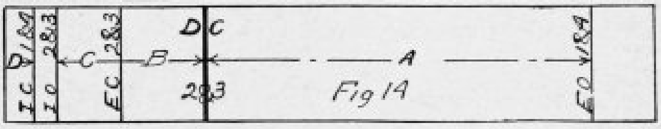
44. **The Compression Event.** In more than one way this event is as important as the rest, and, contrary to the careless thinker, it does not rob the motor of power. It is true that it requires power to force the piston upward from 556° to 0° dead center; but as much power as is absorbed here is given up again, even if no combustion did take place on the power side. Setting aside slight compression leakages, the results practically tally. Further than this, in order to get the new charge to burn correctly and form the correct chemical union, it must be compressed. The compression heats the fuel and thus prepares it to give maximum results upon combustion. The compression on most motors is 68 pounds to the square inch.

45. **Laying Out Flywheel.** To lay out the flywheel, according to the valve timing above mentioned—

After the D. C. marks have been located for (1 and 4) and (2 and 3), take two pieces of paper as shown on fig. (13 and 14), and lay out fig. 13 for D. C. marks (1 and 4), and fig. 14 for D. C. marks (2 and 3). (See Fig. 13 and 14.)

First draw a line across the paper one-third of the distance from one end.





For example, we wish to lay out a flywheel 21 inches in diameter. Refer to table No. 17 by going down the first column to the left until we reach 21. In the second column we find the circumference of a 21-inch flywheel is 65.9736 inches.

In the third column we find 1° equals .1832″. In the fourth column we find the space A equals 6 5-8 inches from the D. C. mark.

Draw a line measuring 6 5-8 inches in the direction of the long end of the paper, across the two pieces of paper, and mark the one which represents D. C. (1 and 4), as shown in Fig. 13, E. O. (2 and 3); and on the piece of paper which represents D. C. (2 and

3), as shown in Fig. 14, mark E. O. (1 and 4). This is 36° ahead of first O. C., out center, where the exhaust valves open, represented by space A on the paper.

The exhaust valves close after D. C., represented by space B, which is shown in the fifth column of Fig. 17 for a 21-inch flywheel, equals 1½ inch. Draw a line across the two pieces of paper 1½ inch back of the D. C. mark. On the piece of paper representing D. C. (1 and 4), mark E. C. (1 and 4); and on the paper representing D. C. (2 and 3), mark E. C. (2 and 3). This is space B, equaling 8°.

The next space is C, which equals 6°. (See Fig. 17, the sixth column, for a 21-inch flywheel). C equals 1⅛ inch. From the mark B, measure 1⅛ inch and draw a line across the two pieces of paper. On the piece of paper representing D. C. (1 and 4), mark this line I. O. (1 and 4). And on the paper representing D. C. (2 and 3), mark I. O. (2 and 3). (See Fig. 17, seventh column.) The space D equals 2° and indicates where the intake valves close. D equals 5-16 inch for a 21-inch flywheel. Measure 5-16 inch from C, and draw a line across the two pieces of paper. On the piece of paper representing D. C. (1 and 4), mark I. C. (2 and 3); and on the piece of paper representing D. C. (2 and 3), mark I. C. (1 and 4). Now we have the paper laid out corresponding with the D. C. marks which indicate where all valves open and close. Notice that the space A and the mark where the exhaust valves open are ahead of dead center and with rotation; and the space B C and D follow D. C., and against rotation.

Now having the flywheel laid out with the D. C. marks (1 and 4), also (2 and 3), lay the piece of paper Fig. 13 on the flywheel with the dead center mark (1 and 4), on the paper corresponding with the D. C. marks on the flywheel with the space A in the direction of rotation. (See No. 35, Fig. 10.)

Transfer these marks to the flywheel. Repeat same with Fig. 14 by placing D. C. marks (2 and 3) over the D. C. marks (2 and 3) on flywheel. Transfer marks as before, and you have the flywheel properly laid out. (See Fig. 10.) No. 35 represents paper Fig. 13, No. 36 represents Fig. 14

Dia.	Cir.	1°	A-36°	B-8°	C-6°	D-2°
15"	47.124 "	.1309"	4 3-4"	- 1"	3-4"	1-4"
16"	50.2656"	.1396"	5"	1 1-16"	13-16"	1-4"
17"	53 4072"	.1483"	5 5-16"	1 1-8"	7-8"	1-4"
18"	56.5488"	.1570"	5 5-8"	1 1-4"	15-16"	9-32"
19"	59 6904"	.1658"	5 15-16"	1 5-16"	1"	9-32"
20"	62.8320"	.1745"	6 1-4"	1 7-16"	1 1-16"	9-32"
21"	65.9736"	.1832"	6 5-8"	1 1-2"	1 1-8"	5-16"
22"	69.1152"	.1919"	6 15-16"	1 9-16"	1 3-16"	5-16"
23"	72.2568"	.2006"	7 1-4"	1 5-8"	1 1-4"	5-16"
24"	75 3984"	.2094"	7 5-8"	1 11-16"	1 5-16"	11-32"
25"	78.5400"	.2181"	7 15-16"	1 3-4"	1 3-8"	11-32"
26"	81.6816"	.2268"	8 1-4"	1 13-16"	1 7-16"	11-32"
27"	84.8232"	.3255"	8 5-8"	1 7-8"	1 1-2"	3-8"
28"	87 9648"	.2443"	8 15-16"	1 15-16"	1 9-16"	3-8"
29"	91.1064"	.2527"	9 1-4"	2"	1 5-8"	3-8"
30"	94.2480"	.2618"	9 9-16"	2 1-16"	1 11-16"	1-2"
31"	97.3896"	.2705"	9 7-8"	2 1-8"	1 3-4"	1-2"
32"	100.5312"	.2792"	10 1-8"	2 1-8"	1 13-16"	1-2"

FIG. 17

For larger flywheels double any of the above dimensions. For a 41-inch flywheel take 20-inch and 21-inch spaces and add them together.

46. **Clearance of Tappets.** The clearance at the tappets is the space between the tappet or adjusting screw and the end of the valve stem. On most tractors when they are new this clearance is from 1-64 to 1-32 of an inch. This clearance changes, however, as the motor wears, as any wear in the valve-operating mechanism retards the opening of the exhaust valve and allows it to close earlier, and the same is true of the intake valve. Consequently this space becomes less and less if we keep the events at their proper length. Therefore it is necessary for us to find the proper clearance at the tappet to give us the proper length of events on one exhaust valve, in order to set the cam shaft. (See Fig. 10, No. 13 and 16.)

47. **Rule to Find Clearance at Tappets.** Turn the motor in the direction of rotation until the exhaust cam, cylinder number one, is straight down, as shown in Figure 11. Screw tappet up against end of valve stem. Turn motor in direction of rotation until the exhaust valve just starts to lift, gritting on seat with screw driver (see Fig. 10, No. 8). Mark flywheel under the pointer. Turn the motor in the direction of rotation until the exhaust valve raises and returns to the seat again, so that valve just grits on the seat. (See Fig. 10, No. 9.) Now mark flywheel under pointer again, and measure the distance between the two marks. If the motor is not too badly worn, this event would be anywhere from 6 to 30 degrees too long, say 6°. Mark back against rotation 3 degrees from the last mark made on the flywheel, and move flywheel back to this mark. Since you have opened the exhaust valve slightly, screw tappet down until the valve just grits on the seat, and lock in this position. Turn the motor in direction of rotation until the cam is straight down again (see Fig. 12), and measure the clearance between the tappet and the valve stem.

This is the proper clearance to give us the required length of exhaust event. It would be advisable to file a piece of steel the right thickness so in case the cam shaft should be thrown out of mesh this clearance could be found quickly.

48. **Setting the Cam Shaft.** In order to set the cam shaft after it has ben removed, it is first necessary to find the clearance of one tappet (see Par. 46), such as exhaust valve No. 1, in order to give the proper length of event (224°). Revolve the motor in direction of rotation until the exhaust valve opens and just closes again, so that the valve just grits on the seat with a screw driver. Now look for mark on flywheel, E. C. (1 and 4). If it is found that this is not near the pointer, make the cam shaft fast in some way so that it will not revolve when the idler is removed. Remove the idler, rotating the flywheel in either direction until the mark E. C. (1 and 4)

comes under the pointer. Place idler back in mesh. If it will not go in mesh, rotate the flywheel back and forth and get the idler in mesh with the mark as near the pointer as possible. Loosen cam shaft and place Mark, E. C. (1 and 4), on flywheel, under the pointer. Adjust tappet up or down, as the case may be, so that the exhaust valve No. 1 closes exactly on the mark. Pay no attention to clearance. You have the cam shaft properly set, and the exhaust valve on cylinder No. 1 timed so it closes exactly on the mark. After loosening the cam shaft and placing the mark, E. C. (1 and 4), under the pointer, and changing the tappet so as to get the valve to close on the mark, you have changed the time of opening the valve. If the tappet was lengthened the event was lengthened. If the tappet was shortened the event was shortened. But this is of no material consequence. We prefer always to have the exhaust valve close on the mark and the intake valve open on the mark.

If there is any slight variation, allow it to be on the other end of the event.

49. **Timing the Valves.** Having the flywheel properly marked, and the cam shaft set, turn motor over until the mark, E. C. (1 and 4), comes under the pointer. Examine the tappets to see if the valve closes on the mark. If necessary screw tappet up or down, as the case may be, until the valve just grits on the seat. Then revolve flywheel in direction of rotation until mark, I. O. (1 and 4), comes under pointer. Screw the tappet up or down until the intake valve just grits on the seat, cylinder No. 1. Supposing the firing order is 1-3-4-2, revolve the flywheel ½ revolution until the mark, E. C. (2 and 3), comes under the pointer. Screw the tappet up or down until the valve just grits on the seat, and turn the flywheel in the direction of rotation until the mark, I. O. (2 and 3), comes under the pointer. Adjust the tappet until the intake valve just grits on the seat on number 3. Turn the flywheel ½ revolution until the mark, E. C. (1 and 4), comes under the pointer. Screw tappet up or down until the exhaust valve just grits on the seat on number 4, and turn the flywheel until mark, I. O. (1 and 4), comes under the pointer.

Screw tappet up or down, as the case may be, until the valve just grits on the seat. Turn the flywheel ½ revolution and repeat the same operation on cylinder number 2. Pay no attention to clearance at tappets after you have found the clearance necessary on number one in order to set the cam shaft. The clearance on the valves which have a great deal of wear will have little clearance, and those that have no wear will have a greater clearance. If it is impossible to get the events the proper length without the valve riding on the tappet, it indicates too much wear, and new parts must be ordered to take out the wear. Such parts are usually plungers, plunger guides, rollers, and roller pins, faces of cams and cam shaft bearings.

Most tractor motors have the valve timing above referred to, but the operator should always consult the instruction book, referring to the tractor he is operating.

If the valve timing in the instruction book does not correspond with the above, the instruction book should be followed, as proper valve timing is essential to high efficiency.

If no instruction book is available and the valve timing not known, the above will give good results on any motor running 800 piston feet per minute; if the motor runs less than 800 piston feet, open the exhaust valve 2° later and close the intake valve 2° earlier for each one hundred piston feet less than 800.

For motors that run faster than 800 piston feet, open the exhaust valve 2° earlier and close the intake valve 2° later for each one hundred piston feet per minute over 800.

50. **Motor Design.** It has been seen that while the cycle of the four-stroke cycle motor is always the same, there is frequently a wide range in design and construction of parts. For instance, an engine may be a single cylinder, 2-cylinder opposed, 2-cylinder vertical, 4-cylinder opposed, 4-cylinder vertical, 6-cylinder vertical, 8 and 12-cylinder, V type.

51. **Cylinder Design.** In either of the above types of motors the cylinders may be cast singly, in pairs, known as twin mounting, or "en bloc," where all cylinders appear in one casting.

In either case care should be used in the design of the cylinder to have uniform thickness of cylinder walls and the combustion chamber, and to have the least number of inches possible exposed to the water jacket. All parts exposed to heat should also be exposed to the water jacket. A water jacket should be supplied with ample capacity for free circulation.

52. **Reciprocating Parts.** All successful gas motors are built with reciprocating parts, and, in such motors, the reciprocating motion must be changed to rotary motion before power can be generated. In a reciprocating motor the travel of the piston, upward and downward, or in and out, is said to be reciprocating motion. Such reciprocating parts cause vibration and strain. No matter how perfectly the engine is balanced, these strains increase as the rapidity of motion increases. The piston, piston pin, and the upper portion of the connecting rod reciprocate, while the lower portion of the connecting rod and crank shaft rotate; and it is evident that the faster the piston reciprocates, the faster the crank shaft rotates.

53. **Piston Pins.** All true bearings usually consist of a hardened steel journal running against a soft metal bearing. The wrist pins of the motors are made of a special steel, turned and ground to a slight oversize. Then they are case-hardened and polished to exact size. Case-hardened steel is a process which forms a hard outer crust or shell that cannot be touched with a file. Such a hard polished surface

will run with a minimum of friction or wear. Since the pressure on these pins is very great the bearing material used against them consists of a bushing in the end of the highest grade of bronze. Such material not only stands the high pressure, but also the high temperature, due to heat being radiated and conducted downward from the piston head. Many motors have undersized wrist pins with very short bearings.

54. **Connecting Rod.** The connecting rod of a motor is subject to very great strains, and it has long been known that cast steel is highly inadequate for such construction, containing blowholes and flaws and subject to crystallization, due to vibration. As a result they assume an I-beam section. Such a section is capable of taking great compression strains without bowing. In order to get the desired results, the connecting rod is made of drop forged steel annealed, the annealing removing all internal strains from the piece. The minimum length for a connecting rod is 2¼ times the stroke. If the rod is much shorter than this, then during the power stroke considerable side thrust is placed upon the cylinder on account of the extreme angle the rod is making with the cylinder center line, and excess cylinder and piston wear results.

55. **The Crank Shaft.** The crank shaft of an internal combustion motor should be drop forged of a high-grade nickel steel, which is very tough and long-lived and not susceptible to crystallization; it should have large bearings to insure low working pressure; it should have large fillets in all corners; and it should be highly polished so as to secure the smoothest working surface possible, and balanced both mechanically and explosively.

56. **The Flywheel.** A heavy balance wheel securely bolted or keyed to the crank shaft (preferably bolted).

After the crank shaft has been so designed that the weigth of pistons and connecting rods balance one another and the impulses are so spaced within the cylinder that they occur equal distances apart, a flywheel of proper weight will then control the revolutions of the crank shaft with comparative evenness and enable the motor to deliver practically uniform power at all times by absorbing a portion of the energy during the power stroke and giving it up during the idle strokes.

The flywheel should be of ample weight, perfectly balanced and in all cases placed between the motor and the load.

57. **The Cam Shaft.** There are two methods of making up a cam shaft. One is by having drop forged shaft with all cams forged on same. The other is by having the cams separate from the shaft and keyed or pinned onto the shaft.

In the larger motors these cams are placed on the cam shaft and securely held in place by Woodruff keys and tapered pins.

The Woodruff keys prevent any rotary motion of the cams and the tapering pins any side motion. With

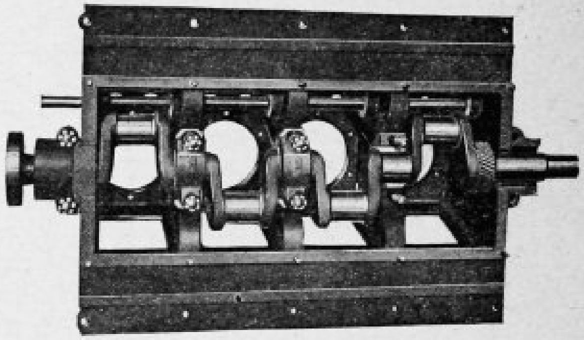


FIG. 18

this construction it makes it possible to replace cams without replacing entire shaft. On the smaller motor the cams are drop forged directly on the cam shaft. After cams are located on shaft as above they are placed in a grinder and ground to proper size.

58. **Crystallization.** In the construction of an internal combustion motor the greatest enemy to be overcome is crystallization. This determines the life of the motor; therefore, the best material should be used throughout, which should be tough and should have a high elastic limit. Low pressure should be maintained on all working surfaces to insure proper lubrication. The crank shaft should be so designed with a suitable flange to which the flywheel can be securely bolted. In all cases the flywheel should be located between the motor and the load so that the power developed in the cylinders when once transmitted to the flywheel will not have to return through the crank shaft, as this develops crystallization, and shortens the life of the crank shaft. To insure long life the motor should be balanced both explosively and mechanically. Crystallization is developed by shocks. The greater the shock, the more rapid the crystallization; therefore, it has been found that a motor of the multiple cylinder type insures against crystallization. This also decreases the size of the working parts and brings all materials closer to the water jacket which insures an even temperature, makes it possible for higher compression, and for more uniform motion and lighter weigth.

The bearings on all motors should be taken up directly against the wear which insures against dislocation of the crank shaft, keeps the crank shaft in line with the transmission, does not change the travel of the piston upon the cylinder walls, and does not increase nor decrease the area of the combustion chamber. See Fig. 18.

59. **Valve Mounting.** Amongst the different makes of tractors, great variation in valve mounting is

shown. Normal American practice in machine design permits of three engine cylinder types, namely:

(a) A dome head cylinder.
(b) An ell head cylinder.
(c) A tee head cylinder.

60. **Valve Parts Definitions.** The gas motor valve is termed mechanically a **poppet valve,** consisting mainly of:

(a) **A Head,** the disc portion, which constitutes the valve proper.

(b) **A Stem,** the rod portion, which constitutes a valve lifter.

The head has the peculiar bevel known as the valve face which must fit exactly to a counter bevel known as the valve seat, formed on the cylinder casting. The stem joins the head with a good-sized fillet which is essential in preventing exhaust valves from warping with heat. Note that most valves are interchangeable, i. e., the exhaust and admission valves are of the same dimensions. This does not mean that the operator can indiscrimniately place a used admission valve in place of an exhaust or vice versa, but that a new valve, carried as an extra, may be used as either.

61. **Wear in Valve Operating Parts.** Trouble in this part of the engine is usually due to lack of proper lubrication, incorrect assembling, or carelessness in adjustment. An outline is given herewith of possible troubles caused by poor operation:

(a) Crank Shaft Gear may be loose on keyway, or due to crank shaft bearing adjustment, out of position.

(b) Idler Gear holding stud incorrectly set.

(c) Cam Gear usually the last gear of timing gear train to show wear, more generally loose on keyway of cam shaft.

(d) Cam Shaft Bearings: Bearings badly adjusted pulling shaft out of alignment or causing cam gear to bind mating gears.

(e) Inlet and Exhaust Cams: If properly hardened never show wear. Can be hammered loose by large clearance at plunger adjustment.

(f) Roller Plungers: Rollers may be loosened on pins by hammering of incorrect plunger adjustment; any lost motion in these parts would shorten the event.

(g) Plunger Guides must be carefully tightened to crank case. Carelessness in mounting is frequently the cause of the breaking of holding cap screws.

(h) Adjusting Screw and Lock Nuts: With every motor should be sent a clearance gauge. The adjusting screw on plunger should be so set and then carefully locked in place by lock nut that gauge will just pass.

62. **Rapidity of Motion of Parts.** After having seen the crank shaft of a 7¼x9 motor revolve while the motor is in service, a revolution of 500 to 540 per minute will not seem extraordinary. At the same time it will help you realize, under the heading of Motor Construction, how superior the construction of all rotating and reciprocating parts will have to be above stationary parts. For instance, 540 revolutions per minute means 9 revolutions per second; or any cycle of any cylinder's piston is performed complete in 2-9 seconds.

63. **The Reduction Gear Train.** Observation of the valves upon any one cylinder as the crank shaft rotates will show that any particular valve, say the exhaust, opens but once and closes but once during a cycle. Consequently, the valve-operating machinery may need only operate one-half the crank shaft speed. This speed reduction is secured in the gear ratio between crank shaft gear and cam gear of the reduction or timing gear train.

(a) The Driver—the crank shaft gear of 38 teeth.
(b) The Idler—the intermediate gear of 56 teeth.
(c) The Follower—the cam gear of 76 teeth.
(d) The Second Follower—the magneto drive gear of 38 teeth.

64. **Rule for Determining Gear Speeds.** The following rule may be applied to spur or bevel gears but not spiral or helical: The speeds of two mating gears are indirectly proportional to the number of teeth. In simpler language this may read: The speed of the first gear is to the speed of the second gear as the number of teeth on the second gear is to the number of teeth on the first gear. Thus, the number of teeth on the first gear divided by the number of teeth on the second gear will give a quotient, which, multiplied by the speed of the first gear, will give the speed of the second gear. Applying this rule to the reduction gear train will give, by result, two turns of the crank shaft to one of the cam shaft. Multiply the number of teeth on the drive shaft which is 38 by the number of revolutions it makes per minute, in this case 533.33, and divide by the number of teeth on the driven shaft, in this case 76, and the product will give the speed of the driven shaft.

Example: $38 \times 533.33 \div 76 = 266.66$ R. P. M.

65. **Setting the Timing Gears.** On any crank shaft gear there is an even number of teeth. These teeth pass a stationary point in each revolution. If the crank shaft gear has 38 teeth, the rotation of the crank shaft gear the distance of one tooth moves the crank shaft 1-38 of 360° or 9.47°.

Again, if the cam gear has 76 teeth, the rotation of this gear one tooth will change the valve timing 1-76 of 720° or 9.47°, since one revolution of the cam shaft means a complete cycle in the action of the valves.

A complete change of one tooth earlier or later of the crank shaft gear with idler or cam gear with idler, actually results in a valve timing change of 9.47°.

Therefore if the mark on the flywheel does not come under the pointer the operator can determine how many teeth the cam shaft gear should be changed either forward or backward.

66. **Marked Assembly of Gears.** If a correctly assembled motor be turned over to in-center 0° cylinder No. 1, and the crank shaft and idler gears be marked upon their mating teeth, likewise, the idler and cam gears upon their mating teeth, then it is not possible to make a mistake if for any reason the motor be taken down and reassembled. The gears can be readily slipped on according to their marked teeth.

67. **Accessibility.** One of the main points to be considered in the construction or selection of a motor for tractor service is accessibility of the above mentioned parts, as there is a constant wear upon them which must be taken care of at frequent intervals in order to keep up the efficiency of the motor. If one can get at these parts easily, he will take care of them promptly; if not, he will put it off until "a rainy day," which is usually a long ways off, thus causing unnecessary wear. "A stitch in time saves nine," as the old saying goes.

68. **Determining the Direction of the Rotation of the Motor.** In placing cams on the cam shaft it is necessary to have the inlet cam follow the exhaust cam, as the exhaust event occurs first in the cycle. As the exhaust event is longer than the intake event, the exhaust cam must be thicker at the point. The direction of the rotation of the motor can be determined by noting the position of the cams. If the cam shaft gear meshes with the crank shaft gear, then the crank shaft will run opposite to the cam shaft. If an idler is placed between the cam shaft gear and the crank shaft gear, then the crank shaft and cam shaft will run in the same direction.

In considering the direction that a motor runs, always look at the flywheel, and determine whether the flywheel revolves with the hands of a clock or against them. If it revolves with the clock it is termed a clockwise motor, if against the hands of the clock it is termed a counter clockwise motor.

69. **Two-cylinder Tractor Motors.** There are several tractors which use the two-cylinder four-stroke cycle motor. Some of these have the two cylinders on one side of the crank shaft cast en bloc (see Fig. 19); others have the cylinders opposed (see Fig. 22). Where two cylinders are on the same side of the crank shaft they cannot be balanced mechanically and explosively. The motor shown in Fig. 19 is balanced mechanically but not explosively. In this motor two power impulses are 180° apart, and then 540° before there is another. The crank shaft for such a motor is shown in Fig. 20. To have the same motor balanced explosively by a crank shaft such as shown in Fig. 21 would be used. The crank pins B are on the same center line, one of them at 0° and the other at 360° in the cycle. In this case the counter weights A are used to assist in balancing the motor mechanically. If the cylinders are set opposed as shown in Fig. 22 the crank shaft shown in Fig. 20 is used; and the motor is balanced both mechanically and explosively.

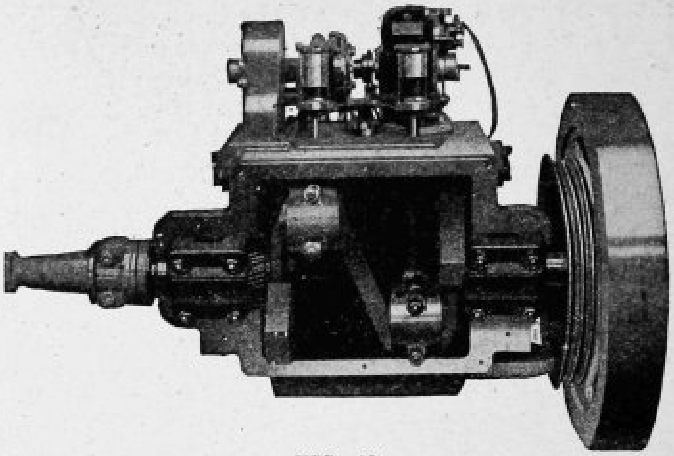


FIG. 19

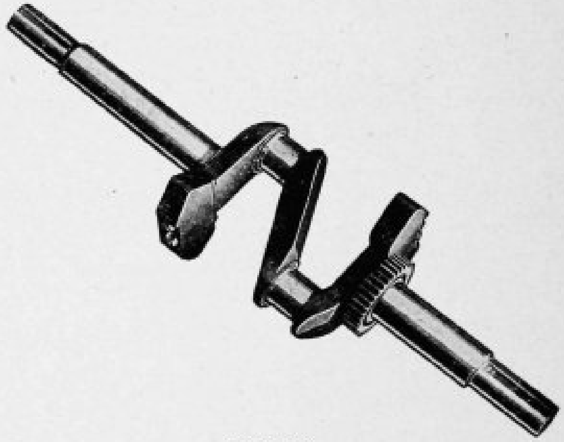


FIG. 20

70. **Cylinder Number One.** The question is often asked, which is cylinder number one. The cylinder on either end of the motor can be called number one. By going over the firing order of a motor and startting from either end, it will be discovered that the firing order is exactly the same. If it is 1-3-4-2 from one end, it is also 1-3-4-2 from the other end.

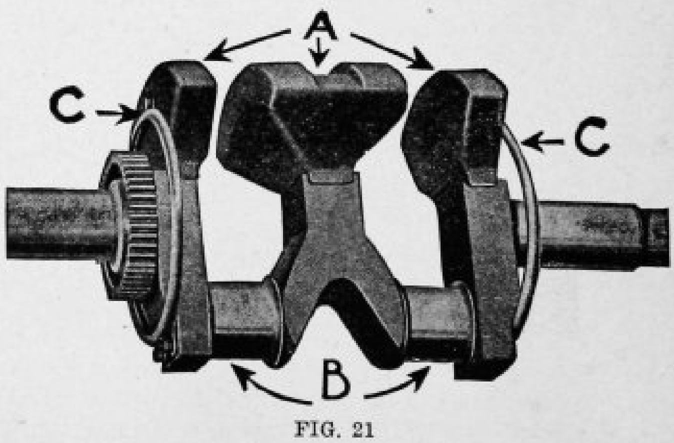


FIG. 21

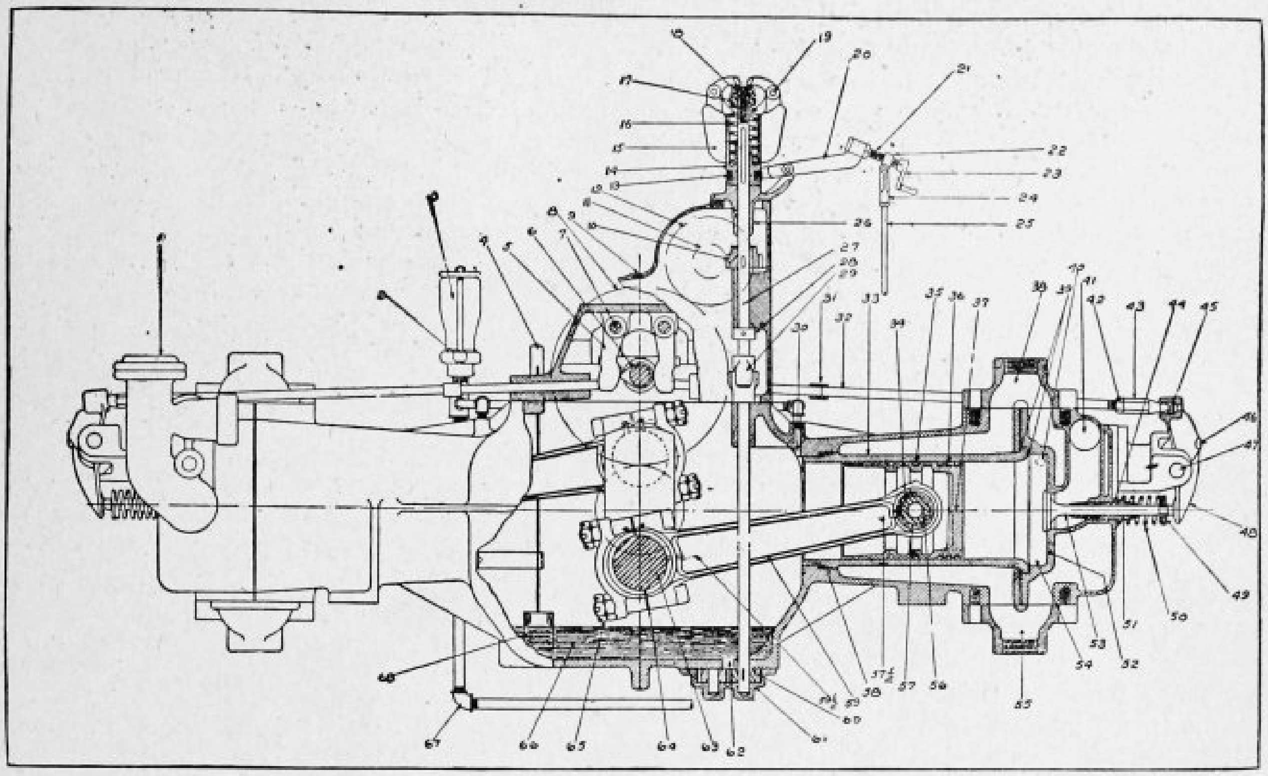


FIG. 22

71. **Firing Order.** A four-cylinder motor can fire in two ways, 1-3-4-2 or 1-2-4-3. This depends on the relation of the cams on No. 2 and 3 to one another. 1 and 4 cams are always at 180° of each other on the cam shaft, while No. 2 and 3 are 90° from 1 and 4, but No. 2 cam can be 90° ahead of No. 1, and No. 3 90° behind No. 1. Then the firing order would be 1-3-4-2. The question often arises: Which is the best way to fire a motor, 1-2-4-3 or 1-3-4-2? There is no difference that is beneficial to the operation of the motor. On most four-cylinder motors the order of firing is 1-3-4-2. On most six-cylinder motors it is 1-4-2-6-3-5.

72. **To Determine the Firing Order.** To determine the firing order, all that is necessary is either to examine the tappets as shown in paragraph 71, or to turn the motor over and watch the exhaust valve close on cylinder No. 1. Then watch closely the exhaust valve on 2 and 3,—the one that closes next is the one that fires next. If No. 3 closes after No. 1, then the firing order is 1-3-4-2; but if No. 2 closes next, the firing order is 1-2-4-3.

73. **To Determine the Firing Order by the Clearance at the Tappets.** Example: Consider a four-cylinder motor that has 1-32 inch clearance between the valve stems and the tappets. Suppose that when you examine the tappets on No. 1, you find that you can rattle both tappets, thereby, examining No. 4. You find you can rattle the exhaust, but not the intake. This would prove to us that No. 1 is on the power, and No. 4 is on the intake.

If when examining No. 2 you find that you can rattle both tappets on No. 2, you know that No. 2 is on compression. Then on No. 3 you can rattle the intake, but not the exhaust, and you know No. 3 is going up on the exhaust, these conditions show that the firing order is 1-2-4-3. Suppose the crank shaft is in the same position as above, you find that you can rattle both tappets on No. 1 and rattle the exhaust but not the intake on No. 4, but you can rattle both tappets on No. 3, but can rattle only the intake and not the exhaust on No. 2, this would show that the firing order is 1-3-4-2, also that No. 1 is 90° in its cycle, No. 2 is 270° in its cycle, No. 4 is 450° in its cycle and No. 3 is 630° in its cycle. No. 1 and 4 are on the out stroke and No. 2 and 3 are on the in strokes, No. 1 is on the power event with 54° left of the power event, No. 3 is on the compression event with 90° left of the compression event, No. 4 is on the intake event with 106° left of the intake event, No. 2 is on the exhaust event with 98° left of the exhaust event (See Fig. 25.) With a little practice in five minutes one can determine the firing order of the motor. He should observe clearance between each tappet and the valve stem to see that they are about alike, and convince himself whether or not the tappets have been tampered with. A little practice in this will be very advantageous to the operator in detecting any valve or ignition trouble.

74. **To Locate the Position of the Pistons and Crank Pins in the Cycle.** In order for the operator to thoroughly understand the motor and to be able

to make quick adjustments, he should be able to understand the motor so perfectly that when looking at it he understands the position of the valves and pistons as though the cylinder walls were made of glass.

In order to do this, it is necessary for the operator to locate the position of each piston in its cycle. After he has located the position of one piston, he should be able to tell the position of all the others. We wish to have it understood that when speaking of a motor we always refer to a four-cylinder vertical motor, unless otherwise specified, owing to the fact that the majority of gas tractors use the four-cylinder vertical motor.

There is a clearance between the tappet or push rod and the end of the valve stem in this motor from 3-1000 to 1-16 of an inch, depending on the size of the motor.

To locate the position in which a four-cylinder motor is standing, we will say that the clearance between the tappets and the end of the valve stem on this motor is 1-32 of an inch. In this case when the valve is closed and the plunger is clear down off the cam, the clearance between the valve stem is 1-32

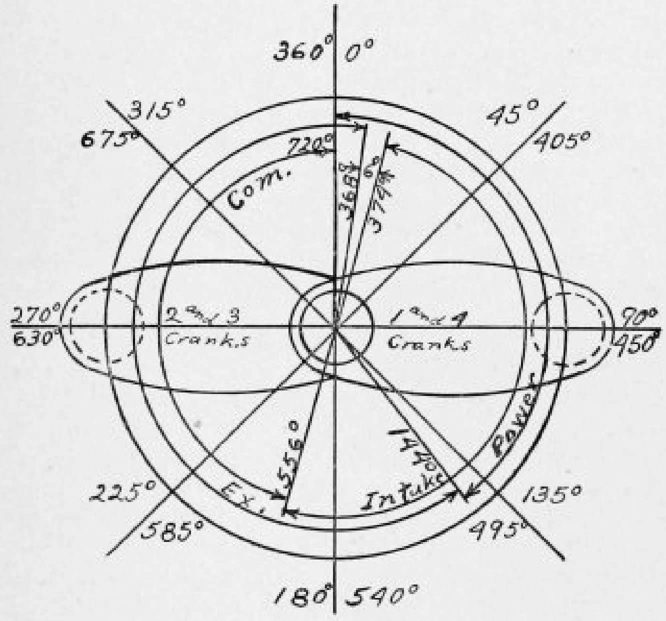


FIG. 23

inch. By taking hold of the plunger it can be rattled, and the valve is tight on the seat. This would indicate that the valve was closed. By looking at a four-cylinder crank shaft, you will notice that when crank No. 1 and 4 are up, crank No. 2 and 3 are down. This being the case, when No. 1 crank is going up No. 4 is also going up, and No. 2 and 3 are going down. (See Fig. 23.)

By referring to the valve timing diagram, Figs. 15 and 16, you will notice that when the pistons are going up, one of them is on the exhaust event and the other is on the compression event, and the other two cranks are going down. One of them would be on the power and the other on the intake event. When the piston is going down it is either on the power or intake event. If it was on the power, you can rattle both tappets. If it is on the intake, you can rattle the exhaust, but not the intake.

If a piston is going up, it is either on the exhaust or compression. If it is on the exhaust, you can rattle the intake tappet, but not the exhaust. If on compression, both tappets can be rattled.

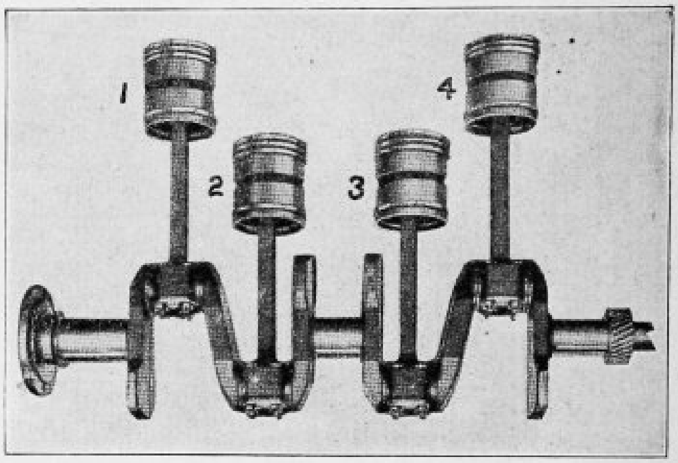


FIG. 24

On a four-cylinder motor, 99 times out of 100, the crank shaft stops very nearly horizontal, that is, 1 and 4, we will say, would be 90° and 450° in their cycle, while 2 and 3 would be 270° and 630° in their cycle, or near that position. (See Fig. 23.) The reason for this is that, to stop a motor, we open the throttle wide and throw off the ignition switch, if the firing order is 1-3-4-2. When the motor has slowed down until the flywheel has just energy enough to bring No. 1 up against compression and past D. C., the gas compressed in No. 1 gives new life to the flywheel. But when No. 3 comes up against compression, it overcomes the energy in the flywheel, causing it to reverse and travel backward until No. 1 piston backs up against compression. This reverses the flywheel again, causing the flywheel to rock back and forth and finally come to rest in the above named position at right angles to the imaginary cylinder center line. (See Fig. 24.)

We will say that a motor has stopped. Then the crank shaft lies flat. Two cranks are at 90° from dead center and the other two cranks are at 270° from dead center. We will say that the firing order on this motor is 1-3-4-2. If No. 1 has passed D. C. and traveled 90°, it is on the power event and both tappets can be rattled. No. 1 is going down on the power event, consequently No. 4 is also going down; and No. 1 being on the power event, No. 4 would necessarily be on the intake event; and if No. 1 would be at 90° in its cycle, No. 4 would have to be at 450° in its cycle. Now if No. 1 and 4 are going down, No. 2 and 3 are going up. No. 1 has just fired and is on its power event. No. 3 is going to fire next, therefore is on the compression event and 630° in its cycle. Both tappets could be rattled. Since No. 3 is going up, No. 2 will also be going up. No. 3 is going up on compression, No. 2 would necessarily be going up on the exhaust. No. 2 fires 180° ahead of No. 1. No. 1 is at 90° in its cycle and No. 2 is 180° ahead of No. 1. 180 and 90 would be 270: therefore, No. 2 would be 270° in its cycle on the exhaust event with 98° left of the exhaust event. (See Fig. 25.)

By examining the tappets, you will find that you can rattle the intake and not the exhaust. Now, a motor standing in this position, by examining the tappets you would find that you could rattle both tappets on cylinder No. 1. You could rattle the exhaust but not the intake on No. 4, you could rattle both tappets on No. 3, and could rattle the intake tappet but not the exhaust on No. 2. (See Fig. 25.)

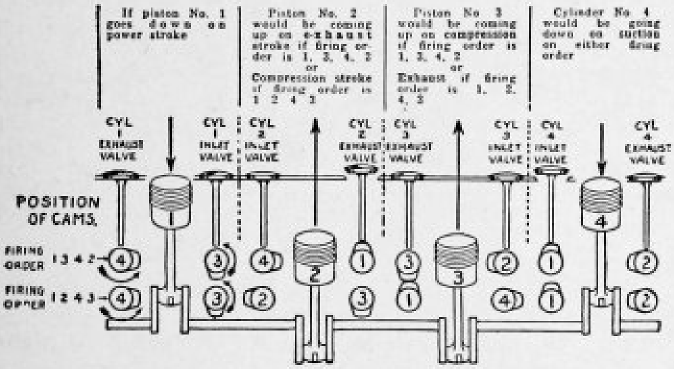


FIG. 25

75. **Horse Power.** Horse power (or H. P.) is the rate of doing work. It is the amount of work done in a certain period of time. The unit of power measurement is the horse power. The horse power of a motor is the number of foot pounds of work it will develop per minute, divided by 33,000, which will be equal to the H. P., as 33,000 pounds raised one foot in one minute equals one H. P. or 550 pounds one foot per second.

For illustration consider a team of horses which is hitched to a load. We find from statistics that a horse will pull on the tugs the equivalent to one-seventh of his weight, and will keep going comparatively steady for some time. He will pull half of his weight on the tugs for a short time; but when loaded with more than one-seventh of his weight, he requires frequent rests.

This team of horses, we will say, weigh 1,400 pounds each. The average weight they should pull is estimated to be two hundred (200) pounds each, or a total of four hundred (400) pounds. We will say this team travels at the rate of two and one-half (2½) miles per hour. This would equal 220 feet per minute, and the result would be as follows: 220 times four hundred equals eighty-eight thousand pounds, divided by thirty-three thousand which equals two and sixty-six one-hundredth horse power.

76. **Horse Power of Motors.** In order to determine the horse power of a motor, it is necessary to know the pressure applied and the feet traveled in a minute. By multiplying the pressure applied by the feet traveled per minute, you have the foot pounds. By dividing the foot pounds by 33,000, the horse power can be found; which, in a motor, would be the indicated horse power or the power developed in the cylinder.

Owing to the fact that it takes power to overcome friction, it is necessary to deduct from the indicated horse power the power to overcome friction in the motor. We find from actual practice that the power necessary to overcome friction in a one-cylinder heavy-duty motor would require 20% of the power generated, 15% in a two-cylinder, and 10% in a four-cylinder. The loss in these motors depends upon the weight of the rotating and reciprocal parts.

After you have found the power developed which is the indicated horse power of the motor, it would be necessary to multiply the indicated horse power by 80-100 for a one-cylinder, 85-100 for a two, and 90-100 for a four-cylinder, to obtain the brake horse power.

To determine the B. H. P. of the motor, it is necessary to find the average pressure during the power stroke from diagram Fig. 27. If it is a four-cylinder motor this would also equal the mean effective pressure. To find the pressure on the piston, multiply the area of the piston by the M. E. P. This would equal the average pressure applied. Multiply this product by 800, and divide by 33,000. This would equal the I. H. P. Multiplying this product by the efficiency of the motor would give the B. H. P.

77. **Proper Speed of an Internal Combustion Motor.** The standard speed of a heavy duty internal combustion motor has been fixed at 800 feet travel of the piston per minute. Therefore, the revolutions per minute of the motor would depend entirely upon the stroke as it would be necessary to have the crank shaft make the proper number of R. P. M. to give the piston 800 feet travel. A motor which has a 6-inch stroke makes one foot piston travel in each revolution. Therefore, the motor would have to run 800 R. P. M. to equal 800 piston feet. This would be the proper speed of the motor.

Problem: What is the proper number of R. P. M. of a motor 7¼x9? Multiplying 800 feet by 12 equals 9,600, therefore the proper speed of a heavy duty motor is 9,600 inches. Since in the motor there is nine inches in one stroke, and it takes two strokes to complete one revolution, there will be 18 inches piston travel in each revolution. 9,600 divided by 18 equals 533.3, therefore the proper R. P. M. of a 7¼x9 is 533.3.

78. **Specific Heat of Gasoline.** The specific heat, or amount of heat measured in B. T. U. (British Thermal Unit) will raise one pound of pure water one degree

Fahrenheit (from 39° to 40° Fahrenheit). One pound of gasoline will give off heat approximately equal to 18,000 B. T. U. It may be given off at once or it may take considerable time, depending on the conditions under which the combustion takes place. It will always be given off, however, if the combustion is complete. 1 B. T. U. = 778 foot pounds or .0236 H. P.

79. **Combustion Chamber, Proper Size, Etc.** The combustion chamber is the clearance between the piston and the cylinder head. When the crank is on dead center, the size of the combustion chamber depends entirely on the compression desired. This clearance on most up-to-date tractors is 31% of the volume sweep of the piston. A good method of determining the size of the combustion chamber on a motor would be to place one cylinder on dead center zero degree in the cycle. Now weigh a pail containing several quarts of water. Then fill the combustion chamber with this water, being careful not to spill any in order to get accurate dimensions. After filling the combustion chamber full, again weigh the pail with the remaining portions of water and multiply the pounds used by 27 (which is the number of cubic inches in a pound of water). This will give the cubical contents of the combustion chamber.

Now divide the cubic inches contained in the combustion chamber by the cubic inches contained in the volume sweep of the piston, which will give the percentage of clearance. After this is found, by referring to the diagram No. 26 one can easily obtain the compression and explosive pressure.

80. **Average and Mean Effective Pressure**. It must be understood, the above pressures depend on the compression carried, and the compression depends on the area of the combustion chamber. The compression can be obtained by a pressure gauge, by connecting it to the cylinder at a spark plug opening, or priming cock, using a check valve between the gauge and cylinder, disconnecting the spark plug wire so that the cylinder to which the pressure gauge is connected cannot fire. See that the governor and throttle valve is wide open so that full compression is obtained. After finding the compression by referring to diagram Fig. 27, the average and mean effective pressure can be obtained.

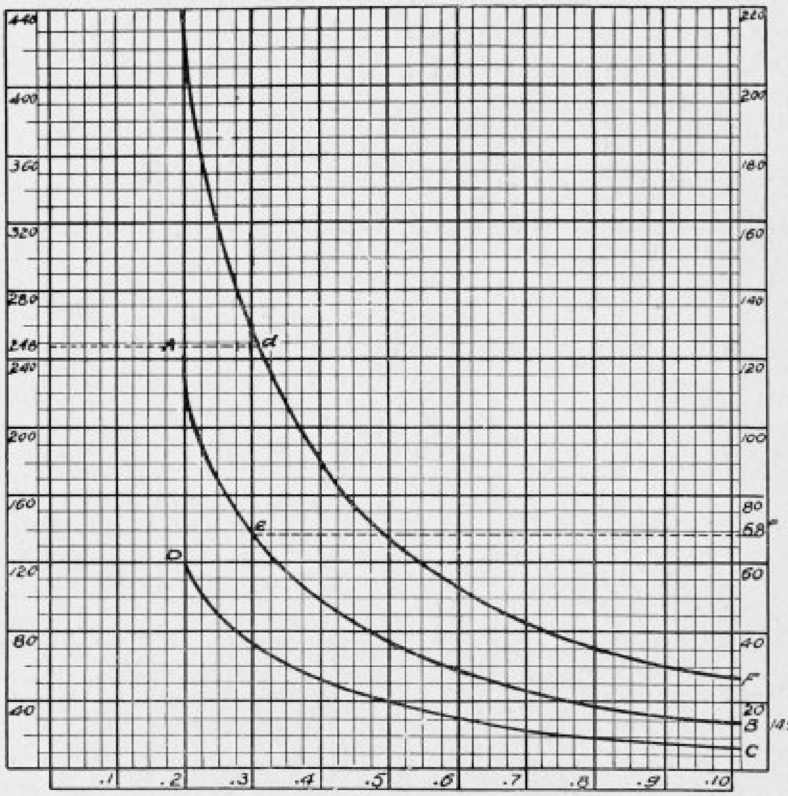


FIG. 26

81. **Volume Sweep of Piston.** Volume sweep of piston means the space displaced by piston while traveling from an in-center to an out-center. The volume of this piston displacement would be the area of the piston multiplied by the stroke. This would give the cubical inches of gas taken into the cylinder, when the intake valve is open and the piston has traveled from in-center to out-center.

Problem: What is the piston displacement of a one-cylinder motor 4½x5?

Rule: 4.5x4.5x7854 = 15.9043x5 = 79.5215 cubical inches displacement.

To find the displacement of a 2, 4, 6, 8 and 12 cylinder motor, multiply the above cubical contents found for one cylinder by the desired number of cylinders.

Problem: What is the relation between the area of the combustion chamber and volume sweep of the above motor?

Suppose that when we place the above motor on D. C. and fill the combustion chamber with water, we find that it holds just one pound, or 27 cubic inches.

Rule: 27 ÷ 79.52 = .34%. We find the above motor has thirty-four per cent clearance.

82. **Method of Using Diagram Fig. 26.** From the diagram Fig. 26 one may read directly, without calculation, the relative volumes for a given compression, or the compression for a given ratio of volumes, and the approximate maximum explosive pressure, and may construct the theoretical indicator diagram.

The curved line A B indicates the relation between volume and pressure during compression, and is to be read by the scale at the right of the figure. The line C D is the same as A B, except that it is drawn to the scale at the left of the figure. The line E F represents the relation between volume and pressure after the charge has been ignited, and is to be read by the scale at the left of the figure.

Problem: What is the compression, and explosive pressure, when there is a 31% clearance in the combustion chamber?

At the point corresponding on the horizontal scale to the ratio of volume equals thirty-one one-hundredths or .31, erect a perpendicular line to e, cutting the curved line A B at e. Then draw a horizontal line to the scale at the right. It will be noticed that it touches the scale at a point corresponding to about 68 pounds. The compression is therefore 68 pounds absolute.

To find the approximate explosive pressure, continue the line corresponding to .31% upward until it intersects the line E F in d. Draw a horizontal line d, to the left hand scale; said line will cut the scale at the point indicating the explosive pressure to be expected under favorable circumstances. In this case it is about 248 pounds.

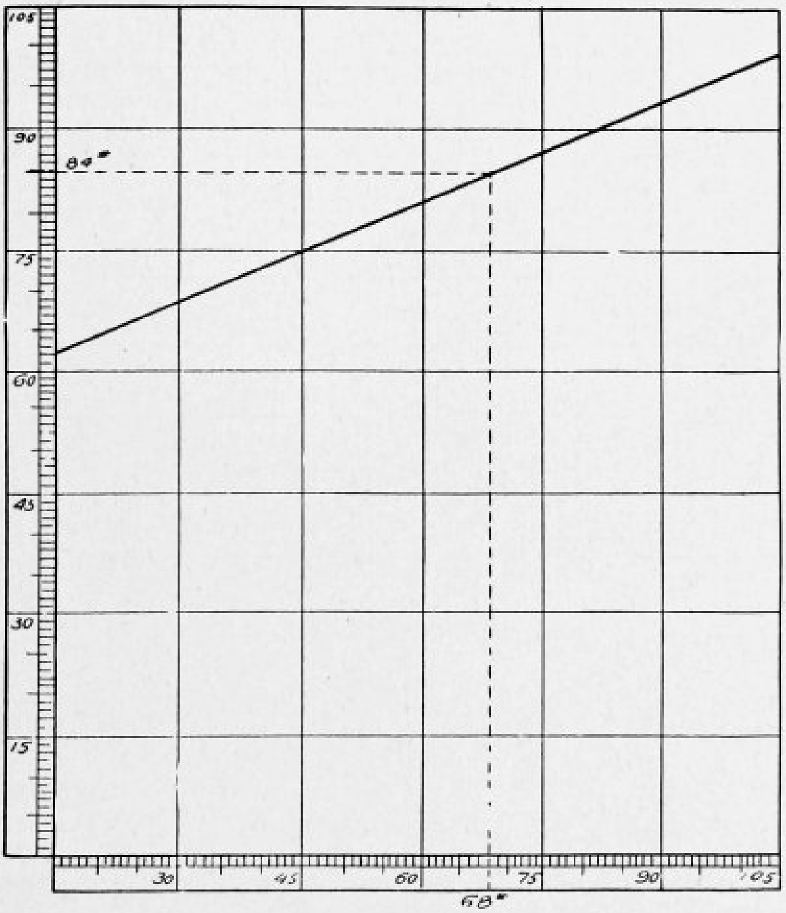


FIG. 27

The vertical scale represents absolute pressure, that is, the gauge pressure plus atmospheric pressure (14.5) in pounds per square inch, and the horizontal scale at the bottom of the figure represents the total cylinder volume. It will be noted that the latter scale is divided into tenths and hundredths.

The theoretical indicator diagram is to be read by the left hand scale, and is represented by the lines C D (compression curve), D E (explosion line), E F (expansion curve), and F C (exhaust line).

The area enclosed by these lines represents the indicated work of the engine per working stroke.

83. **Average Pressure During the Power Stroke.** The average pressure may be read directly without calculation by referring to diagram Fig. 27.

The horizontal scale at the bottom represents gauge pressure of compression. The vertical scale represents pounds per square inch of average pressure.

The method of using the diagram may be illustrated by the example assumed above. The absolute compression pressure was about 68 pounds. Commencing with a point on the horizontal line corresponding to 68 pounds, draw a vertical line to the point where it intersects the heavy line running diagonally from right to left. From this point draw a horizontal line to the left, touching the vertical scale. It will be noticed that this point corresponds to about 84 pounds, which is the average pressure to be expected during the power stroke. The pressure obtained from this diagram is the average pressure during the power stroke only.

84. **Mean Effective Pressure.** The average pressure found from Fig. 27 represents the M. E. P. on a four-cylinder motor only as the power impulses are 180°. For a one-cylinder motor divide the average pressure by four, as there are three idle strokes to each power stroke. This would equal the M. E. P. for a one-cylinder.

Divide the average pressure by two to obtain the M. E. P. for a two-cylinder motor. For a six-cylinder motor the M. E. P. is one and one-half the average pressure.

For an eight-cylinder motor the M. E. P. is twice the average pressure, as one power impulse overlaps the other, 90°.

Problem: What is the M. E. P. for a 1, 2, 4, 6 and 8 cylinder motors when the average pressure is 84 pounds?

Rule: 84 ÷ 4 = 21 lbs. M. E. P. on a 1-cylinder motor.
84 ÷ 2 = 42 lbs. M. E. P. on a 2-cylinder motor.
84 ÷ 1 = 84 lbs. M. E. P. on a 4-cylinder motor.
84 + 42 = 126 lbs. M. E. P. on a 6-cylinder motor.
84 + 84 = 168 lbs. M. E. P. on a 8-cylinder motor.

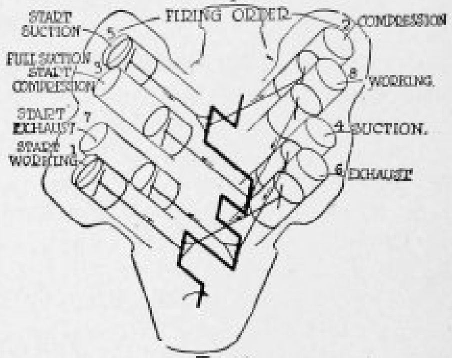
From the above pressures you will note that the M. E. P. for a six and eight-cylinder motor is greater than the average pressure, due to the fact that one power impulse overlaps the other. On a six-cylinder motor one power impulse overlaps the other sixty degrees, on an eight-cylinder motor 90°, as shown in Fig. 28, 29, 30. You will note from these illustrations that two pistons are on the power stroke at the same time that two are on the exhaust, two on the intake, and two on the compression.

THE ORDER OF FIRING AN EIGHT-CYLINDER MOTOR

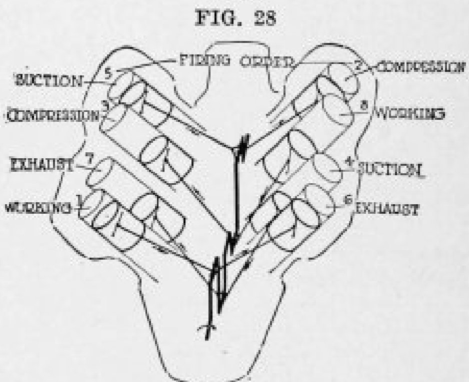
In firing, the order alternates from one side to the other, so that there is a power impulse from a cylinder on one side followed by an impulse from a cylinder on the opposite side. The order of firing is indicated below:

FRONT
6X—X1
4X—X7
8X—X3
2X—X5
REAR

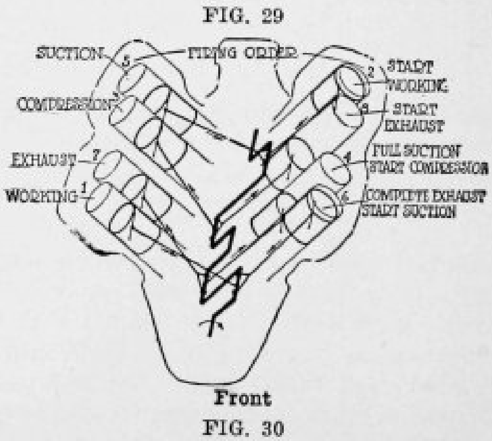
That is, No. 1 cylinder on the right fires first, then No. 2 on the left, No. 3 right, No. 4 left, and so on. As to the timing, the inlet valves open at top dead center and close 45 degrees after bottom dead center, while the exhausts open 45 degrees before bottom dead center and close at top dead center.



Front
FIG. 28



Front
FIG. 29



Front
FIG. 30

85. **Pressure in Cylinders.** In performing the different strokes of the cycle, three pressures are obtained in the combustion chambers, viz.: Normal, Positive and Negative.

Normal pressure is that pressure which is equal to that of the atmosphere, 14.70 pounds at sea level. Zero pounds Gauge-Normal Pressure.

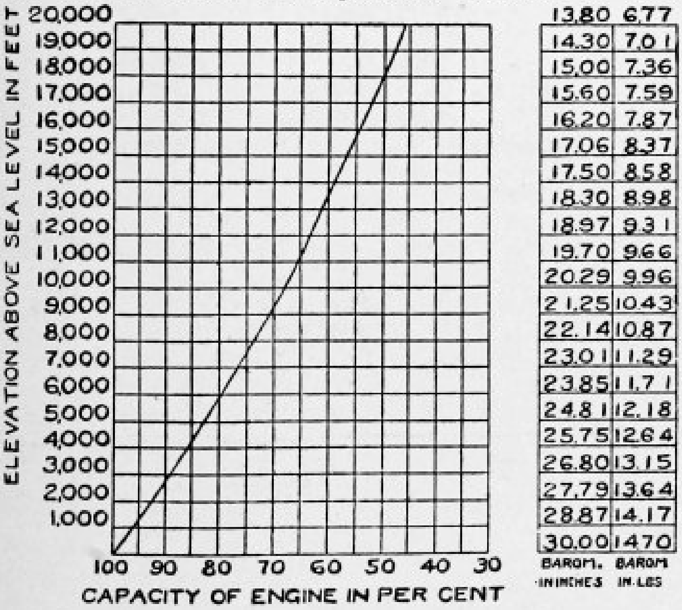
Positive pressure is pressure higher than atmosphere.

Negative pressure is lower or less than atmosphere.

A negative pressure is measured in inches which means inches of mercury in a "U" tube. For example: If we have five inches of negative pressure, or vacuum, as it is commonly called, it would mean that there is five inches difference in the levels of the mercury in the "U" tube.

Mercury is 12 times heavier than water, therefore, for each inch of negative pressure or vacuum, we would raise water 12 inches. A perfect vacuum equals 30 inches at sea level.

86. **Influence of Altitude upon Powers of Motors.** From the above formula, we get the H. P. of a motor at sea level where the atmospheric pressure equals 14.70 lbs. Since the pressure becomes lighter as we ascend, the power of the motor becomes less. The power of the motor can be changed somewhat, however, by decreasing the area of the combustion chamber to correspond with the altitude. For easy calculations refer to diagram Fig. 31. You will note that the column to the left represents elevation in feet,



EFFECT OF ALTITUDE ON AIR PRESSURE AND GAS ENGINE HORSE POWER

FIG. 31

and the column to the right represents the atmospheric pressure, starting at sea level and going up to an elevation of 20,000 feet. You will note that the atmospheric pressure at sea level is 14.70, and it depreciates to 6.77 at 20,000 feet. The figures at the bottom of the diagram represent percentage of power lost by the motor. You will note that a motor that develops 100 H. P. at sea level will generate only 45 H. P. at an elevation of 20,000 feet; therefore, it would be necessary for us to reduce the area of the combustion chamber in the same proportion as we have reduction in air pressure, to obtain the same H. P.

87. **Brake Horse Power or B. H. P.** From the preceding paragraphs we find that the horse power of a motor depends on the M. E. P., and the M. E. P. is regulated by the compression carried, and the compression depends on the relation between the area of the combustion chamber to the volume sweep of the piston, and the altitude at which the motor is working. The higher the compression, the more power the motor will develop per cylinder volume and the higher will be its thermo and mechanical efficiency. The height of compression is regulated, however, by the ignition point of the fuel used. (This will be taken up later.)

Problem: What would be the B. H. P. to be expected of a four-cylinder motor 7¼x9, running 533.3 R. P. M., with thirty-one per cent clearance in the combustion chamber?

Rule: 7.25x7.25x.7854=41.282 square inches, area of piston. By referring to diagram Fig. 26 we find with 31% clearance we have 68 pounds compression and 248 pounds explosive pressure. By referring to diagram Fig. 27 we find with 68 pounds compression we have 84 pounds average pressure, which on a four-cylinder motor is also the M. E. P. or Mean Effective Pressure.

Example: $$\frac{41.282 \times 84 \times 800 \times 90}{33{,}000} = 75.6585 \text{ B. H. P.}$$

In the above example we find that 533.3 R. P. M. equals 800 piston feet, the mechanical efficiency is ninety one-hundredths (.90).

Problem: We find that a 7¼x9 will develop 75.6585 B. H. P. at sea level, where the atmospheric pressure equals 14.70 lbs. If this motor was shipped to an altitude of 5,000 feet, what horse power would be expected?

By consulting diagram Fig. 31 we find that the atmospheric pressure is 12.18 lbs., a loss in pressure of 17%; therefore the power of the motor would be 83% of 75.6585.

Rule: $75.6585 \times .83 = 62.796550$.

By decreasing the area of the combustion chamber 17% of the former area, the horse power would be 75.65 at 5,000 feet.

88. **Testing for Compression.** The motor should be tested for leakage at least once a week. Turn the motor over against compression, and notice if the compression is good on all cylinders.

Leakage is liable to occur at the valve seats, piston rings, valve cap gaskets, and spark plugs. The valves require attention according to the size and construction of the motor and the fuel used.

If the valves are small and are close to water so that they keep cool they do not require so much attention. If kerosene is used for fuel, the valves require more attention. The exhaust valves require more attention than the intake, as the exhaust valves are held off the seat longer, at which time they are surrounded by a hot gas which burns the carbon out of the material the valves are made of, causing little black specks or pits on the seat.

At first the pits are small and far apart, but with continued use they grow larger and more numerous, until they lead the gas from one to the other so as to cause leakage.

At the beginning of the power stroke, when the temperature and pressure is high, the gases have a more cutting effect,—cutting away the material, and causing the leakage to increase rapidly.

On large motors, especially those burning kerosene, the exhaust valves should be examined and in most cases ground once a week. Owing to the heat which burns the carbon out of the valves, black specks are formed on the seat.

When examining the valves, these specks may look small and far apart,—almost invisible to the eye. But if a reading glass is used, the specks would appear to be large, and practically connected by a number of small ones. If the valves were placed back in the motor and run for another week, a reading glass would not be required to see the specks leading from one to the other through which the gases have been escaping.

If the valves are ground often, less time will be required, and less material removed. The valves will last longer and the motor will be of higher efficiency.

Pistons and rings should be examined for the collection of carbon on the piston head and in the grooves around the rings. This causes the rings to stick and also to leak. This sediment of carbon on the piston head keeps wearing off and mixing with the oil on the cylinder walls. This oil mixture has a cutting effect, causing the piston to become loose and pound.

If the rings stick in the grooves they do not spring out against the cylinder walls. This condition causes a leakage so that the rings are soon burned away, and early repairs are necessary.

When the valve caps are replaced, the cap is often tightened down on dirt which is allowed to get under the gasket. It will be found that when the dirt is cleaned off the next time the cap is removed, the gasket will leak. This leakage causes a loss of pressure resulting in a high temperature which will cut out a groove in the metal through which gas will escape. The same is true of spark plugs, consequently there is a waste of fuel and a loss of power. When cranking a motor, take particular care to see that the compression is alike on all cylinders.

89. Grinding the Valves. There is a wide range of valve mountings which determine the method of removing the valves for grinding. There is the motor which has the valve in the head. (See Fig. 33.) There is the Ell head motor with the valves in the pocket on the side of the cylinder which has the detachable head. Others have only a valve cap which can be removed so that the valves may be ground. (See Fig. 34.) In any case it is necessary to remove the head (see Fig. 33), or cap (see Fig. 34), and valve spring. Then remove the valve from its seat (see Fig. 35), and clean all the carbon off the valve, valve seat, and valve stem. Use a fine emery cloth, if necessary, to clean the valve stem.

Examine the valve. If it is in fair shape, that is, if it is not too badly pitted and the metal is not burned, it will not take long to reseat it. Place a light coil spring on the valve stem so that it tends to hold the valve up and off from its seat.

Place a small amount of fine carborundum valve grinding paste, or paste of fine emery and lard oil, on the valve seat. By using a brace holding a screw driver or grinding tool, and placing the tool in the slot on the top of the valve, the valve may be revolved back and forth on the seat with very little effort. (See Fig. 36 and 37.)

If the valve is ground steadily, revolving it in one direction and not lifted from its seat, it will be cut more on one side than on the other, and rings will be cut into the valve and seat, so that both will be

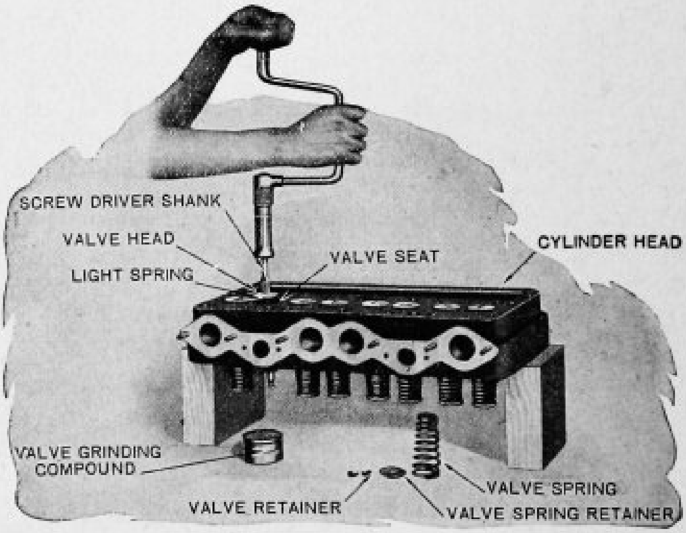


FIG. 33

spoiled. By allowing the spring to lift the valve from its seat and to start at a new point after each quarter revolution, the valve will be ground evenly all around.

The best method of doing this is to turn the valve about one quarter of a revolution in one direction, lift the valve from its seat, replace it, and revolve it another quarter of a revolution in the same direction.

Again lift the valve and turn half a revolution in the same direction without allowing the valve to touch the seat. Then reverse the direction, allowing valve to touch the seat a quarter revolution at a time.

If no valve grinding compound is at hand, the following recipe may be applied: Mix emery powder No. 135 with lard oil until paste is formed. If weather is cold and heavy, add a trace of kerosene and secure a paste of such consistency that it will not quite run from valve face. Apply to valve and grind. Then remove as stated before. Apply a fresh batch of emery paste and proceed. Don't try to do the entire valve grinding on one application of paste and oil.

After grinding for a short while remove the valve, and clean the valve seat to see if it has been sufficiently ground. If it is ground sufficiently, the line of contact of the valve on its seat should have a bright, silvery polish.

If any discolored or pitted places remain, the valve must be ground more. To get the best surface on a valve seat, finish the grinding by making turns very short and lifting the valve frequently. When finished, clean every particle of grit from the valve, the valve seat, valve chamber and valve guide, using care not to get any grit in the cylinder. Great care must be exercised to remove all traces of emery. See that end of valve stem is square, that no hollow appears in top adjusting screw, and that proper clearance is obtained before job is completed.

90. Removing Cylinder Head. Whenever it is necessary to remove cylinder head, do not drive any

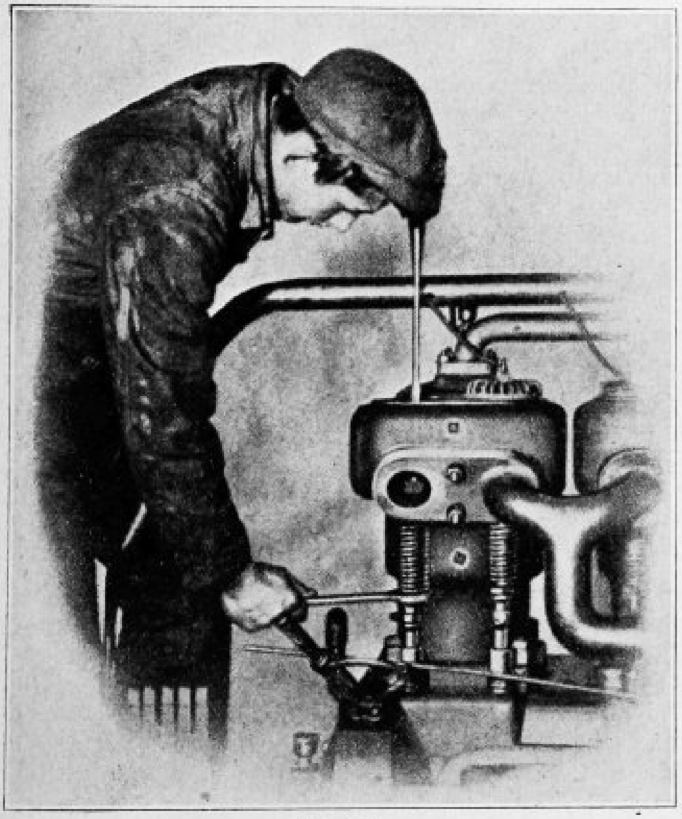


FIG. 34

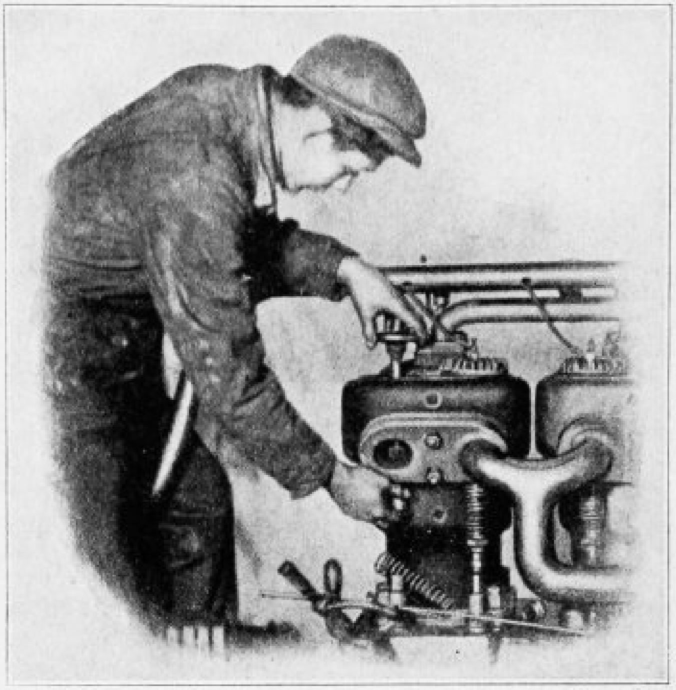


FIG. 35

form of wedge into the joint between cylinder and head. This will surely damage the gasket, in which case the head cannot be replaced until a new gasket is provided. If cylinder head cannot be readily jarred loose by tapping on the side of the cylinder head after stud nuts have been removed, place a piece of hard wood in the exhaust or intake openings. Then drive head off with heavy hammer.

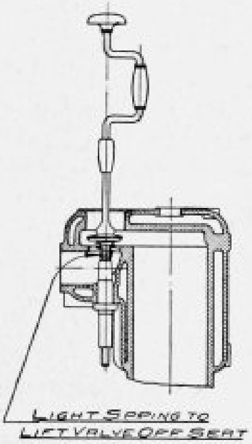


FIG. 36

91. Replacing Cylinder Head. Before replacing, clean the surfaces for the joints thoroughly, put a coat of graphite and oil on the gasket if a copper gasket is used. If a gasket is to be made, use a sheet of asbestos paper, soak for 24 hours in boiled linseed oil to make it moisture proof. Then place the gasket on the cylinder, put a coat of graphite and oil on the upper side of the gasket, then replace nuts, put graphite and oil on all threads.

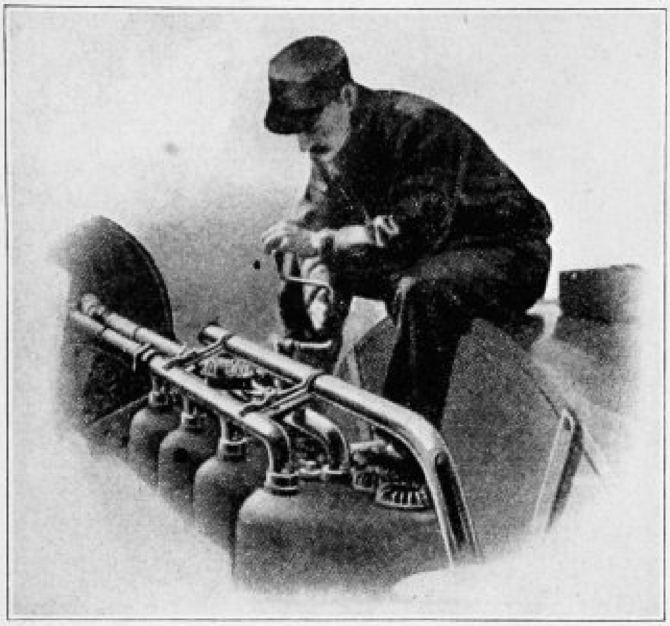


FIG. 37

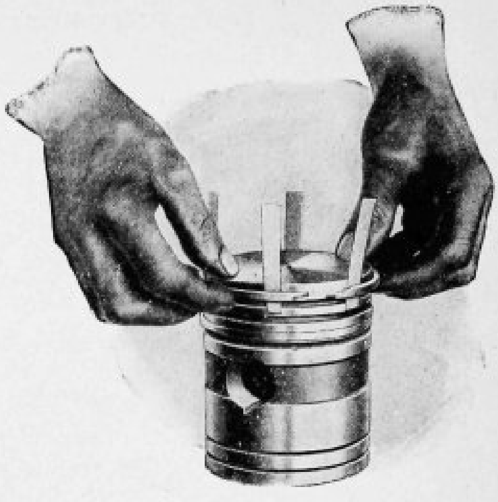


FIG. 38

FIG. 39

Tighten all nuts fairly snug. Then tighten uniformly, giving each nut a small part of a turn at a time. Continue this until all nuts are tight. DO NOT SCREW ONE NUT DOWN PERFECTLY TIGHT AND THEN GO TO THE NEXT, AS YOU WILL NOT SECURE AN EVEN PRESSURE ON THE GASKET IN THIS MANNER.

Do not leave center nuts on cylinder heads to be tightened last. After motor has been running a few minutes, and the water is hot, tighten the nuts again.

92. Removing Piston Rings. It is often necessary to remove the piston from the cylinder, and to clean the rings and the grooves. To remove the piston, take off cylinder head, if detachable, remove crank case cover or oil pan, remove cotters and nuts from connecting rodbolts, remove connecting rod bearing cap. Now carefully remove the liners from the bolts.

Be careful not to lose any liners and don't get them mixed up. When reassembling the liners must be placed on the bolts from which they came.

If a multiple cylinder motor and all pistons are removed at once, be careful that they are marked, so in replacing the piston is put back in the same cylinder. After the connecting rod has been loosened, then the piston is ready to be removed. (See Fig. 46.) If a detachable head, remove by pushing on the connecting rod. If not a detachable head, remove the piston by pulling on the connecting rod. If the rings are found to be fast in the grooves, clean them by washing in kerosene. Work around in the grooves until they are free.

Now remove the first ring with the aid of three thin metal strips. (See Fig. 38.) Insert these strips under the ring at the joint, leaving two of them close to the joint. Work the other one to a position opposite the joint. The ring is now out of the groove and can be easily removed.

Remove the others in like manner. Clean the rings and ring grooves in the piston thoroughly, using a screw driver. Scrape them if necessary. (See Fig. 39.)

93. Replacing Piston Rings. After all carbon has been removed and piston rings are washed, clean with gasoline. Try each ring in its groove to see if it fits properly. (See Fig. 41.) See that they are not too loose, and that the edges are smooth. If too loose or rough, they should be replaced with new ones. Also examine the joints to see that ends of rings have not been burned. Also see that the circumference of the ring is bright. If any portion is black, the ring does not fit the cylinder and should not be used.

When replacing the rings, put the center ones in first, using the metal strips as before so as to slide the ring over the groove. After the rings are in position, wash piston in gasoline to remove all grit and dirt. Considerable care is required in taking the rings off and replacing them, as they are easily broken. Then oil the piston and rings thoroughly, place the joints at equal distances around the piston, and replace the piston in the cylinder, repeating the removal operation.

94. New Pistons and Rings. The piston will eventually wear to such an extent that new ones are required. In fitting a motor with new pistons, see that the piston does not fit too tight. The piston should be .003 in. small at the open end, and .003 in. smaller for each one inch in diameter at the closed end. This will allow for the expansion of the piston when it becomes hot.

In some cases a new piston will not overcome leakage and restore compression. In this case the cylinder has become worn, and over-sized pistons are necessary. In some cases the cylinders must be rebored to proper size. Some motors have removable cylinder linings or bushings which can be removed when necessary, to overcome wear. If new piston rings are to be used, they should be fitted to the proper cylinder to determine if they are too large. If they are too large in circumference, the ring should be placed in a vice and the joint filed. With a ring properly fitted to the cylinder the space between the ends will be equal to 1-32 for a 4-inch bore, and 3-64 for a 6-inch bore, and 1-16 for an 8-inch bore. This will allow for the linear expansion of the ring when the motor becomes hot.

The rings should now be fitted to the piston, and each ring should be fitted to the particular groove for which it is intended. Place the ring in the groove and roll it around. The ring should fit so that it does not bind, and at the same time it should not have any play. Unless the ring is properly fitted to the groove, it will not hold compression. (See Fig. 41.) A good way to gauge this fit is to seat the ring in the groove and fit it so there is just an appreciable up and down movement on the outer side.

If the piston rings are too wide for the grooves, tack a sheet of emery cloth on a flat board and rub the ring on this until it is of the proper thikness. Each ring should be fitted in this manner and placed into the groove it is fitted to. (See Fig. 42.) When new pistons and rings are put in a motor they should be polished so as to remove all rust and rough edges, and washed in gasoline and properly oiled. IF THE PISTON FITS THE CYLINDER TOO CLOSELY, OR THE PROPER SPACE IS NOT LEFT AT THE JOINT OF THE RINGS,—WHEN THE MOTOR GETS HOT AND THE PISTON AND RINGS EXPAND, THEY WILL BIND IN THE CYLINDER, AND SOMETIMES STOP THE MOTOR. It can be started again after the piston and rings are allowed to cool and contract.

Do not work a new motor or one that has just been overhauled too hard. Give it sufficient time to wear in. Many a motor has been ruined by not giving it ample time to wear in.

95. Care of Connecting Rod and Crank Shaft Bearings. The connecting rod bearings should be watched very closely. On large motors they should be examined at least once a day. Most motors have hand hold plates conveniently located for this purpose. These plates should be removed and a bar placed under the connecting rod bearings. Pry up and down to ascertain if there is any lost motion. There should be a liberal amount of lateral motion. If a bearing is loose, remove the cotters and nuts, and the cap. Then remove the liners from the bolts, taking care not to lose or mix them up. These liners are generally of three thicknesses, extremely thin, medium, and heavy. If there is but little lost motion, remove one thin liner from each side, replace the cap and nuts, tighten the nuts firmly, being careful to tighten them all alike, and crank the motor over to be sure the bearing is not too tight. IF TOO TIGHT, DO NOT LOOSEN THE NUTS, but remove them and put in a thin liner. Then tighten up nuts firmly. If the bearing is not too tight or too loose, REPLACE THE COTTERS. Never work on more than one bearing at a time so as to determine if the bearing is properly adjusted.

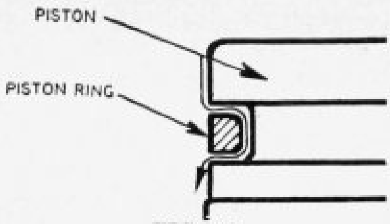


FIG. 40

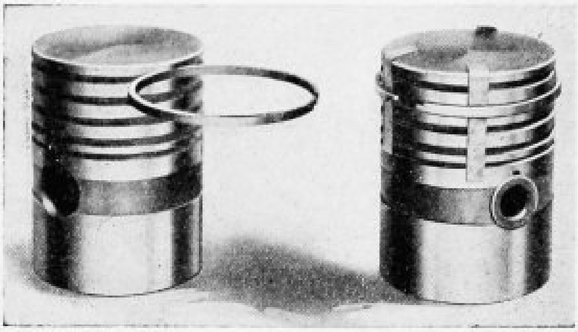


FIG. 41

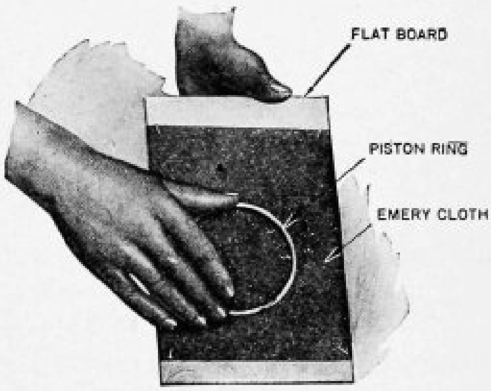


FIG. 42

There is nothing so important as the taking up of motor bearings when necessary. A great many tractor motors have been seriously damaged through carelessness of operators in doing this work.

Not Tightening the Nuts Properly and Replacing the Spring Cotters. The spring cotters should fit the hole snug, and be fastened in such a way that they cannot work in the hole. If they are allowed to work they will wear, and soon loosen and drop into the oil pan.

The connecting rod bolts will loosen, and either the piston will come up through the head of the cylinder or the connecting rod will come out through the side of the crank case. Too much care cannot be exercised in the upkeep of these bearings. If bearnigs are slightly loose, and for any reason they cannot be taken up at once, keep the motor speed well under 800 piston feet per minute, especially when idling.

A motor with loose bearings will pound and do more injury to the bearings with no load at high speed, than with full load at moderate speed.

The crank shaft bearings must be taken up occasionally. The operation is similar to that of taking up the connecting rod bearings. Take up one bearing at a time and crank over to see that the bearing is not too tight.

96. Fitting New Bearings. In case the bearings are worn out, or for any reason new ones must be fitted, a great deal of time and care must be taken. Unless well done it is better left alone. For this work the operator must have mechanical ability, proper tools, and patience. The proper kinds and sizes of BEARING SCRAPERS must be used.

In fitting up a new CONNECTING ROD BEARING, the first thing to do is to take the connecting rod out of the motor, after removing the connecting rod cap, and the connecting rod and piston, from the motor. The connecting rod and cap should be marked before removing so that they may be put back in the proper cylinder and in the correct position for the OIL DIPPER to work.

Most motors use die cast bushings, cast of high grade antifriction bearing metal. Some have bronze backs to prevent the metal from cracking. These bushings are held to the rod with copper rivets.

After cutting copper rivets and removing old shell, you are ready to put in the new shell. The shell with the single oil hole goes in the cap, and the hole lines up with the dipper. The other half, or the part that goes in the rod, has two oil holes. Place the cap in a vise and knock the shell down in place by means of a hammer and a round piece of hard wood, nearly equal to the diameter of the shaft. Never strike the bearing shell directly with a hammer, as it will batter it out of shape. With the wood and hammer knock the shell out again and file or scrape the flanges of shell if they show BURRS. It is very important that the shell fit firmly in the cap as running conditions would soon hammer the bearing loose if a burr on the shell is holding it up.

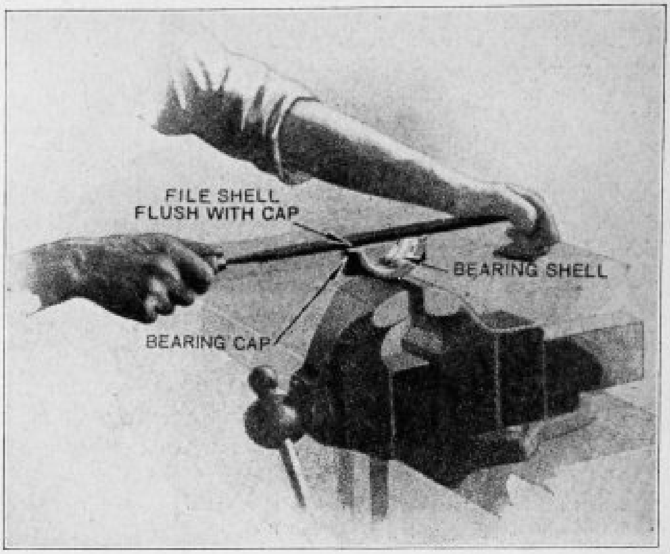


FIG. 43

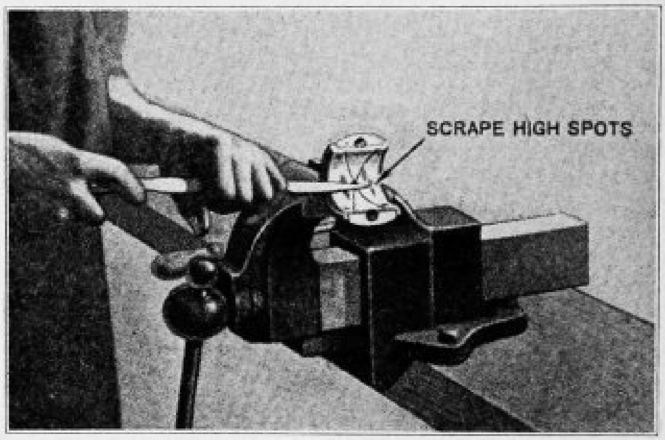


FIG. 44

After driving the shell in place again drill holes through the shell to correspond to the holes in the cap. These holes must be countersunk from the bearing side so that the rivet heads will not run against the crank shaft. Put in new rivets and fasten shell securely. Next, drawfile the edges of the shell where they project over the top of the cap until they are flush. (See Fig. 43.) With a round file, file the edge of the shell that projects into the bolt holes so that bolts will fit snugly.

Unless this is done the bolts will cramp the bearing shell out of shape. (See Fig. 44.) Placing the shell in the connecting rod is a similar operation and should be done in the same manner. To fit the bearing to the crank shaft each half should be fitted separately. When first fitting the shell it is best to file the inside of top edges for about a ¼ inch down to prevent binding.

An oil reservoir is formed this way and the bearing will be prevented from binding on the sides. Turn the bearing cap in the position it will occupy when fitted, and try it on the proper crank pin journal. It will probably be found too long, and it will be necessary to drawfile the ends of the shell. The bearings should go down in place and have play equal to the thickness of a piece of paper. The filing should be equally divided between the two ends.

The edges should be made perfectly smooth. The ends of the shell should be rounded off with a bearing scraper to correspond with the fillet on the crank shaft. The crank shaft journal should be coated with a thin film of Prussian blue, which may be obtained at any paint store in a collapsible tube. If this is not obtainable, take some soot, lampblack or other coloring, and mix with oil.

Put the bearing cap in place and rotate a few times on the shaft. The HIGH SPOTS will be indicated by the colored marking on the shell. Remove the high spots by means of a bearing scraper, and care should be taken not to remove too much metal at a time. (See Fig. 45.)

After each operation, spread the coloring film over the entire bearing. Continue until contact, as indicated by the coloring, is made over almost the entire surface of the bearing.

Replacing the crank shaft bearings is accomplished in the same manner as replacing the connecting rod bearings, but is a more complicated and difficult undertaking. After removing the crank shaft and old shells, then examine the crank shaft journals to see if they are badly cut or scored.

These should be smoothed as much as possible. A practical way of doing this is to wrap a piece of fine emery cloth of the proper width around the journal. Pull back and forth on the strip, polishing the shaft and cutting down the high spots until a smooth surface is obtained.

Care should be taken that the journal is of uniform diameter. If the shaft is out of round (which is caused by running with loose bearings), it must be sent to the factory and ground to a true diameter.

If the shaft is badly flattened and much grinding is necessary, then special bearings will have to be furnished.

Before assembling, clean all surfaces and OIL GROOVES. Be sure the parts are placed in their correct positions and properly assembled.

See that all nuts are tightened firmly and cotters are replaced. After bearings have been taken up, see that for the first day or two they get a liberal amount of oil.

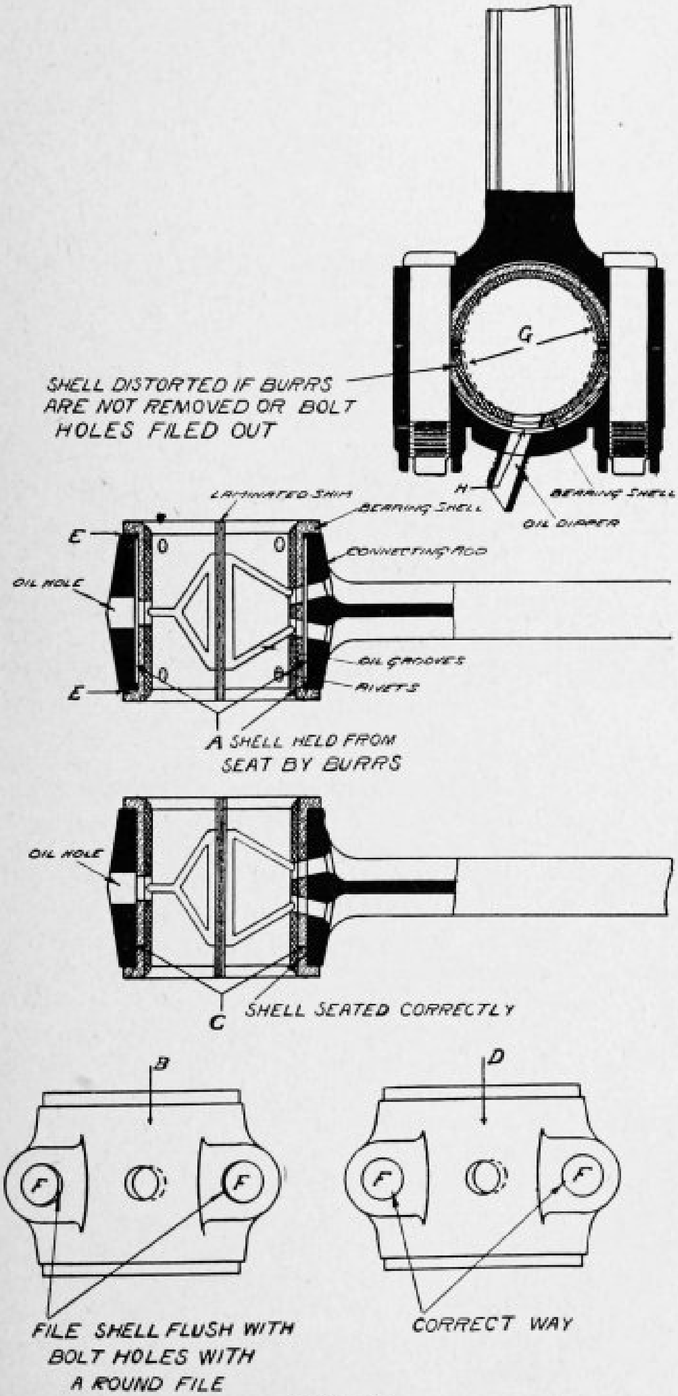


FIG. 45

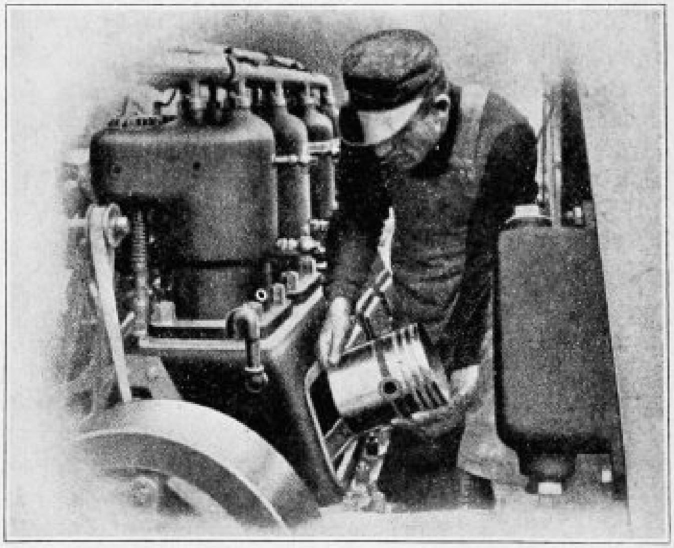


FIG. 46

97. Care of Piston Pin and Bushings. Three methods are employed for placing a piston pin in the piston. These methods are:

(A) The piston pin is held firm in the piston, securely fastened in such a manner that it is impossible for it to work loose. A bronze bushing is placed in the upper end of the connecting rod which furnishes a suitable bearing between the connecting rod and the piston pin.

(B) The piston pin is securely fastened to the upper end of the connecting rod and passed through reamed holes on either side of the piston which furnishes a suitable bearing.

(C) The piston pin is securely fastened to the upper end of the connecting rod with bronze bushings in the piston which furnish a suitable bearing. In either case above mentioned, if the piston pin or bushing become worn, a sharp knock is caused at each revolution of the fly wheel.

To remedy this in A construction it is necessary to replace the pin and bushings; in the B construction it is necessary to replace the pin and piston; in C construction it is necessary to replace the pin and both bushings.

To do this in the case of A and C, drive out the old bushings from connecting rod or piston. The new bushings can be pressed in with a vise or driven in with a hard wood block and hammer, being careful that it goes in straight.

The oil holes in the bushings should line up with those in the connecting rod or piston. With the construction C, the end of the bushings should be drilled and tapped, and the lock screws put in place, and the holes peined over, making it impossible for the bushings to work loose.

To fit the pin in the bushings, a perfect fit must be obtained to insure a good job. Usually it is only necessary to polish both the pin and inside of bushing with fine emery cloth. Sometimes the end of the pin is slightly blurred and has a wire edge, and this should be removed with a fine file or emery cloth.

The entering end should be slightly beveled. Care should be taken not to dress the pin or bushings too much, as this might make them too loose. A perfect fit must be obtained to have a good and lasting job.

Before placing assembly back in motor, wash the parts thoroughly with gasoline. BE SURE THAT THE PISTON PIN IS SECURELY FASTENED, making it impossible for it to get loose and work endways so as to score the side of the cylinder. If wire or spring cotters are used, be sure that they are perfectly tight and cannot vibrate so as to wear and drop out.

98. Babbitting Bearings. Some motors are constructed with the bearings babbitted integrally with the connecting rod and the crank case. If these bearings for any reason must be replaced, the operator must have some mechanical ability and previous experience. If he has not had this training he should employ a mechanic who has. This is especially true of the crank shaft bearings.

For the connecting rods, it is necessary to have a babbitting jig. (See Fig. 47.) With this jig it is comparatively easy to rebabbit the connecting rod, although one should have experience in order to do a good job. It requires a great deal of time and care unless the operator is prepared to do this, and has the tools and equipment necessary. It is better to send the connecting rod to the factory or branch office and have it rebabbitted or exchanged. For this reason one should have an extra rod on hand to put in the motor, if necessary, while the other is being sent to the factory. In replacing these rods it is necessary to scrape the bearing in the same manner as described in paragraph No. 96.

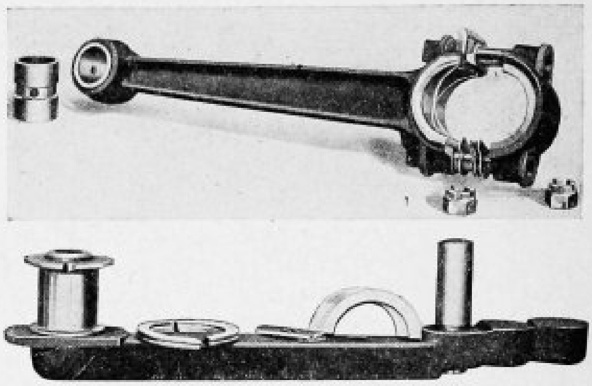


FIG. 47

99. Tuning the Motor. Speaking in the terms of a gas engine mechanic, the motor becomes out of tune. This is true that the working parts of a motor wear with every hour of use and the efficiency of the motor grows less. In the foregoing paragraphs we have taken up the function and construction of parts and their time and method of operation.

In paragraphs 88 to 98 inclusive we have explained the care of a motor. In Lesson No. 2, the proper timing of valves was discussed. It must be remembered, however, that the valve timing changes with use of the motor, as the valve operating mechanism wears, the valves open later and close earlier.

The exhaust valve should be open at 144° in its cycle, which allows ample time for the exhaust gases to expand to atmospheric pressure.

But if the exhaust valve opens later the gas does not expand to atmospheric pressure by the time the crank reaches 188° in its cycle, at which time the piston starts on its inward stroke. This pressure causes what is called "loading the piston." If five pounds pressure remains on the piston during the exhaust stroke, the M. E. P. is lowered five pounds.

If the exhaust valve opens later, it also closes correspondingly earlier. This would mean that the exhaust gases accumulated during the exhaust stroke of the piston have not had ample time to expand to atmospheric pressure, therefore at 368° we have a positive rather than atmospheric pressure. This means that the combustion chamber is compressed with burned gases which have no means of escape, so are forced to mingle with the entering gases. This condition cuts down the volume of new gases allowed to enter the cylinder for each power stroke.

Wear has caused the exhaust valve to open later and close earlier. The same is true of the intake. Although the exhaust valve closes earlier and leaves a positive pressure in the combustion chamber, it does not rush back into the intake manifold because the intake valve also opens later.

This allows the piston to travel downward and expand the gases to normal pressure before the intake valve opens.

The intake valve opening later causes an extreme high negative pressure during the intake stroke, which also would cut down the M. E. P.

If the intake valve opens later, it closes correspondingly earlier. Instead of having atmospheric

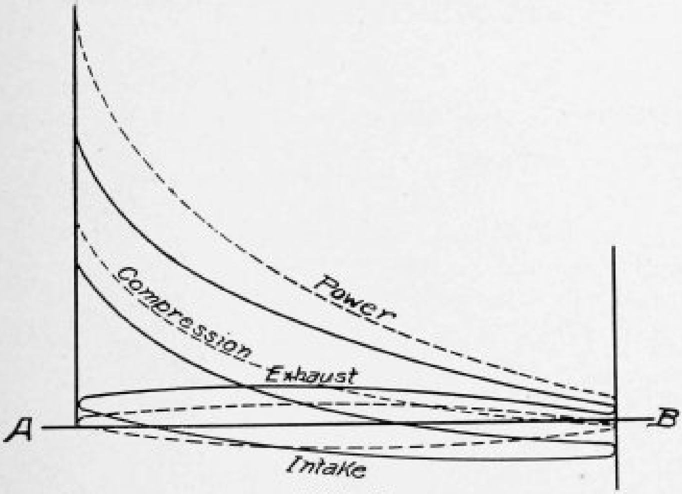


FIG. 48

pressure at 556° and a complete change of new gas, we have a negative pressure, and only a partial charge of new gas.

Having a negative pressure at 556° and the intake valve closed, it is necessary for the piston to travel in on the compression stroke some distance before atmospheric pressure is reached, causing a low compression.

Having a low compression and only a partial charge of new gas to burn, the explosive pressure is greatly reduced, and consequently the M. E. P. is very low.

We must deduct from the already low M. E. P. the positive or back pressure during the exhaust stroke and the negative pressure during the intake stroke. This causes a great loss of power and reduces the efficiency of the motor. (See Fig. 48.) The broken lines represent an ideal gas engine indicator card with proper valve timing. The solid lines represent a gas engine indicator card with the exhaust valves opening at 164° and closing at 348°, the intake opening at 394° and closing at 556° The line A-B represents the atmospheric line.

From this diagram it is plain to see the high pressure during the exhaust, and at 360°, the high negative pressure during the intake and at 540°. Under this condition compression does not begin until 610° in the cycle is reached, the diagram also shows the low compression and explosive obtained at 720°.

To remedy this, time the valves often by adjusting screws or tappets (see Fig. 49 and 50), place the marks on the fly wheel E C under the pointer, and adjust the adjusting screw or tappets so that the exhaust valves just seat, repeat this on each cylinder in the order of firing.

Place the marks I O under the pointer and adjust the tappets so that the intake valves just opens. Repeat as above.

Pay no attention to clearance. It is of no value except for taking up wear and setting the cam shaft after the motor has become worn. If no clearance exists after the valves are properly timed, the parts are badly worn, and new valve operating parts should be ordered.

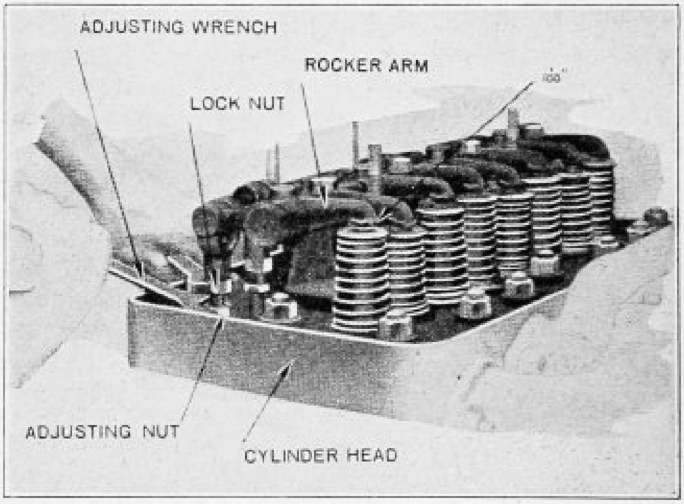


FIG. 49

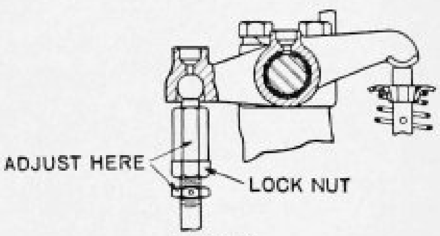


FIG. 50

CHAPTER II

COMBUSTION

100. The burning of Any Gas. The gas motor, like the steam engine, is a heat motor. It transforms heat into mechanical energy. Consequently, to be in any measure complete, a study of the gas motor must include a study of the laws of heat.

Many gases are available for combustion within the gas motor cylinder, but the gas most readily obtained, and probably at the lowest operating cost, is gasoline gas. At ordinary temperature gasoline is in the liquid form, but if exposed to the air, will rapidly evaporate, forming quantities of gasoline gas which are borne off by the atmosphere. Liquid gasoline, and also pure gasoline gas uncontaminated with air, are noncombustible. Varying mixtures of gasoline and air become combustible, but usually the percentage of pure gasoline gas compared to the percentage of air required for a rapid combustion is surprisingly small. Roughly speaking, one cubic foot of pure gasoline gas requires about 7.3 cubic feet of air to form a rapid combustible mixture. That is why a little gasoline in an empty tank or barrel makes the tank or barrel become extremely dangerous, while a filled tank or barrel is harmless unless confined in a room and has a small leak.

The gas motor mechanic calls the true proportion of gasoline gas and air required for perfect combustion a mixture. If the percentage of air becomes too small he terms it too rich a mixture; if the percentage of air becomes too great, too rare a mixture. In reality, in all gas motor work one of the most difficult engineering feats is the correct design of an apparatus that will always give the motor the correct mixture, neither too rich nor too rare. This apparatus is termed a carburetor, and its details will be taken up later.

Any individual who has burned fuel in a furnace without permitting enough air to enter has noted the great quantities of soot formed. This is a case of too rich a mixture. A gasoline gas and air mixture behaves in the same fashion. If the mixture is too rich, the resulting combustion will smudge the cylinder, burn with a yellow flame, and emit black smoke from the exhaust. If the mixture is very rare, the combustion might not take place at all; or, if it does result, it will be an incomplete one. Either too rich or too rare a mixture will not produce the required expansion for full power.

101. Composition of Air. There are three elements of nature we must understand to successfully master gas engineering

AIR, WATER, AND FUELS. Air is composed principally of three gases, nitrogen, oxygen, and carbonic acid gas. They are mixed in the following proportions: Nitrogen, four parts; oxygen, one part; and a slight quantity of carbonic acid gas. Of these three gases oxygen is the most important, for to its agency are owing the existence of animal life, the maintenance of combustion, etc.

If we measure the gases contained in the air by weight, we find oxygen 23 per cent and nitrogen 77 per cent.

The atmosphere has a pressure or weight af just 14.7 lbs. per square inch at sea level. The higher we ascend in the air, the less the pressure becomes. See Fig. 31, Chapter One.

A space void of air is called a vacuum, and is measured in inches of mercury. A vacuum sufficient to raise a colunm of mercury one inch in a U tube is termed one inch of vacuum. The same negative pressure will raise a colunm of water 13.6 inches, as water is 13.6 times lighter than mercury. Water is 815 times heavier than air at the sea level, with a mean temperature (56 degrees Fahr). Thirty-two inches of mercury is a perfect vacuum at sea level.

If a vacuum existing in a vessel should suddenly be opened to the natural atmosphere by means of a valve, the air at a maximum density of 14.7, would rush into the vessel at the rate of from 1,300 to 1,400 feet per second.

At a temperature of 60 degrees Fahr. at sea level, there are 13.817 cubic feet of dry air to one pound.

If a volume of air were compressed into one-half of its space, its density would be doubled; and if compressed into one-fourth of its space, its density would be increased fourfold, and so on.

Air at a constant pressure expands .461 of its volume for each degree (Fahr.) of heat communicated above zero, and doubles its volume at 480 degrees (Fahr.).

102. Water. Water is composed of oxygen and hydrogen. At 62 degrees Fahr. there are 27.71 cubic inches of fresh water to one pound.

A column of fresh water 34 feet high, at a temperature of 60 degrees (Fahr.), will have a pressure of 15 lbs. per square inch at the base.

A column of fresh water one foot high, at a temperature of 62 degrees (Fahr.), will have a pressure of .434 lbs. per square inch at the base.

Water at 56 degrees Fahr. is just 13.6 times lighter than mercury, and 815 times heavier than air at sea level at a temperature of 60 degrees Fahr.

Water expands with both heat and cold. It is heaviest, or at its greatest density, at a temperature of about 39 degrees Fahr., or 4 degrees Cent. At this point it will expand either with heat or cold.

Water with a temperature of 32 degrees Fahr. has the same weight as water at 47 degrees Fahr.

One cubic foot of fresh water at a temperature of 60 degrees Fahr. weighs 62.37 lbs. One U. S. standard gallon, 251 cubic inches, or 294 cylindrical inches, at 60 degrees Fahr., weighs 8.33 lbs. Consequently there are about 7½ gallons per cubic foot of water. Twenty-eight cubic inches, or 35 cylindrical inches, of fresh water at the mean temperature of 56 degrees Fahr., weighs one pound.

One cubic foot of ice at 32 degrees Fahr., the freezing point, weighs 57.5 lbs. One cubic foot of freshly fallen snow weighs 5.2 lbs. Freshly fallen snow has twelve times the bulk of water.

Fresh water will boil in a perfect vacuum at a temperature of 72 degrees Fahr., in the open air at sea level 212 degrees Fahr., and under a pressure of 15 lbs. per square inch at a temperature of 234 degrees Fahr. Water will expand 2¼ per cent in volume while it is being raised from 60 degrees Fahr. to 212 degrees (boiling point).

Water, at normal atmospheric pressure at sea level, increases its volume 1,700 times while it is being raised from 212 degrees to vapor or steam.

103. Heat Values or British Thermal Units (B. T. U.). Heat is produced by the burning of fuels, and is measured in British Thermal Units (B. T. U.).

The amount of B. T. U. depends upon the composition of the fuels. There is no known common fuel which has available more concentrated heat power in a given quantity than the hydrocarbons, and that burns so completely. This heat may be measured by B. T. U.

Note I—B. T. U. One B. T. U. is the amount of heat required to raise the temperature of one pound of pure water 1 degree, from 39 degrees to 40 degrees Fahr. Water at 39 degrees is selected because that is the point of greatest density. A B. T. U. will do 746 foot pounds of work, or .0236 H. P. It requires 42.42 B. T. U. to produce one H. P.

Oxygen and one pound of carbon burned completely liberates 14,650 B. T. U.

Oxygen and one pound of hydrogen burned completely liberates 52,000 B. T. U.

Combinations of carbon and hydrogen liberate relatively quantities of heat units depending on the above facts.

104. Influence of Temperature upon Combustion. Though a true mixture burns with startling rapidity it does not explode. If a flat sheet of newspaper is burned, the fire must start at some point where ignition is effected and extend in a flame wave slowly across the paper. If the paper is room temperature and has an ignition point of 500 degrees, then, before any part of the paper will start burning, it must be heated from room temperature to 500 degrees. After the first particle is ignited, it will be necessary for this first particle to raise the neighboring particles from room temperature to 500 degrees, if the combustion of the paper is to continue. We will suppose it will take three seconds to burn the paper.

Take a duplicate piece of paper. Warm it to 450 degrees. Ignite the first particle, and this first particle will have less work in bringing the neighboring particles to their ignition temperature, with the result that the flame wave will travel across the paper much quicker. Obviously, the pre-heating fuel increases the rapidity of the combustion. This holds good for gasoline gas and air mixture. The electric spark at the spark plug starts the flame wave which travels slowly if the mixture is cold, rapidly if mixture is hot Therefore compression is conductive to higher efficiency.

In figuring the proper volume of air to mix with a given quantity of fuel, one takes into account the fact that one pound of hydrogen requires eight pounds of oxygen to burn it, and one pound of carbon requires two and one-third pounds of oxygen to insure its combustion. Air is composed of one part of oxygen, and three and one-half portions of nitrogen by weight. Therefore, for each pound of oxygen one needs to burn hydrogen or carbon, so that four and one-half pounds of air must be allowed. To insure combustion of one pound of gasoline which is composed of hydrogen and carbon, we must furnish about ten pounds of air to burn the carbon and about six pounds of air to insure combustion of hydrogen, the other component of gasoline.

While it may usually be considered that air has little weight, we learn that at a temperature of sixty-two degrees Fahrenheit, about fourteen cubic feet of air will weigh a pound; and to burn one pound of gasoline would require approximately two hundred cubic feet of air. This amount provides for combustion, theoretically, but in common practice we allow considerable more. By consulting the table of properties of fuels, we find that a greater amount of air is required for the theoretical chemical combination. This is due to the fact that in practice we never can obtain a perfect and uniform mixture, as every particle of oxygen does not come into contact with every particle of fuel; hence, an excess of air is supplied to insure complete combustion. If the gas or fuel mixture is not properly proportioned, the rate of burning will vary; and if the mixture is either too rich or too lean, the power of combustion is reduced and the amount of power applied to the piston is decreased proportionately.

105. Fuels (Gases). While the accompanying tables give the calorific values of various gases as determined by the calorimeter, it will be found that they develop widely different values in the cylinder of a gas engine, the difference being due to compression pressures, ignition system, etc.; and it will be found that it is the heat value of the mixture that rules, rather than the calorific value of the fuel itself.

From the table we see that a rich gas (high in B. t. u.) requires more air to burn it than a lean (or rare) gas (low in B. T. U.); hence the cylinder of the motor will take in less of the actual combustible in the case of the rich gas, than in the case of the lean gas; therefore the actual heating value of the charges in the cylinder is more nearly equal than given in the tables. Again, a lean gas can be used under higher compression better than a rich gas; and as high compression is conducive to efficiency, the lean gas again gains in actual heating effect. Rich gases and gases high in hydrogen value ignite more readily than others, but can be used only under low compressions, as the temperature developed by high compression causes them to pre-ignite.

Another item affecting the theoretical calorific value of fuel, either solid, gaseous, or liquid in the cylinder of a motor, is the rate of flame propagation or rate of burning.

The rate of flame propagation is, in part, an individual characteristic of the fuel which is still further affected by surrounding conditions. For example, wood burns at a slower rate than gun powder. Gunpowder burns with a slow, powerless flash when in the open air, but when confined under pressure burns almost instantaneously and is capable of establishing an enormous pressure and temperature.

(a) The rate of flame propagation of all gases is increased by placing them under pressure before starting combustion. The pressure causes the molecules or particles of fuel to crowd closer together, consequently decreasing the distance through which the combustion must act.

(b) As the heat loss of a burning gas by radiation (and by conducting away of the heat by the walls of the containing vessel) is increased by the length of time of burning, it follows that the greatest rate of flame propagation is conducive to the greatest efficiency. Hence, within certain limits, the greater the compression, the higher the rate of flame propagation, and the higher the efficiency, or effective heating value of the fuel. The limit of compression depends upon the ignition point of the gas or fuel used.

The rate of flame propagation is decreased by incorrect proportions of oxygen and the fuel; mixtures containing an excess of fuel, or over rich, burn very slowly, even with high compression.

Mixtures that are rich in gasoline ignite quicker than those which have a large proportion of air, but are only suitable when starting or at low speed, as the rich mixture ignites easier than the lean.

Rich mixtures are more easily ignited than lean.

Partially consumed fuels, or fuels burned with insufficient oxygen, as a rule, produce evil smelling and highly colored products of combustion. Fuels thoroughly burned are odorless and colorless.

In order that maximum efficiency be obtained in burning gaseous fuel, the following conditions must exist:

106. Summary.

1. High Calorific Value:
   1. Great amount of energy per unit weight.
2. Rapid Propagation of Flame:
   1. Reduces heat losses by radiation and conduction to walls of containing vessels.
   2. Increases the possible speed range of motor or the volume of gas burned in a given time.
   3. Presents several advantages in ignition, etc., in the pratical motor.
3. Complete Combustion (Perfect Mixture):
   1. Develops full value of fuel.
   2. Increases rate of flame propagation with increased efficiency.
   3. Produces maximum pressure in given sized vessel.
   4. Produces odorless products of combustion.
   5. Causes a minimum of carbon deposits.
   6. Increases ease of ignition.
4. High Compression (Reduced Volume):

Fuel—Properties of Gases

GAS	B. T. U. per Cubic Foot	Cubic Feet of Air Required to Burn One Cubic Foot of Gas		Usual Compression Lbs. per Square Inch	Ratio of Gas to Air	Explosion Pressure in Lbs. per Square In.	Temperature of Combustion, F. Degrees	Ignition Temperature, F. Degrees	Weight per Cubic Foot, Lbs.	Candle Power	Average Pressure
		Actual	Theoretical								
Natural Gas	1000	12.60	9.	130	1–12.6	375		1100	.0459		94.00
Natural Gas	1000			110	1–6	245		1100			72.00
Coal Gas	650	9.00	5.85	80	1–9	285		1200	.035	18.00	85.00
Producer Anthracite	140	1.20	1.85	160	1–1.2	360		1450	.065		88.00
Water Gas (Uncarb.)	290	3.60	2.20					1	.044		
Water Gas (Carb.)	500	8.50	5.15		1–8					22.00	
Blast Furnace Gas	94	1.10	.70	170				1560	.080		77.5
Acetylene	1560	20.00	12.60								
Gasoline Vapor	520	8.20	7.30	70	1–12	245	1865	1050			79.00
Gasoline Vapor	520			70	1–8		2950	925			82.00
Gasoline Vapor	520			70			3100	910			84.50
Kerosene Vapor	520			60	1–8	285	3160	945			85.00
Coke Oven Gas	520	7.5	5.4						.042		
Alcohol	520			180		450					
				180							

The values given above are approximate, and vary not only with the engine used, but also with the methods used in producing the gas, and the character of the fuel used. The figures will give an idea of the relative value of the gas in a rough way.

FIG. 51

1. Increases rate of flame propagation with increased efficiency.
2. Produces maximum pressure and temperature.
3. Increases ease of ignition.
4. Has practical mechanical advantages.

In summarizing the properties of fuels, we find that in order to obtain maximum efficiency in the gas motor we must understand the calorific value of the fuel used, and its individual characteristic. We find many conditions will enter into the use of fuels in varying types of motors, and carburetion of which we will learn later.

The calorific value of a fuel may be very closely calculated if the chemical composition or analysis of the fuel is known.

The calorific value of a fuel is determined by an instrument known as the Calorimeter in which a sample of the fuel is burned, and the rise in temperature of a known quantity of water is noted.

107. Compression. Compression should be carried as nearly as possible to the ignition temperature of gas; the temperature of ignition varies inversely with the calorific value of the fuel. Every fuel has a limit to which compression may be carried. Gases high in hydrogen ignite easly and should be used with low compression.

As high compression which results in rapid flame propagation is conducive to the highest efficiency, it follows that at all times there should be the correct chemical mixture of air and fuel to obtain the maximum explosive pressure, as the higher the compression, the greater the force exerted by the rapid combustion.

It may be stated thus: As a general thing the maximum explosive pressure is three and one-half times the compression pressure prior to ignition. A charge compressed to eighty pounds will have a maximum of approximately two hundred and fifty pounds on each square inch of the piston area at the beginning of the power stroke.

108. Fuels (Liquid). The principal liquid fuels used in the internal combustion motor are as follows:

1. Gasoline.
2. Kerosene.
3. Naphtha Distillate.
4. Alcohol.
5. Benzol.
6. Crude Oil.

Liquids are utilized in the cylinder of the motor in the form of a vapor or spray, the more volatile liquids, such as gasoline and alcohol, being converted into vapor at atmospheric temperature; and the heavier non-volatile, such as kerosene and crude oil, being sprayed into a highly heated vaporizer, or sprayed into the heated cylinder direct.

The more volatile liquids are vaporized in a device known as the carburetor, and the ingoing air, which is near atmospheric temperature, absorbs the liquid as it passes into the cylinder.

The percentage of a liquid fuel per cubic foot of vapor varies with the temperature of the air, the boiling point of the liquid, the pressure and humidity.

The specific gravity of the crude oil will range from 10° to 56° Baume. The crude from Pennsylvania will average 40° Baume while that of Texas will average 20°.

Pennsylvania crude oil will average 20 per cent yield of gasoline, while Texas will yield about 3 per cent.

The table "Properties of Fuels (Gas)" will give calorific value, weights, densities, and air required for combustion, etc.

109. Density—Specific Gravity. "Density" is the mass per unit volume, or is equal to the mass divided by the volume. Density is generally expressed in terms of specific gravity.

"Specific gravity" is the ratio of density of a body to that of another body taken as a standard. (Water is generally taken as the standard with fluids and solids.) Water is at maximum density at 4° C. (39° Fahr.). The gases are generally referred to hydrogen as a standard, although air is frequently taken as a standard for gases.

110. Gasoline. Gasoline of the American trade has a specific gravity which varies from 61 Baume to 72 Baume degrees, depending on its percentage of hydrogen. The value of 61 Baume denotes a light grade of gasoline, and 72 Baume is the quality used in gasoline stoves. With a specific gravity of 61° Baume the analysis of 1,000 parts of gasoline gives 838 parts carbon, 155 of hydrogen, and 7 of impurities; and with this composition there are about 18,000 heat units per pound. The vapor of gasoline expands to 1,200 times its liquid volume, so that a gallon is equal to 160 cubic feet of vapor. At 74 degrees Baume gravity gasoline weighs 6.16 pounds per gallon. One pound of the liquid is equivalent to 26 cubic feet of pure vapor, and dividing the 18,000 B. T. U. by 26 gives 692 heat units per cubic foot. Two and one-half cubic inches equals one B. T. U.

The boiling point of gasoline such as is used in explosive motors varies from 150 to 180 degrees Fahr.; and the flash point, from 10 to 14 degrees Fahr To completely burn the vapor from one pound of gasoline, 189 cubic feet of air are required, and dividing this by 26 gives 7.3 as the volume of air required for one volume of gasoline vapor. This ratio may be increased to 10 parts of air to one of gasoline vapor; but if any less than 7.3, a residuum of unburned fuel will be left in the exhaust. 20.75 cubic inches of mixture equals 1 B. T. U.

111. Kerosene. As kerosene forms about 42 per cent of the distillate of crude oil, it is apparent that this material is replacing gasoline to quite an extent, particularly in heavy duty motors, for stationary purposes, and most farm tractors are bringing it into general use.

In addition to the unlimited supply of heavier fuels, the difference in the price of kerosene compared to gasoline is on an average of about one-half, and the crude oils about one-third that of gasoline. If considered from a point of view of heat units contained or heating value, kerosene would be a better fuel than gasoline; but we find many disadvantages which do not make it so suitable for use in existing types of motors. The chief difficulty which retards its use is that it will not vaporize readily at ordinary temperatures; and before it will evaporate sufficiently to form a gas with air, it must be heated. This calls for specially constructed vaporizing devices and jacketed manifolds, which will be described in proper sequence.

Owing to its slow rate of evaporation, it is contended that it cannot be used as successfully as gasoline on high speed motors where flexibility of control is desired, and when the engine must be accelerated from its minimum to its highest speed in a short time. On slow and moderate speed motors it has been employed with considerable degree of success. It contains more carbon in its composition, and as the combustion of kerosene vapor is not apt to be as complete as gasoline gas, more carbon will be deposited in the interior of the combustion chamber than when gasoline is burned. There are many experiments being made with special devices for carburetion of the heavier liquid fuels, and the present devices have made it possible to secure good commercial results, and there is much to encourage their future use.

112. Alcohol. Experts who have carefully studied the question have unanimously arrived at the conclusion that it is by fermentation, and fermentation alone, that growing vegetation can be rapidly converted into available fuel. Therefore the fuel of the future is alcohol.

Alcohol is most easily prepared from starchy substances. The vegetable is converted into dextrine and maltose when fermentation is started by the addition of a small quantity of yeast. This conversion results in the formation of alcohol.

No less than 95 per cent of the grape sugar is split up into alcohol and carbon dioxide. Potatoes contain some 20 per cent, wheat 60 per cent, and rice 83 per cent of starch; but, although the two latter contain so much larger a proportion of starch, the former will always be the more economical source, because the crop per unit area is so much larger, one acre of grain yielding some 8 to 10 cwt., and an acre of potatoes some 20 to 24 cwt. of starch. A ton of potatoes yields from 25 to 30 gallons of alcohol.

Another very suitable vegetable is beetroot, which is (under favorable circumstances) even a cheaper source of alcohol than potatoes, although the beetroot crop takes more out of the land. Recent experiments have shown that even ordinary wood sawdust can give 50 gallons of 90 per cent alcohol per ton weight of sawdust. Indeed the supply of alcohol is practically unlimited, because it can be extracted from any vegetable matter containing starch or sugar.

Owing to the high price of gasoline, the question of adopting alcohol as a fuel for internal combustion motors is one which has already received no little attention in the United States, in France, and in Germany. As usual, one finds that when we desire to make ourselves acquainted with the value of alcohol as a fuel, it is to work done in these countries that we must refer.

The United States Department of Agriculture in 1906 carried out a series of both elaborate and exhaustive experiments with alcohol as a fuel. The conclusions arrived at will be stated later.

113. Excise Restrictions. Owing to excise restrictions, the sale of the pure spirit is not permitted until it has been what is termed "denatured" by the addition of some other ingredient which shall render it so unpalatable or noxious as to be undrinkable. Germany uses pyridine bases, benzine, and methyl alcohol; France, methylene; the United States, methyl alcohol and benzine; England, methyl alcohol; and so on.

In all present calculations or comparisons, it is then this denatured or methylated spirits that we must consider, it being the only form of alcohol which is available for industrial purposes; in the future, however, these restrictions will be changed.

Comparison between alcohol and gasoline.—Let us compare the present denatured or methylated alcohol and gasoline. So far as actual practical results are concerned they should not be judged by their thermal value only, as that would lead us to the erroneous conclusion that alcohol had but little chance as a competitor.

The following is the result of a test made with a pair of 8 h. p. motors, one designed for gasoline and the other for alcohol: Methylated alcohol, 373.5 grams per horse-power hour; gasoline, 340 grams per horse-power hour. The efficiency calculated for the gasoline being 16.5 per cent, and for alcohol 28 per cent. The fact that it is possible to obtain so much higher a degree of efficiency from alcohol is due to (1) the greater facility with which complete combustion can be obtained and the lesser quantity of air required as compared with gasoline. (2) With alcohol, a far higher compression, and consequently a higher thermal efficiency, is obtainable. It has been found that motors worked with perfect safety with as low a compression as 90 lbs.

This is possible owing to the non-inflammability of alcohol, which distils over at 170° F., whilst 67° F. is the lowest temperature at which it can be ignited.

(1) Conclusions of the U. S. Board of Agriculture on the use of alcohol. Any ordinary motor operating with gasoline or kerosene can be run on alcohol without any structural change.

The chief disadvantage of alcohol is that it requires a high temperature for evaporation, and therefore it is difficult to start a motor with alcohol when it is cold.

(2) When an engine is run on alcohol it is less

noisy than when running on gasoline.

(3) For air-cooled automobile motors alcohol is especially suitable as a fuel.

(4) The fuel consumption is better at low speeds than at high ones.

(5) An ordinary gasoline motor will give some 10 per cent more power when burning alcohol, but at the expense of a greater fuel consumption.

But by especially adapting the motor to the use of alcohol, 20 per cent more power is obtainable, with a greater economy of fuel.

One objection to the use of alcohol as a fuel is that in the process of combustion aldehyde, acetic acid, etc., are formed; and that if the process of combustion is not complete, a corrosive action is set up in the cylinders. This is no doubt true; but there is no difficulty in making the combustion a complete one, since the amount of air required is only one-third that which is necessary when using gasoline, and the explosive range of alcohol vapor is rather more than three times that of gasoline.

114. Advantages and Disadvantages of Alcohol as a Fuel.

ADVANTAGES

(1) The fact that alcohol is a homogeneous spirit causes the presence of oxygen to be conducive to better carburetion.

(2) It has a distilling temperature of only 170° Fahr.

(3) It has a large range of explosive mixtures, 4 to 13.6 per cent.

(4) The motor is less noisy when working.

(5) It admits of a higher compression, and therefore an increased thermal efficiency.

(6) It has from 10 to 20 per cent more power per unit of cylinder volume.

(7) It has a purer exhaust.

(8) It has greater safety.

DISADVANTAGES

(1) The present high price of alcohol makes it prohibitive.

(2) It has a low calorific value, therefore slow combustion.

(3) The slow piston speed requires a heavier type of motor.

(4) A higher vaporizing temperature is required.

None of these is at all of a formidable character, and number one disappears at once with removal of excise duty.

Even at the present time, in districts where there is a good supply of cheap raw material for the manufacture of denatured alcohol, and which are at the same time remote from supplies, alcohol can immediately compete against gasoline as a fuel for internal combustion motors.

As gasoline and kerosene, etc., become dearer and dearer by reason of their exhaustion, alcohol will become a stronger and stronger competitor, and in course of time will entirely supplant the present-day kerosene motors.

Motors will be in course of time especially designed for the use of alcohol, and will be vastly superior in efficiency to present-day adaptations. To show to what state of perfection this same adaptability can be carried, one has only to consider the French army manoeuvre requirements, viz., that their motor vehicles shall be capable of working at a moment's notice on either gasoline, benzol, or alcohol.

The best external combustion motor has an efficiency of 13 per cent. And in the case of the gasoline motor it has risen as high as 25 to 30 per cent. With alcohol an efficiency of 25 to 30 per cent is obtained without any difficulty. (Constituents of methylated alcohol: Carbon 51 per cent, hydrogen 13 per cent, oxygen 36 per cent.)

CHAPTER III

CARBURETORS

115. The carburetor. A carburetor is a mechanical device for breaking up volatile fuels into fine molecules and mixing them with the proper proportion of air (oxygen) necessary for complete combustion, regardless of air volumes or velocity. The resulting mixture is what a motor mechanic terms a true mixture.

The better carburetors break up the volatile fuels into finer molecules and mixes them with the proper proportion of air, regardless of air volumes, velocities or reasonable angularities.

116. True Mixture. True mixtures were easily obtained on the earlier type of motors, due to the fact that they were equipped with what was known as the hit and miss governing principle. These motors took in the full volume sweep of the piston on each intake event until the proper speed was obtained. Then the governor would cut out the valve-operating mechanism, causing the motor to idle until the speed had been reduced, and then the governor would allow the taking in of another charge on each intake event until the speed was increased to normal, that is (i. e.) 800 piston feet per minute.

You will notice that with this principle the air velocity and volume remains constant. These motors were also used for stationary purposes, and so were placed on a solid foundation. Consequently there was no change in angularities. A carburetor for such a motor was comparatively simple. Such a carburetor is found in Fig. 52, showing the carburetor at rest. It has a float chamber A, and a float B operating float valve E. The fuel enters past the float valve E and fills the chamber A until the float enters past the float valve E. and fills the chamber A until the float rises and closes the valve E. Thus the float maintains a constant fuel level in the chamber A. The fuel also passes through the duct D to the center of the main body of the carburetor C. This duct develops into a nozzle in the center of the air passage and extends about one-eighth of an inch above the fuel level in the bowl A., as shown in the Fig. 52. This cut shows the fuel level when the motor is standing.

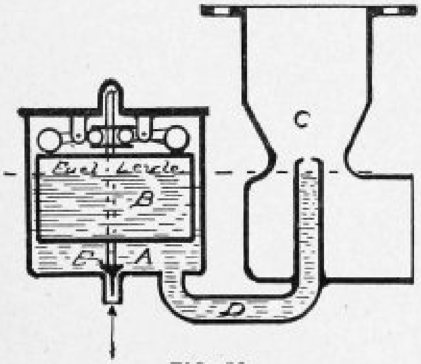


FIG. 52.

117. Adjusting Carburetor with Constant Air Volume and Velocity. Upon turning the motor over, the air travels through the carburetor as shown by the arrows in Fig. 53. The negative pressure which causes the inrush of air, also causes the fuel to pass out of the nozzle, as shown by the small arrow. It mingles with the inrushing air. With a little experimenting the size of the nozzle could be determined that would give us a true mixture under these conditions, namely constant volume and velocity. It can be seen from the figures that the carburetor for a motor working under these conditions is very simple; and after being properly adjusted no further adjusting is necessary.

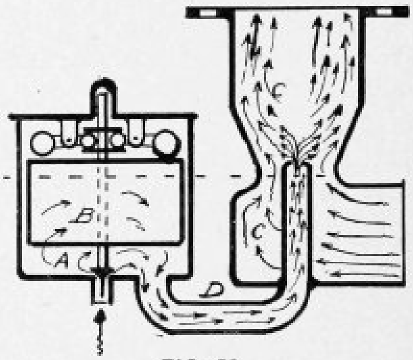


FIG. 53.

118. Adjusting Carburetor for Variable Air Volumes and Velocities. As time went on, and the use of the internal combustion motor became more popular, a demand was made for a motor of greater flexibility, and the throttling governor was adopted for use on motors for electric light plants, tractors, and automobiles. This brought new burdens on the carburetor, so that many mechanics spent a great deal of time and money trying to improve the carburetor so as to give a true mixture with the varied air velocities and

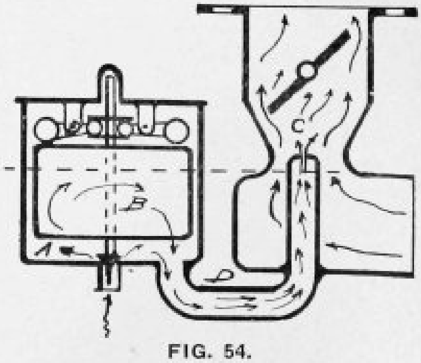


FIG. 54.

volumes. Up to date there have been more than 50,000 patents issued on the carburetor.

In the latest type of carburetors, we have one that will give the proper mixture at all times regardless of volume and air velocity. Let us refer to Fig. 54 which is a sectional view of the same carburetor as that shown in Figs. 52-53 except that it is equipped with a throttle valve. The throttle valve is one-quarter open,—the position it would be in if the tractor was traveling idle down the road or across the field. The fuel is entering through the nozzle and being

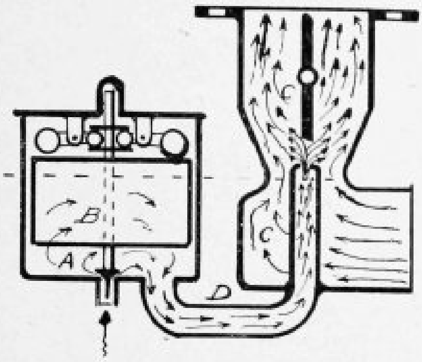


FIG. 55.

mixed with air entering through the main intake. The large arrows represent the air. The small arrows represent fuel. We will say that the nozzle is of the proper size to give a proper mixture when the throttle is one-quarter open and the tractor is running light, we arrive at the field and drop the plows in the ground. Now the throttle is thrown wide open (See Fig. 55) so that the amount of air that is entering through the main air intake has tripled. In this case, we have six arrows of air to eight arrows of fuel. One would naturally think that with a carburetor built in this manner that the fuel supply would increase in proportion to the air velocity, but such is not the case. We find that the fuel supply increases more rapidly than the air supply, and this is the stumbling block in the path of success in such a simple carburetor.

The law of liquid flow tells us in substance, that the flow of liquid from the jet increases under suction faster than the flow of air, and nature's laws are unchangeable. The law of gravity and the law of liquid flow cannot be overcome, so this spoils our simple type of carburetor for the new working conditions demanded; namely, varied volume and velocities. As the ratio of one to seven in gasoline and air cannot be maintained constantly under varying suctions or air velocities, what really happens is that the flow of gasoline from the jet increases under suction faster than the flow of air, giving a mixture which grows richer and richer as the air velocity increases; a mixture containing a much higher percentage of fuel at higher suction than at low. To overcome this difficulty such a carburetor as shown in Fig. 56 has been designed. The duct D leads up past the fuel reservoir with the second nozzle F communicating with the duct D, and the fuel reservoir. In this carburetor, when the plows are not used and the air velocity is very low; the

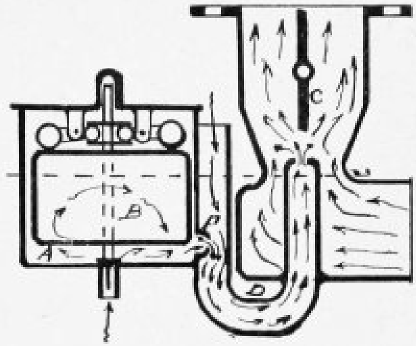


FIG. 56.

nozzle in the center of the carburetor is of proper size to give a proper mixture. The instant that the plows are put in the ground, the throttle valve opens, the suction soon exhausts the fuel supply in the duct D, and air is allowed to enter the top of duct as indicated by the arrows, and the nozzle F is emptied which is of the proper size to give a proper mixture when the plows are in the ground. The suction of the motor has no influence upon the nozzle F, whatsoever. This gives

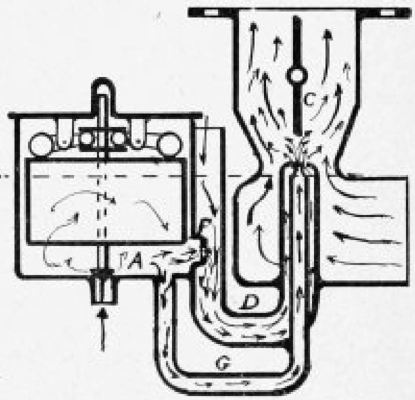


FIG. 57.

us two regulations, one when the plows are in the ground and the other when they are out of the ground.

This would be an ideal carburetor for a tractor motor providing, of course, that plowing conditions were always the same; but we find that plowing is not always the same. We have the hard spots and the soft spots, and with carburetor, Fig. 56, if the nozzle F was of proper size to give a proper mixture in ordinary plowing, when we strike a hard spot where the load is extremely heavy and the air velocity extremely high, an insufficient supply of fuel would flow out of F, producing a lean mixture which would cause a popping-back at the carburetor and a loss of power.

This made it necessary to take one step further and build such a carburetor as Fig. 57 which has a compound nozzle in the center of the main body of the carburetor. Nozzle G is added which communicates at the bottom of the main supply reservoir A, while D is open to the atmosphere and communicates with nozzle F, as shown in Fig. 56.

These nozzles are of proper size so that when we have one-fourth throttle or light load, a proper mixture is furnished by the two nozzles D and G, supplied from the main reservoir A. When the plows are in the ground and the throttle is open, the proper mixture is furnished by nozzle G and the nozzle F, which give a proper mixture with air flowing in from the top of the duct D as before. We have no influence from the suction of the motor upon the nozzle F. The fuel supply through the nozzle D has depreciated under suction, but the fuel supply in nozzle G has increased in proportion and continues to increase under the ex-

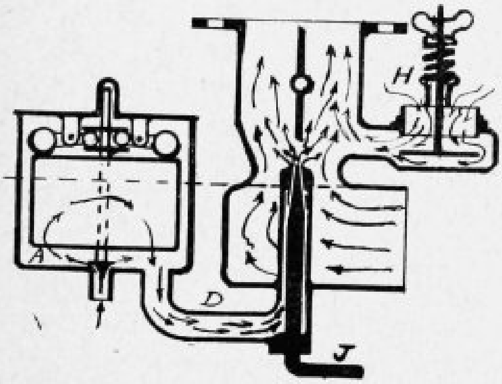


FIG. 58.

tremely heavy load in the right proportion to give us a proper mixture.

This would be an ideal carburetor, very simple and with no adjustment and not apt to get out of order, if the atmospheric conditions were unchangeable, and if the fuel was always of the same grade. But since the atmospheric conditions and the fuel are variable, it seems necessary that from time to time we should be able to readjust the carburetor so as to correct the mixture.

This leads to the adoption of a secondary air valve which is shown in Fig. 58 at H. This air valve is held on its seat by a spring and has a thumb nut for adjusting the tension upon this spring. The duct D is connected with the main float chamber, and the nozzle is of proper size to furnish a proper mixture at one-fourth throttle. At full throttle where the air velocity increases, the mixture becomes richer as said before. At this time the valve H is permitted to open and allow the air to enter through a secondary port and mix with the rich gas leading from the nozzle so as to reduce it to the proper proportion to give a proper mixture at heavy loads for full throttle.

We wish to call your attention to the fact that when speaking of a carburetor and velocity, we do not speak of speeds of the motor but of air velocity. We might have a high air velocity at a low piston speed, or we might have a low air velocity at a high piston speed; but in talking of speeds in connection with a carburetor, we mean air speeds or velocities. The valve H has an adjustment which regulates the tension on the spring, which holds the valve on its seat. This affords adjustment for extremely heavy loads.

Fig. 58 is also equipped with a needle valve J for changing the size of the orifice or nozzle in the duct D so that the opetrator can change the size of this orifice to get proper mixtures at low air velocities. The needle valve J has a thread by which it can be adjusted to increase or diminish the size of the jet to get proper mixture at low velocity, and the proper mixture at high velocity may be obtained by regulating the tension on the spring valve H.

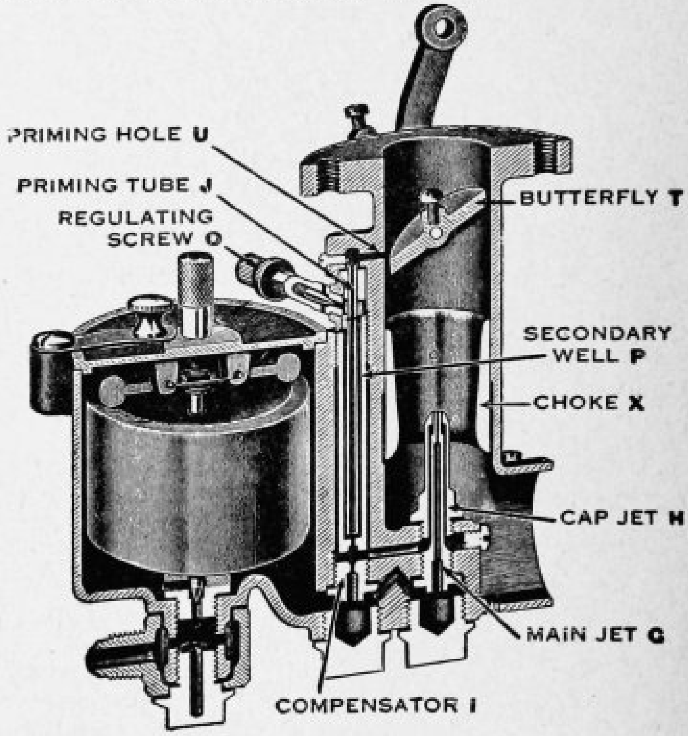


FIG. 59.

Fig. 57 represents what is known as the compound nozzle principle of carburetion which has grown very popular in recent years for tractor, automobile, and airplane service. Carburetors of this principle are now being manufactured by some of the well-known carburetor manufacturers in both this country and in Europe.

A carburetor of this type is shown in Fig. 59 which represents a Model L Zenith Carburetor built on the principle shown in Figs. 54-57 inclusive. In Fig. 54 is shown a jet D, from which with increasing air velocity, there is an increasing flow of fuel, resulting in a mixture which grows richer and richer.

In Fig. 57, there are two jets, D. and G. At high velocities, the flow of fuel from Jet D. grows less, causing a lean mixture while the flow from Jet G, under the same circumstances, grows richer.

By combing these two jets, D and G, one through which the flow increases, and the other through which the flow decreases, in proportion, to each other, one would balance the other, so that a true mixture would be obtained under all air velocities and volumes.

Principles of Carburetion
as
Recently Developed and Employed
in the
New Stromberg Plain Tube Carburetor

FOREWORD

The new Stromberg Carburetors are a response to the demand of present economic conditions: the threatening scarcity of gasoline fuel, the depreciation in quality, and the increasingly critical requirements of the motorist of today.

Old methods were not adequate: for new results it was necessary to employ new principles: and starting from the elementary carburetor form, the PLAIN TUBE, a design was developed which though simple in construction, performed a number of new functions, hitherto unaccomplished but vitally essential to the efficient use of present day heavy fuels.

A Plain Tube Carburetor is one in which both the air and the gasoline openings are fixed in size; and in which the gasoline is metered automatically, without the aid of moving parts, by the suction of air velocity past the jets.

Along with the advantage of simplicity, and freedom from derangement, this construction allows the whole air supply to be taken through a heater, which increases the efficiency, eliminates danger from backfire, and tends to prevent dirt and grit from entering the motor through the carburetor.

THE AIR BLED JET

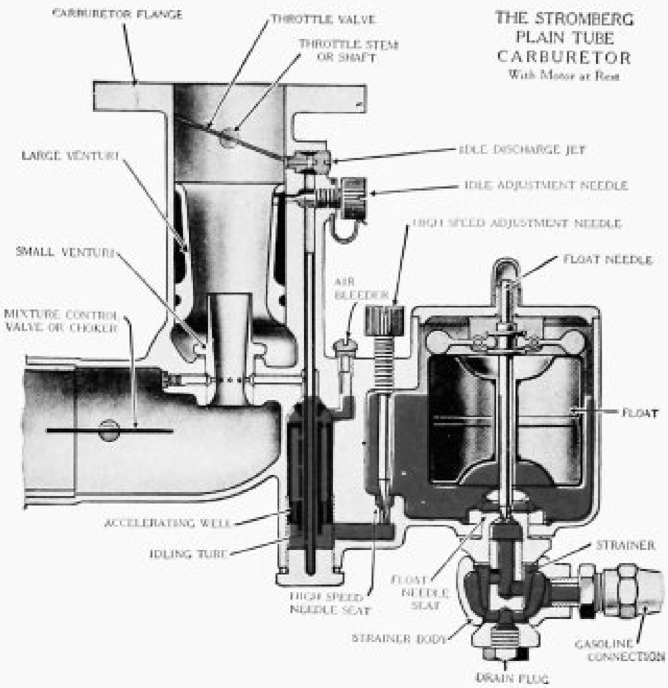
An elementary requirement of a carburetor is that, as a metering device, it shall properly proportion the gasoline and air throughout its operating range.

The first inquiry which arises in connection with this new design is, how can the desired mixture be maintained with such simple construction, when air valves, metering needles, etc., have previously been found necessary?

The answer is found in the principle of introducing a small amount of air into the gasoline jet before it sprays out into the main air passage, forming what is known as an "Air Bled Jet."

This air, taking the form of tiny bubbles, breaks up the gasoline discharge, frees it from the retarding action of surface tension ata low suctions, and regulates the gasoline flow so that it responds to the motor suction exactly, and in rigorously accurate proportion to the air flow.

Thus the function of proper mixture proportioning, previously so complicated and difficult is performed with a single nozzle, by a simple construction indeed.

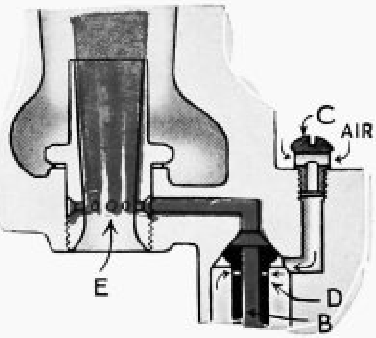


THE STROMBERG PLAIN TUBE CARBURETOR
With Motor at Rest

A Plain Tube Carburetor is one in which both the air and the gasoline openings are fixed in size; and in which the gasoline is metered automatically, without the aid of moving parts, by the suction of air velocity past the jets.

Along with the advantage of simplicity and freedom from derangement, this construction allows the whole air supply to be taken through a heater, which increases the efficiency, eliminates the danger from backfire, and tends to prevent dirt and grit from entering the motor through the carburetor.

AN AIR BLED JET



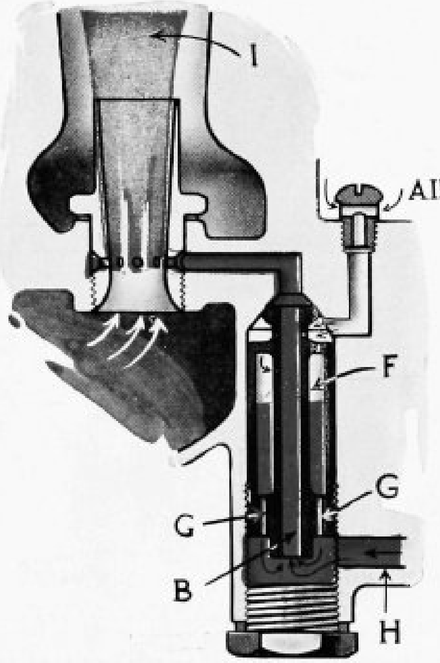
The gasoline, leaving the float chamber past the point of the high speed adjusting needle, rises through a vertical channel "B." Air taken in through the "Air Bleeder" or protecting cap "C," discharge into the gasoline channel through small holes "D," breaking up the flow and producing a finely divided emulsion. This then issues forth through a number of jets into the high velocity air stream of the small venturi "E."

This construction gives a constant proportion of air to gasoline and atomize the fuel most completely.

THE ACCELERATING WELL

It is a familiar fact that economical and efficient mixture settings always seem to lag in response to the opening of the throttle and are also very susceptible to changes in temperature, while adjustments that are flexible show an increase in gasoline consumption. This is found due to a relative lag of the heavier gasoline particles passing through the intake manifold to the cylinders, causing a temporary excess of air and deficiency of gasoline just after the throttle is opened.

Good acceleration from an economical setting, therefore, requires a temporary enrichment of the mixture. Syringes, dashpots and the like have been used for this purpose, but in this carburetor these have been dispensed with, and the accelerating well principle is employed instead. With this, the extra gasoline discharge is automatically governed by the suction of the motor, thus giving a lively response to the throttle and the prompt, powerful acceleration which motorists so much desire.



Concentric and communicating with the passage "B," which conducts the gasoline from the measuring orifice to the jet, is formed a reserve chamber, or "Accelerating Well," "F." With the motor idling or slowing down this well fills with gasoline, and whenever the venturi suction is increased —by opening the throttle or faster engine speed—the level in the well goes down and the gasoline thus displaced passes through the holes "G" to joint the flow from "H," thus more than doubling the normal rate of feed. The amount and rate of discharge can be graduated, as required by different motors, different grades of gasoline, etc., by changing the holes in the top and side of the well.

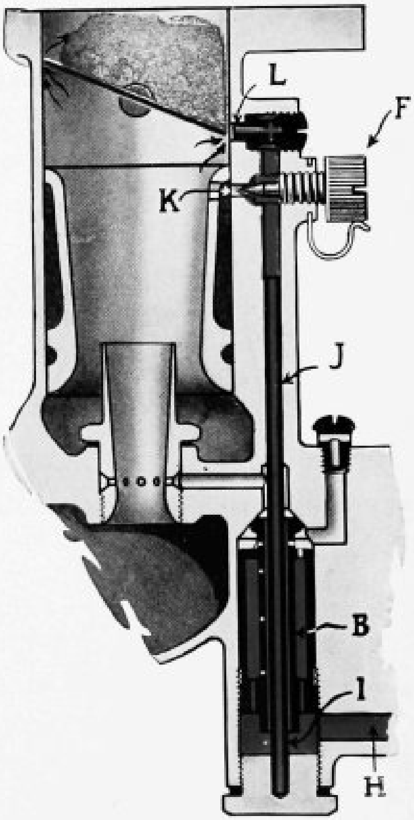
THE IDLE

The earlier carburetor types usually contained a mixing chamber in which the gasoline, after its discharge from the nozzle, was supposed to mix with the air and evaporate.

As the fuel became heavier and heavier its limit of evaporation was passed, with the result that these mixing chambers at low speeds became collectors of gasoline, causing "loading" and "choking."

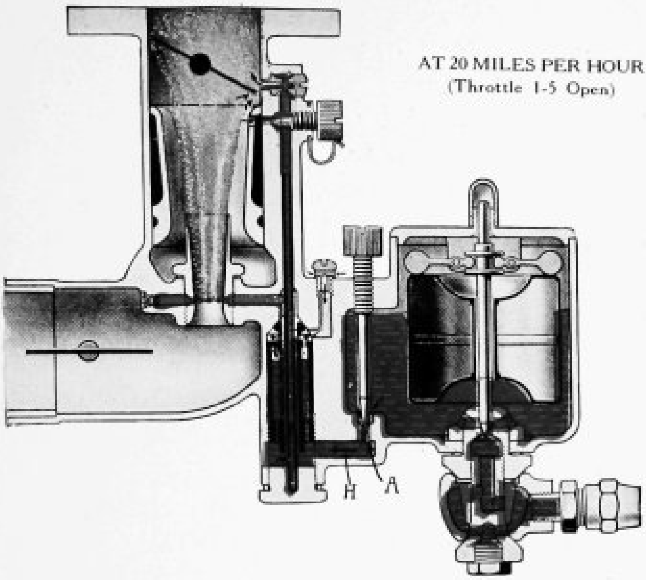
In this carburetor the gasoline, during idle and low speed running, is carried up to the lip of the throttle, where it is discharged directly into the intake manifold in an extremely fine spray. Thus any improper collection of gasoline in the carburetor is made impossible.

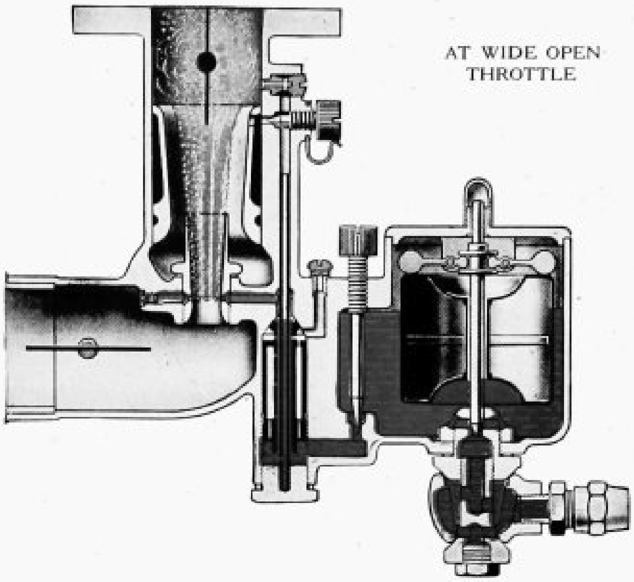
The atomization of this low speed supply is further assisted by dilution with air, the amount of which is governed by the adjusting screw "F," whose position controls the idling mixture.



WITH MOTOR RUNNING IDLE

In the center of the passage "B" is located a tube "J." When the throttle is closed gasoline is drawn in through hole "I," mixed with air taken in at "K" and discharged through the idling jet "L" with the highest degree of atomization, due to the fact that a vacuum of more than eight pounds exists above the throttle when the motor is idling.





AT PARTIALLY OPEN THROTTLE

As the throttle is opened from idle, more gasoline is drawn past the high speed needle "A" and it begins to discharge, as shown above, into the small venturi as well as through the jet at the edge of the throttle. Thus the gasoline is given alternative paths, so that it can follow the one leading to the greater suction. By this means a high degree of atomization, so essential to economy, is assured at all times.

At wide open throttle, all the gasoline is taken through the main venturi jets, as shown on the opposite page.

THE ECONOMIZER

We find by actual driving tests and scientific research alike that a richer mixture proportion is needed for power at wide open throttle, than for ordinary pleasure car driving at nearly closed throttle, the difference depending upon the volumetric charge per cylinder.

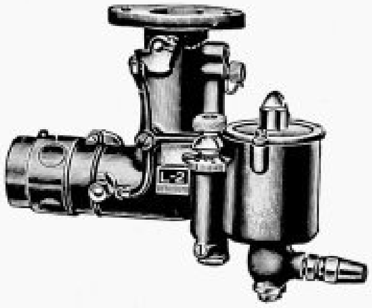
With a carburetor giving a single mixture proportion under all conditions, the best pulling power can be obtained only with a considerable waste of fuel during ordinary closed throttle driving. Also, the operation of a motor at wide open throttle is very much more sensitive to low temperatures than closed throttle, and the average driver, no wishing to waste time while the motor warms up, sets the mixture unduly rich in the winter months.

To overcome these difficulties we have developed our "Economizer" attachment, which graduates the gasoline adjustment, positively and definitely, to the point of highest efficiency for each throttle position.

THE COMPOUND VENTURI TUBE

The Venturi Tube is ordinarily used in carburetor design to produce a high air velocity at the jet without undue restriction, creating the atomizing suction by air velocity only. The double venturi tube construction as shown, developes this action to the highest degree possible, and operates to concentrate on the jets a tremendous suction, much greater than hitherto known in a carburetor; yet the air restriction is kept to a minimum.

ECONOMIZER ON TYPE L CARBURETOR



The high speed gasoline needle is held by the nut, which is supported on the lever arm **at closed and open throttle.** The proper needle adjustment for wide open throttle is thus obtained with the nut.

But with the throttle in ordinary driving positions—ranging **from 15 to 40 miles per hour**—the roller drops into the cam notch, which permits the lever arm to drop free, so that the high speed nut is then supported upon the economizer nut. This lowers the high speed needle into its orifice, and partially cuts off the gasoline for these speeds.

The amount of drop can be regulated by the pointer, which thus gives a special adjustment for the greatest possible economy for these speeds. This, it will be noted, does not interfere with the maximum power adjustment.

At exceedingly high air velocities, the fuel in the duct D is exhausted. Then nozzle F is called upon to furnish the fuel for jet D, so that a regulation is afforded for exceeding heavy loads.

By extending duct D above the fuel level in A, air may enter as soon as the fuel is exhausted in duct D. This prevents any influence from the suction of the motor on nozzle F.

These two jets D and G, together with the compensating nozzle F and the air inlet at the top of the well leading to jet D would give us a carburetor that would produce a uniform homogeneous mixture at all times regardless of volumes or air velocities. This is what is known as the compound nozzle principle of carburetion which is rapidly gaining favor with motor operators, due to the fact of its simplicity. After once adjusted to suit the motor, there is no further adjustment necessary and no working part to get out of order.

119. The Compound Nozzle Principle described in the foregoing explanations is incorporated in the Model L Zenith Carburetor. A cross sectional view of the Zenith "Compound Nozzle" as shown in Fig. 59 will make it easy to understand the compound nozzle principles in its simple form.

By combining these two types of rich and poor mixture carburetors, the Zenith Compound Nozzle was evolved. In Fig. 57 we have both the direct suction, or richer type, leading through nozzle G, and the Zenith "constant flow" device shown at nozzle F. One counteracts the defects of the other, so that from the cranking of the motor to its highest speed there is a constant ratio of air and fuel to supply efficient combustion.

120. The Idling Device. In addition to the Compound Nozzle, the Zenith is equipped with a starting and idling device, terminating in a priming hole at the edge of the butterfly valve, where the suction is greatest when the valve is slightly open. The fuel is drawn up by the suction at the priming hole, and, mixed with the air rushing by the butterfly, giving an ideal slow speed mixture. At high speeds, with the butterfly valve opened further the idling device ceases to operate because the fuel from the compensator I flows to the cap jet G. (See Fig. 59.)

121. Adjusting the Zenith. In the Zenith, the quality of the mixture is fixed, once for all, by the choosing of the three variables—Choke Tube, Main Jet and Compensator, according to the indications described below.

The size number of these three parts constitute what we call the "Setting." The size number is stamped on the end of each part.

The Chokes are numbered in millimeters according to the size of their smallest inside diameter.

The Jets and Compensators are numbered in hundredths of a millimeter. A one hundred jet has one millimeter hole and is smaller than a one hundred five jet. They are graded by five hundredths of a millimeter apart.

The following tests should be made with method, first determining the Choke, then the Main Jet, then the Compensator.

122. Variable 1—Choke Tube. This is really an air nozzle of such a stream line shape as to allow the maximum flow of air, without any eddies, and with the least resistance. It is held in place by a screw and can easily be changed when the Butterfly Throttle has been removed.

Choke Tube Too Large. The pick-up will be defective and can not be bettered by the use of a large Compensator. Slow speed running will not be very smooth. The motor will have a tendency to "load-up" under a hard pull and at high speed the exhaust will be of an irregular nature. (This "loading-up" will be much worse if the manifold is too large or too cold.)

Choke Tube Too Small. The effect of a small Choke Tube is to prevent the motor from taking a full charge with the throttle opened fully. The pick-up will be very good, but it will not be possible to get all the speed of which the car is capable. Bear in mind that when the Choke is increased, more air is admitted and the mixture is correspondingly thinned.

123. Variable 2—Main Jet. The Main Jet is easily removed after unscrewing the Lower Plug. The influence of the Main Jet is mostly felt at high speed.

Main Jet Too Large. At high air velocity it will give the usual indications of a rich mixture; irregular running, characteristic smell from the exhaust, firing in the muffler, sooting up at the spark plugs and low mileage.

Main Jet Too Small. The mixture will be too lean at high air velocity and the motor will not attain its maximum. There may be back-firing at high speed, but this is not probable, especially if the Choke and Main Jet are according to the factory setting. This back-firing is more often due to large air leaks in the intake or valves, or to defect in the fuel line.

124. Variable 3—Compensator. The Compensator is easily removed after unscrewing the Lower Plug.

From the explanation of the Zenith Principle given, it is readily noted that the influence of the Compensator is most marked at low velocities. The Compensator size is best tried out under a heavy load as regular as possible and as long as possible and of such load as would cause the motor to labor. A long, even, hard pull of this sort taxes the efficiency of the Compensator to the utmost, and will indicate readily the correctness of its size.

125. Air Sleeve. The air sleeve is provided with an air strangler and temperature regulator. The two large rectangular holes can be closed entirely or partially by the brass band held together by a knurled headed screw. In Fig. 10 the regulator is shown half open. The air strangler shutter is actuated by a lever, having a coiled spring to bring it back to the open position.

The air sleeve slips into a right angle adapter which can be turned in any direction to more easily connect the flexible tubing. The adapter slips into the air opening of the carburetor. The air sleeve is bored out to receive the flexible tubing.

Flexible tubing should be attached to the air sleeve to supply the carburetor with air that has been heated by the exhaust pipe stove.

The air sleeve with strangler and temperature regulator is made in straight and angle forms. The throttle lever or levers can be furnished as desired from several standard designs.

126. Starting the Motor. Open the throttle a little way. There will be a strong suction in the idling tube J, which will raise the fuel contained in idling jet P, and thus prime the motor. In cold weather, use the strangler (see Fig. 59), openging throttle a little more, and allow the motor to run a few minutes before throwing on the load. It is better to run the motor under load for a time with strangler partly closed—until motor is well warmed. In running, the air strangler should be open.

127. Schebler Carburetor—Model D. Carburetors for Variable Speeds. A cross sectional view of the well known Schebler Carburetor is shown by Fig. 60, and is of the type commonly used on automobiles, boats, and aeroplanes, having variable speed motors.

The carburetor is connected to the intake of the engine by pipe screwed or flanged into the opening R, the gas passing from the carburetor to the motor through this opening.

D is the spray nozzle which opens into the float chamber. B, the opening of the nozzle being regulated by needle valve E which controls the quantity of fuel flowing into the mixing chamber C.

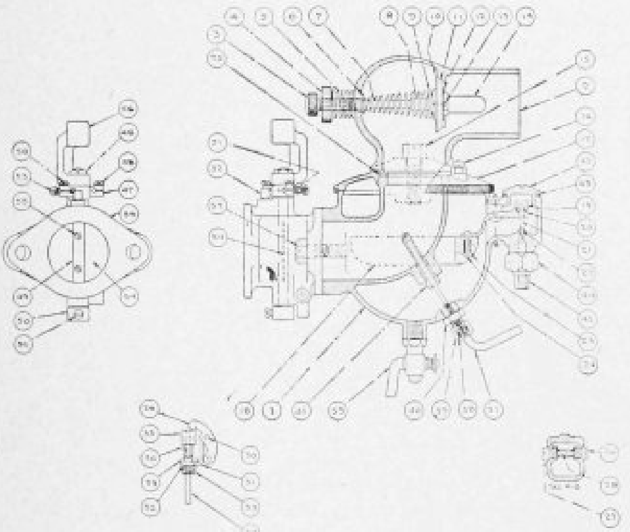


FIG. 60.

On the suction stroke of the engine, air is drawn through the upper left hand opening, past the partially open secondary air valve A, past the needle valve D, through the mixing chamber C, and into the motor through R.

The suction of the engine produces a partial vacuum in the mixing chamber C which causes the gasoline to issue from the nozzle through the passage H, and is taken into the motor through R, thoroughly mixed. The amount of mixture entering the motor and consequently the motor speed is regulated by the throttle valve K, operated by the lever P.

In order that the amount of spray given by the nozzle D be constant, it is necessary that the level or height of the gasoline in the nozzle be constant. The level is maintained by means of the float F, which opens, or closes the fuel supply valve H, opening it and allowing fuel to enter when the level is low, and closing the valve when the level is high.

The carburetor is connected to the gasoline supply tank, by pipe connected to the inlet G, through which the fuel flows into the float chamber B. The float chamber carries a small amount of fuel on which the float F rests. The richness of the mixture is controlled by opening or closing the nozzle needle valve E, which passes through the center of the nozzle D.

The float F surrounds the nozzle in order to keep the level of the liquid constant when the carburetor is tilted out of the horizontal by climbing hills, or by the rocking of the boat when used on a marine motor.

A drain cock T is placed at the bottom of the float chamber, for the purpose of removing any water, or sediment that may collect in the bottom of the float chamber.

At low speeds, the secondary air valve A lies tight on its seat, allowing a constant primary opening for the incoming air through the space shown at the bottom of the valve.

When the air velocity is much increased, the vacuum is increased in the mixing chamber C, which overcomes the tension of the air valve spring O and allows the valve to open and admit more air to the mixing chamber. The action of the auxiliary air valve keeps the mixture uniform at different motor speeds, as it tends to keep the vacuum constant in the mixing chamber.

When the motor speed increases, the flow of gasoline is greater, and consequently more air will be required to burn it; this additional air is furnished by the automatic action of the valve, and when once adjusted, compensates accurately for the different motor speeds.

The fuel is generally supplied by a tank elevated at least six inches above the level of the fluid in the float chamber; although in some cases the fuel is supplied by air pressure on a tank situated below the level of the carburetor.

In some types of carburetors, the float chamber B is surrounded by a water jacket that is supplied with hot water from the cylinder jackets of the motor. This keeps the fuel warm so that it evaporates readily under any atmospheric condition.

The quality of air admitted to the carburetor is controlled by an air valve shown in the air intake by the dotted lines. This is adjusted by hand for a particular engine and is seldom touched afterward.

When starting the motor it is necessary to have a very rich mixture for the first few revolutions, this mixture being obtained by "flooding" the carburetor.

On the Schebler carburetor, the mixing chamber is flooded by depressing the "tickler" or flushing pin V. The tickler presses on the float which in turn holds the fuel supply valve H open, causing the gasoline to overflow through the nozzle and cover the surfaces of the mixing chamber.

128. Model L Kingston Carburetor. Fuel enters carburetor from tank at connection (K) and is maintained at a constant level (as shown in cut), through the agency of the float (L). (See figure 61.)

The fuel formed in base of tube (B) will always be present when motor is not running, and is for the purpose of positive starting. When motor starts this pool is quickly lowered to the point of adjustment of needle valve (A) and continues to feed from this point until motor is stopped.

Let us open throttle slowly and see what occurs. Motor now requires a perfect mixture. To thoroughly appreciate what occurs in this carburetor, we must follow the course of air and atomized fuel throughout its entire range.

When motor is running slowly air valve (C) rests lightly on its seat, allowing no air to pass this point, consequently all air must pass through low speed tube (T). Due to the lower end of this tube being close to spray nozzle and all the low speed air having to pass to this point, the atomized fuel drawn from nozzle (B) becomes thoroughly mixed with air in its upward course and is carried in this state to motor.

Let us now open throttle slowly and see what occurs. Motor now requires a greater volume of mixture. Air valve (C) slowly leaves its seat, permitting a small volume of mixture to pass by. At this point a change in operation occurs. The low speed tube (T) still contniues to deliver a perfect mixture, but is being assisted by the air valve opening. The air being drawn through the air valve must pass across spray nozzle (B) between it and the low speed tube (T). As motor speed is increased up to its maximum, air valve (C) continues to rise higher and higher, admitting more and more air, which having to pass across spray nozzle (B) with an ever increasing velocity, becomes thoroughly impregnated with atomized fuel, producing a perfect mixture throughout the entire range.

This carburetor owes its success to the construction which makes it possible to thoroughly impregnate all air with atomized fuel directly at the nozzle and at the point of highest air velocities.

Starting a motor at any time depends upon getting a combustible mixture into cylinders; that is, proper proportions of air and atomized fuel thoroughly mixed.

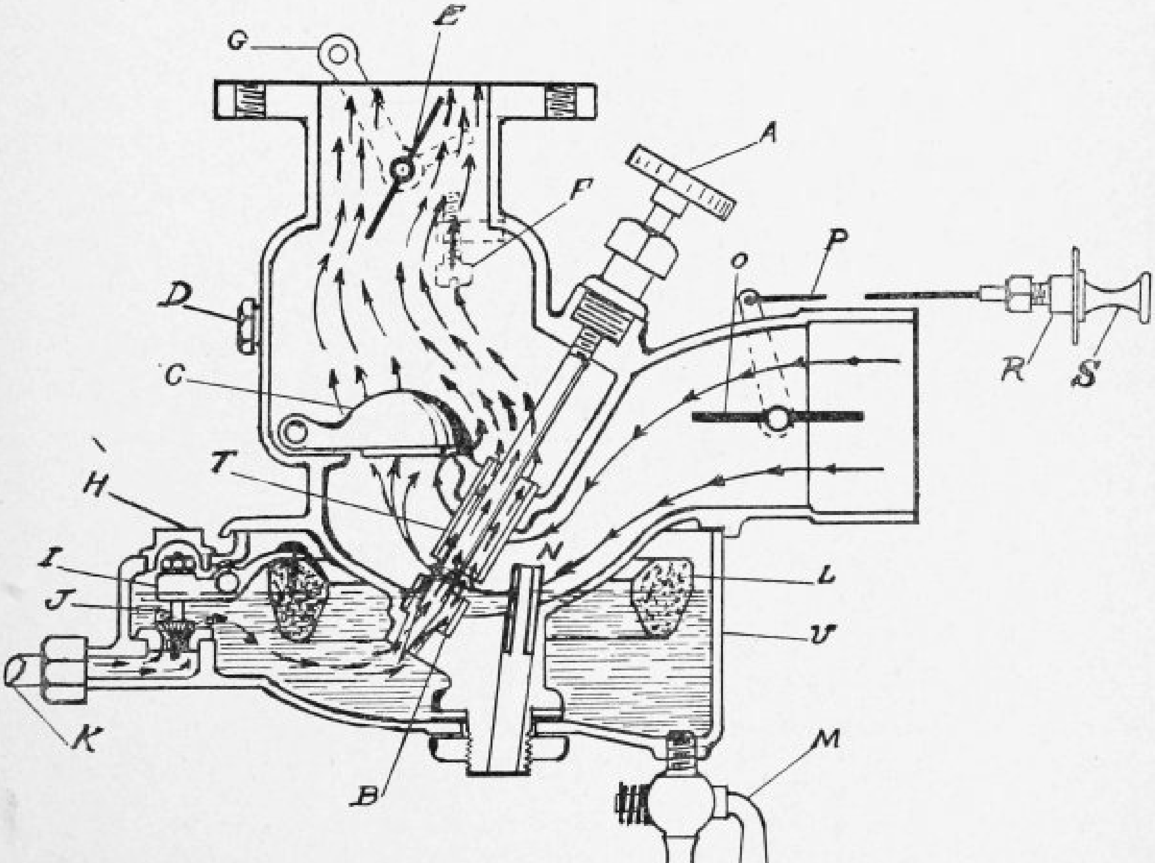


FIG. 61

Difficult starting in cold weather is the result of two inherent properties of fuel. It does not vaporize as readily in cold weather as in warm, nor does it flow through the needle valve adjustment as easily, consequently we cannot get as much by the adjustment in cold weather as we can in warm. This is the reason that opening the needle valve slightly makes starting easier and keeps motor running, which, otherwise, would have a tendency to stop when load was thrown on.

In the Kingston Model L Carburetor, this extra amount of gasoline for starting and warming up period can be obtained by opening the needle valve (A), or by the use of choke throttle (O) placed in air passage.

When starting with cold motor this choke throttle can be closed by pulling wire (P) operated by rod (S) forward. This cuts off nearly all air supply and produces a very strong suction at spray nozzle, which causes fuel to jet up and be carried with the incoming rush of air to cylinder.

A drain cock (M) is placed at lowest point in bowl and should be opened from time to time to free bowl of all water and foreign matter.

129. To Adjust. The Kingston Model L. Retard spark fully. Open throttle about five or six notches on quadrant on steering post.

Loosen needle valve (A) binder nut on carburetor

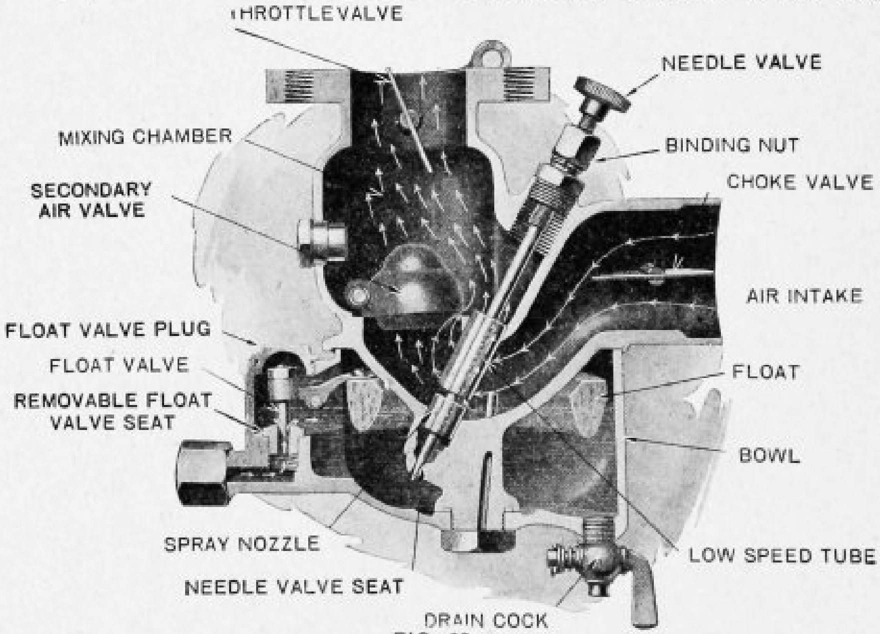


FIG. 62.

until needle valve turns easily.

Turn needle valve (A) until it seats lightly. Do not force. Adjust away from seat one and one-half turns. This will be slightly more than necessary, but will assist in easy starting.

Start motor and open or close throttle until motor runs at fair speed (not too fast), and allow it to run long enough to warm up to service conditions. Now make final adjustment. This carburetor has but one adjustment—the needle valve (A). Close throttle until motor runs at the desired idling speed. This can be controlled by adjusting the stop screw (F) in throttle lever.

Adjust needle valve towards its seat slowly until motor begins to lose speed, thus indicating a weak or lean mixture. Adjust needle valve away from its seat very slowly until motor attains its best and most positive speed. This should complete the adjustment. Close throttle until motor runs slowly, then open rapidly. Motor should respond strongly. Should acceleration seem slightly weak or sluggish, a slight adjustment of needle valve may be advisable to correct this condition.

With adjustment completed, tighten binder nut until needle valve turns under tension.

130. Care of a Kingston Model L Carburetor. The bowl of carburetor is provided with a drain cock at the bottom, which should be opened frequently, as water and other foreign matter will collect in bowl and cause trouble.

Fuel leaks from any cause should be remedied at once. Should the carburetor flood, it is a sure indication that the valve (J), which controls the gasoline supply to the bowl, is off its seat and is probably caused by dirt lodging under this valve. If flooding occurs, remove cap (H), and by means of a small screw driver give the needle valve (J) a few turns. The top of valve is provided with a slot so that it can be turned by screw driver. The needle valve is held in place to lever (I) by means of a ball and socket joint, and the valve must not bind at this point.

It is important to filter fuel when being placed in tank, as any dirt reaching carburetor with fuel will cause irregular working, due to this dirt lodging under float valve, causing carburetor to flood, or clogging fuel passages and nozzle openings.

131. The Kingston Model E inclosed type Carburetor. The construction of this carburetor should be apparent by careful study of cut, figure 64, and little need be said of this feature.

The principles involved, while simple, may require some explanation to those not well acquainted with carbureting instruments.

Let us follow carefully the course of fuel and air until they leave the carburetor in a correctly proportioned mixture.

Fuel is admitted into cup at connection (24) and continues to flow until valve (22) is seated, due to buoyant action of float (5).

Attention is particularly called to shape of spray nozzle (8), which forms a cup around needle valve (7) above its seat. The fuel level being 1-32 inch below its top.

For starting, this excess of fuel is drawn up with the constant air and furnishes a very rich charge for starting.

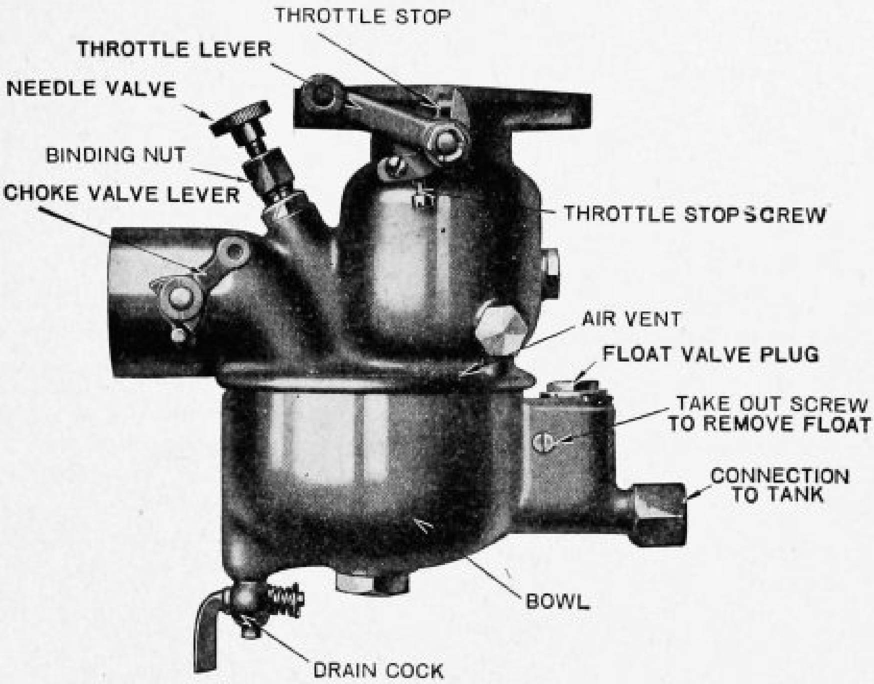


FIG. 63.

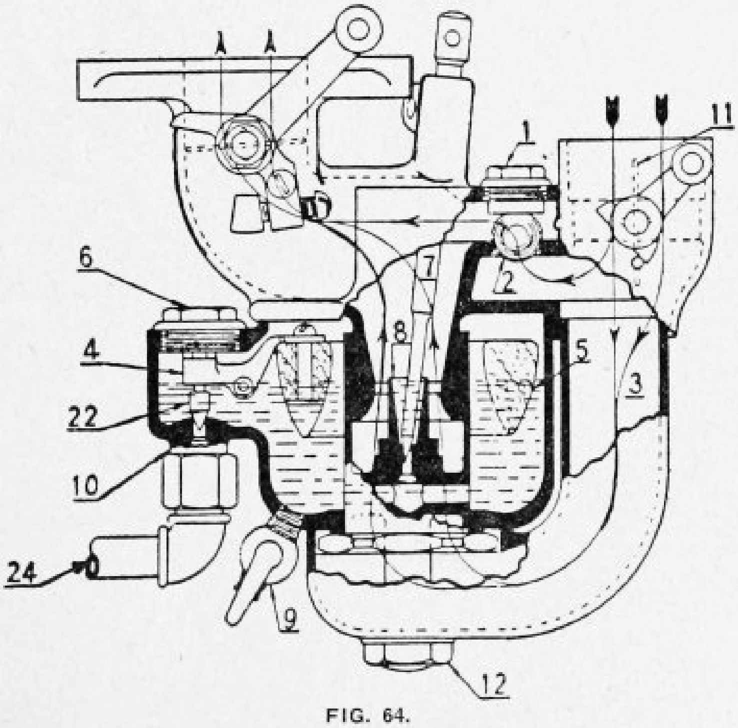


FIG. 64.

At higher speeds this cup is empty, the supply is then drawn from and regulated by the adjustment of needle valve (7) at its seat.

Both primary and secondary air are drawn from a common source, passing by the controller, or (choke) throttle (11) located in air opening, after which it divides; primary air passes down through primary air passage (3) and up through venturi tube, at which point it becomes thoroughly impregnated with fuel spray drawn from nozzle (8). It then continues upward, combining with secondary air which has been admitted by bronze balls No. 2. These balls lift automatically in correct proportion as air velocity increases.

These balls (secondary air controllers) after being lifted from their seats, due to vacuum (or suction), remain floating in the air until motor speed is reduced sufficiently to permit them to again return to their seats. The controller or (choke) throttle (1)) is so placed that it is possible to entirely (or nearly so) cut off the source of air, thus producing a strong vacuum (or suction) at venturi tube for starting purposes in extremely low temperature.

Some facts in connection with this carburetor should be well understood.

It is essential that the level of fuel in bowl be constant and of proper height; that is, from 1-32 inch to 1-16 inch below the top of fuel nozzle No. 8.

132. Kingston Dual Carburetor. The Kingston Dual Carburetor was designed to meet the rapidly increasing demand for a practical instrument capable of handling kerosene and some of the lower grades of distillates.

In construction it is a dual combination of the well-known "Kingston Enclosed Type Model," one side being adapted for the use of kerosene or distillates, the other for gasoline, which may be used for starting or continuous running, as the operator may choose, either unit being brought into communication with the manifold and motor through the agency of an integral three-way valve. Both units are subject to individual adjustments, therefore may be operated on any fuels with maximum economy.

It is extremely simple, there being but one adjustment for each carburetor.

Switching from one fuel to the other is accomplished by means of a single lever, which may be connected to a point convenient to the operator.

Should water be required, the small valve shown in Fig. 65 may be used with good results, and is very simple, having but one adjustment which controls the amount of water admitted to the mixture.

It is entirely automatic, admitting water only when needed.

In operation the motor is started on gasoline and allowed to warm up sufficiently to permit of kerosene or distillate being used, at which time fuel switch or three-way valve is turned to its corresponding position. Should motor fail to maintain its cycle (due to lack of sufficient heat having been generated), switch should be immediately turned to the gasoline side and more time allowed for the warming period.

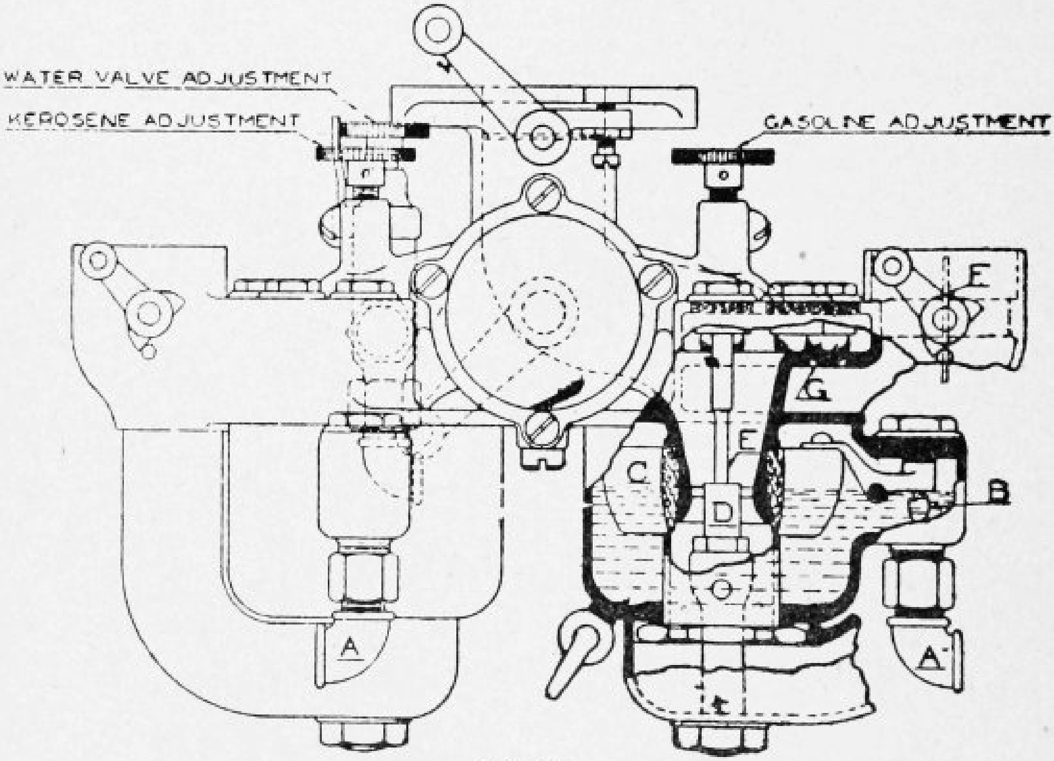


FIG. 65.

With sufficient heating facilities this should not exceed ten or fifteen minutes.

The following installation is recommended: Preheated air could be conducted to the intake of the kerosene carburetor.

The kerosene side requires a much higher temperature than the gasoline side, therefore the collector around the exhaust manifold should be liberal.

Care should be taken to provide openings totaling at least one and one-half times the area of carburetor intake, and should be so located that the greatest amount of air shall pass over the heated surface of exhaust manifold.

Exhaust should surround the intake manifold throughout its entire length, if possible, or at least a generous portion leading from the carburetor. This should include the first bends.

Applying heat directly to the fuel line near the carburetor assists materially.

Temperature of the fuel in bowl should not, however, exceed 100 degrees F.

The above recommendations are intended for genral information.

133. Action and Principle. Fuel is admitted into cup at fuel connection A and continues to flow until valve B is seated, due to buoyant action of float C.

Attention is particularly called to shape of spray nozzle D, which forms a cup around needle valve E above its seat, the fuel level being 1-16 inch below its top.

For starting, this excess of fuel is drawn up with the primary air and furnishes a very rich charge for starting.

At higher speeds this cup becomes empty; the supply is then drawn from and regulated by the adjustment of needle valve E at its seat.

Both constant and auxiliary air is drawn from a common source, passing by the controller, or (choke) throttle F located in airopening, after which it divides, constant air passing down through constant air passage and up through venturi tube, at which point it becomes thoroughly impregnated with the gasoline spray drawn from nozzle D. It then continues upward, combining with auxiliary air which has been admitted through bronze ball ports G, these balls lifting automatically in correct proportion as motor speed varies.

These balls (auxiliary air controller), after being drawn from their seats, due to vacuum (or suction), remain floating in the air until motor speed is reduced sufficiently to permit them to again return to their seats. The controller or (choke) throttle T is so placed that it is possible to entirely (or nearly so) cut off the source of air, thus producing a strong vacuum (or suction) at venturi tube, thereby obtaining a very rich mixture for starting purposes in low temperature.

The Kingston Carburetor is perfectly automatic producing a proper mixture at all air velocities and volumes.

There is no phase of its adjustment which can change after its initial setting.

134. The New Schebler Plain Tube Carburetor The New Schebler Plain Tube Carburetor is a non-moving part carburetor, especially designed for gas tractors.

This carburetor is a decided advance in the science of carburetion, as several new features and principles of carburetion are incorporated in this instrument.

The Pitot Tube Principle is introduced for the first time in the carburetor and this Pitot Tube or improved type of fuel nozzle is so designed and built that it automatically furnishes a rich mixture for

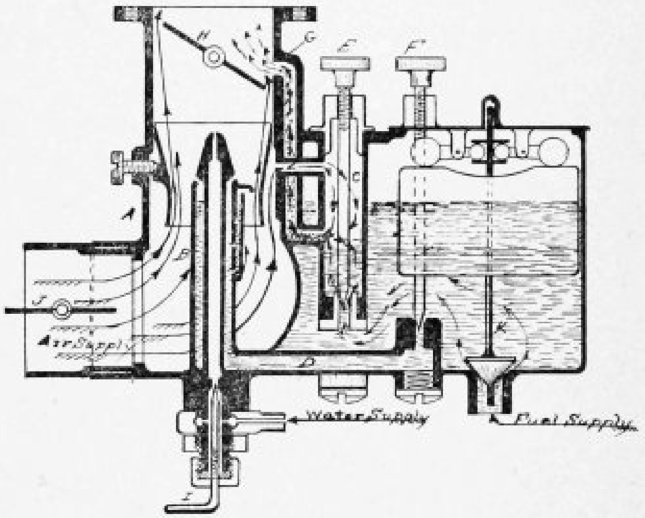


FIG. 63.

acceleration, and thins out this mixture after the normal motor speed has been reached. This furnishes a very economical running mixture at all air velocities, together with a smooth and positive acceleration.

The importance of this Pitot Tube or Nozzle Principle cannot be overemphasized, as it furnishes a flexible, powerful, and economical mixture, without the addition of any complicated moving parts. The

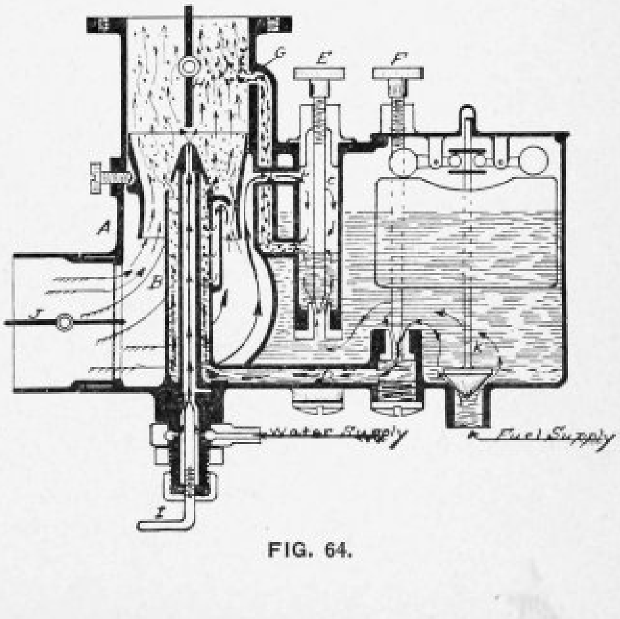


FIG. 64.

carburetor has no parts to wear or get out of adjustment.

Two fuel needle adjustments are furnished—one for low speed and idling, and one for high speed. These adjustments have been found advisable and necessary to properly handle the present heavy grades of fuel and the variations in the motor due to wear, etc. These adjustments also insure the attaining of the widest range of motor speed.

A Double Choker is furnished, and with these two regulating valves E and F, Fig. 63, the motor can be easily be started under the most severe weather conditions and the mixture controlled.

With this carburetor a low drive mixture can be secured without any loading or missing. Also, with this carburetor the maximum speed and power of the motor are guaranteed.

Figures 63 and 64 are sectional views of the new Schebler Plain Tube Carburetor consisting of main body flanged to fit the intake manifold, and main air inlet and fuel chamber such as are found in the carburetor previously described. In the center of the main body there is a choke tube, and in the center of the choke tube in the Pitot tube. The fuel enters the base of the Pitot Tube through port D, which leads to the base of the fuel reservoir. The height of the fuel in the reservoir is regulated by a brass float which controls the float valve, and maintains a level about 3-16 inch below the fuel nozzles in the Pitot Tube. The fuel supply to the duct D is regulated by the high speed needle valve F. Fuel enters at the base of the low speed Port C and is regulated by the low speed needle valve E.

135. Operation and Adjustment. First, open throttle H, Fig. 63, about one-fourth. Open needle valves E and F about two turns. Crank motor, and it should start. By having the throttle valve open one quarter, a high negative pressure is generated between the valve H and the motor. This draws fuel from the port C and enters the mixing chamber at G, which furnishes a rich mixture for low speed. Now regulate E so motor idles nicely; if the mixture is too rich, turn valve E clockwise; if too lean, turn counter-clockwise. Now open throttle slowly; air enters at J, passing up and around the Pitot Tube. The fuel now entering at G, according to our previous lessons, would be growing richer and richer, as you open valve H.

To prevent increasing richness, air is allowed to pass around the choke tube and enter port C through port L, passing down through port C, mixing with the fuel on its way to its outlet G. As we continue to open valve H, the fuel at G continues to get lean, as the air velocity increases. And as the air velocity increases fuel starts to spray from the jets in the Pitot Tube in the center of the choke tube. Now regulate to get a fine mixture at practically three-quarter throttle by adjusting the needle valve F. To lean the mixture, turn clockwise; to enrich it, turn counter-clockwise.

With exceedingly heavy loads and full throttle, the fuel at the main nozzle would grow richer were it not for the port in the side of the Pitot Tube through which air enters and travels down below the fuel level so as to break up the suction on duct D, thus preventing the negative pressure from influencing the fuel supply. Therefore the mixture continues to grow lean. See figure 64 which is a sectional view of this carburetor with full throttle and exceedingly heavy loads. A port in the center of the Pitot Tube is connected to the water supply, and is controlled by the needle valve I. This valve should be opened only in cases of pre-ignition, which occurs only under exceedingly heavy loads.

By this construction we get a true and homogeneous mixture at all times, regardless of air velocity: a rich mixture at low speeds and low compression, and a lean mixture at high speeds and high compression. The air entering the main fuel ducts and mingling with fuel on its way to the nozzles insures that the fuel will be broken up in the finest molecules possible, without the assistance of a moving part to wear or get out of order. This is a step towards high efficiency and extreme simplicity.

The Bennett Multiple Jet, Type C Kerosene Carburetor

136. This carburetor is what is known as a producer type of carburetor. The liquid fuel is converted into a gas in which the heavy particles are broken up or cracked by heat. A sectional view of this carburetor is referred to in Figure 66, in which the workings of the carburetor are clearly shown. When using heavy fuels all the exhaust of the motor is allowed to pass through the carburetor, entering at B and following the line of the heavy arrow passing around the mixing chamber E. This mixing chamber is provided with fins for contracting heat which raises the walls of the mixing chamber to a high temperature. The primary air enters at A and passes around the exhaust pipe B which heats it to a high temperature, down through the duct C, through the ports D, up around the fuel nozzle through the mixing chamber E, and up and past the throttle valve F. The secondary air enters at H, passes by the secondary air valve G and through the duct and mingles with the primary air above the mixing chamber. The secondary air valve G is held on its seat by a spring which has been collaborated so as to give the proper tension at the different speeds of the motor. This spring also supports a lever I which acts on the low speed needle valve, which is also supported by a fulcrum in the center, this fulcrum in turn being controlled by the regulating nut R. The right end of this lever supports the low speed needle valve J. The high speed needle valve K is regulated by the adjusting nut O. At the bottom of this carburetor there is an auxiliary air valve L which is a combination piston and poppet valve. The poppet valve closes off the lower cold air intake. When high speed is obtained the valve raises sufficiently to close the hot air ports D. The poppet valve on K also controls the water supply which enters at T so that at low speeds the water is cut off automatically. Fuel supply, the height of which is regulated by a float and float valve the same as in other carburetors, enters the float chamber S.

137. Operation, Adjustment and Starting. First see that the fuel is in the supply reservoir S. Means are furnished for submerging the float in this carburetor and allowing the gasoline to overflow through the gasoline nozzle in the center of the air chamber. The gasoline is carried at a height one-eighth of an inch below the nozzle, shown at the center of the carburetor in which there are two needle valves, the upper and lower. The lower needle valve is the high speed adjustment and the upper one is the low speed adjustment. Be sure that you have a fuel supply in the reservoir. We open the needle valve O two or three revolutions, enough to know that it will give a rich mixture at high speeds. Adjust the needle valve R by turning it counter clockwise until the low speed needle valve J is on its seat. Then turn clockwise about two revolutions. Now we have opened the low speed needle valve J. Crank the motor and start running it on one-fourth throttle. The exhaust is passing through B around the mixing chamber E, and the mixing chamber is becoming very hot. Regulate the regulating nut R. If the mixture is too rich, turn it counter clockwise, and if too lean turn clockwise. Then put a load on the motor by some means that will cause it to labor and the air supply through A and C and the port D will not be enough and a negative pressure will be formed in the mixing chamber. This overcomes the tension of the spring supporting the secondary air valve G which is opened by the atmospheric pressure. Air enters and passes into the mixing chamber and mingles with the gas from below. This raises the low speed needle valve J by the lever I, opening this adjustment wide so that the regulation will be controlled by the needle valve K. The fuel entering through the nozzle is controlled now by K and passes up into the mixing chamber. The light particles follow up through the center of the mixing chamber and on up to the motor. On the needle valve J there is a ferrule which deflects the heavy particles of fuel up against the hot walls of the mixing chamber where they are evaporated. The current of the air carries this vapor up over this wall, and on up through the duct to the motor. The heavy particles are held to the wall by capillary attraction. If any heavy particles condense in the main duct or manifold, they will flow back to the walls of the mixing chamber and be evaporated the second and third time, if necessary. These molecules become smaller and smaller and are finally taken into the motor cylinder. Having the load on and the air entering through H, the primary air will enter as shown by the arrows at O. When the negative pressure has overcome the tension on the spring on valve G, it has also

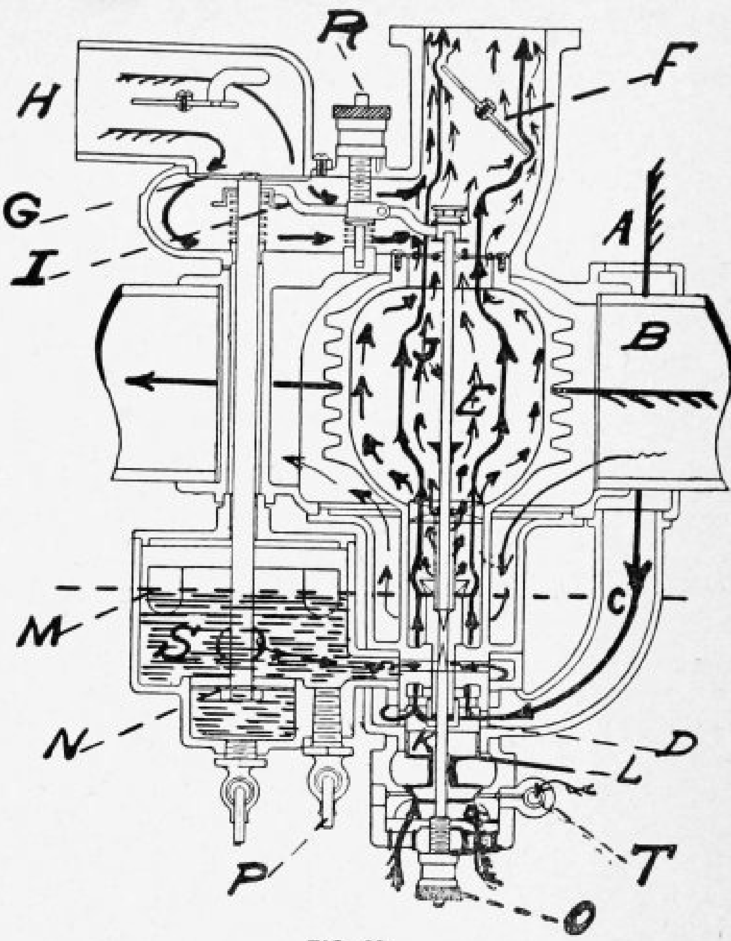


FIG. 66.

lifted the compensation valve L, as above explained.

This valve, when lifted, closes the hot air ports D and allows the cold air to come up from below. Having opened the needle valve O two revolutions, chances are that the mixture is too rich. If so, turn the adjusting nut O counter clockwise until the right mixture is obtained. These adjusting nuts have a ratchet for holding them in their proper position.

Now you have the carburetor properly adjusted; and if the motor has become warm, change to kerosene, shut off the gasoline supply, and turn on the kerosene supply to the float chamber S, and the motor should run nicely on kerosene. This gives us a slow burning charge that has a tendency to heat up the motor. We are also apt to have a deposit of unburnt carbon; and at extremely heavy loads, pre-ignition is liable to occur, which can be distinguished by a sharp knock. In this case it is necessary to use a small amount of water to carry off the extra heat.

A valve at T, connected to the water circulating system, regulates this water supply. Usually one-half of a revolution of this valve is all that is necessary to stop the pounding caused by pre-ignition at heavy loads. (Never use more water than is necessary.)

The valve K drops down, shuts off the water supply, and allows hot air to enter through the ports D. It is almost impossible to run with a lower velocity

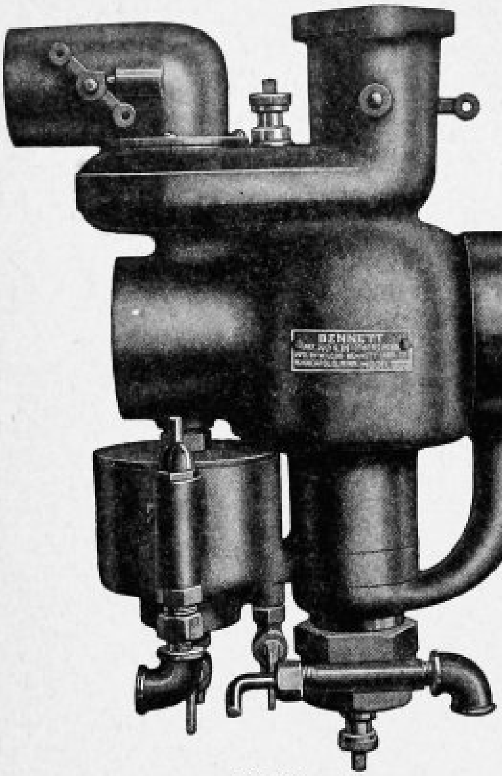


FIG. 67.

with kerosene without the use of a great deal of hot air; therefore we lose power at a time when we can afford to do so. But as soon as the valve K is lifted again by the negative pressure in the carburetor which also overcomes the valve G, the valve L is also lifted, and the hot air from the port D cut off so that the cold air enters from below. This makes an automatic carburetor. Automatically it changes itself from high and low speed adjustments, and automatically cuts off the water supply, when necessary. It also supplies the hot air at low air velocities, and cold air at high air velocities. You will note that the hot exhaust gases pass down and around the duct in which the spray nozzle is located.

This carburetor is supplied with a dash pot N. This dash pot is located in the lower portion of the fuel reservoir and is surrounded by fuel which takes up the chatter of the valve G, and does not allow the valve to chatter or open and close rapidly at low piston speeds. There is a drain cock at P for draining out water and fuel for priming purposes. There is a choke valve in the inlet H which can be closed when cranking the motor to give rich mixtures for starting. Figure 67 is a cut of this carburetor showing the exterior construction. Figure 68 is a line drawing of this carburetor together with an exhaust controlling valve which goes between the carburetor and the exhaust manifold. The exhaust can pass either through the carburetor or directly to the atmosphere. The cut also shows connection to the Bennett air cleaner, which will be taken up later.

This carburetor has been on the market for several years and has become quite popular with tractor manufacturers, and has proven very efficient and practical for burning low grade fuels. This carburetor uses extremely hot air at low speeds for light loads and cold air at high speeds for heavy loads. Automatically it changes from one to the other; and after once properly adjusted, it needs but very little attention.

138. The Holley All Fuel Carburetor. The Holley carburetor is an instrument designed to furnish to the motor a mixture of kerosene vapor and air in the correct proportions for combustion and in such condition that the kerosene can be used satisfactorily as fuel. While the carburetor is designed primarily for the use of kerosene, it will operate with equal satisfaction on gasoline, benzol or California distillate. A sectional view of this carburetor is shown in Fig. 69

1st. **Instruction for operating Holley All-Fuel Carburetor. Greatest fuel opening:** Close shut-off valves

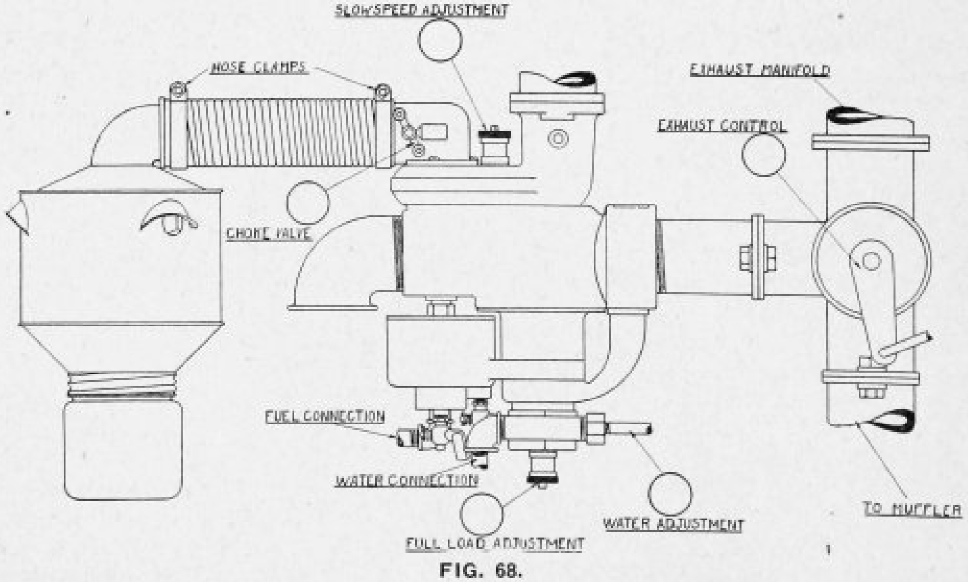


FIG. 68.

to fuel tank. Open valve on fuel line to gasoline tank. Remove cover over float chamber; fuel level should not be over ridge cast inside float chamber. Place pointer to position marked "START" on dial. This is the largest fuel opening and insures easy starting.

2d. **Starting:** Prime with gasoline through priming cups. Retark spark lever, open throttle wide. Close choker valve by pulling looped wire. Crank engine, releasing choker wire as soon as engine starts. If engine falters, pull choker wire but release immediately. Allow engine to run from three to five minutes on gasoline.

3rd. **Smallest fuel opening:** Turn valve on fuel line to kerosene tank. Positions on dial marked No. 1, 2, 3 and 4 represent smaller fuel openings, the position marked No. 4 being the smallest.

4th. **Best operating position:** The position for best operation can be determined by shiftng pointer to the different positions until motor runs properly.

5th. **Idling position:** When idling with hand throttle for any length of time, shift to gasoline and retard spark. This is better for the motor because an idling motor does not create heat enough to properly vaporize kerosene fuel. Adjustment for hand throttle idle can be made by turning screw on throttle lever at carburetor.

6th. **Drain valves:** Drain plug is provided under float chamber and filter screen and should be opened each day before starting tractor, to allow any accumulation of water or sediment to escape.

7th. **To clean:** A cleaning opening is provided in vapor tube. A small rod can be used to remove any dirt that may collect at this point.

8th. **Fuel for starting:** Always star engnie on gasoline before turning on kerosene or other fuel. Any liquid fuel having a final boiling point not over 600 degrees Fahrenheit can be used in the Holley All-Fuel Carburetor.

9th. **How does the carburetor work:** The tractor having two fuel systems; that is, gasoline and kerosene, the fuel line to carburetor is provided with a three-way valve, which when turned to open into the gasoline tank closes off the kerosene tank and vice versa. After the motor has been running at least three minutes on gasoline, the two-way valve can be turned to open into the kerosene tank. The path of rich fuel mixture is shown on the illustration by white and black arrows.

10th. The kerosene enters the float chamber through the float valve, controlled by a metallic float. From the float chamber the fuel passes through a metering hole. By turning the atomizer tube to different positions on the dial, pre-determined sizes of fuel holes are made to register with fuel passage. When leaving this atomizer the fine spray of fuel is mixed

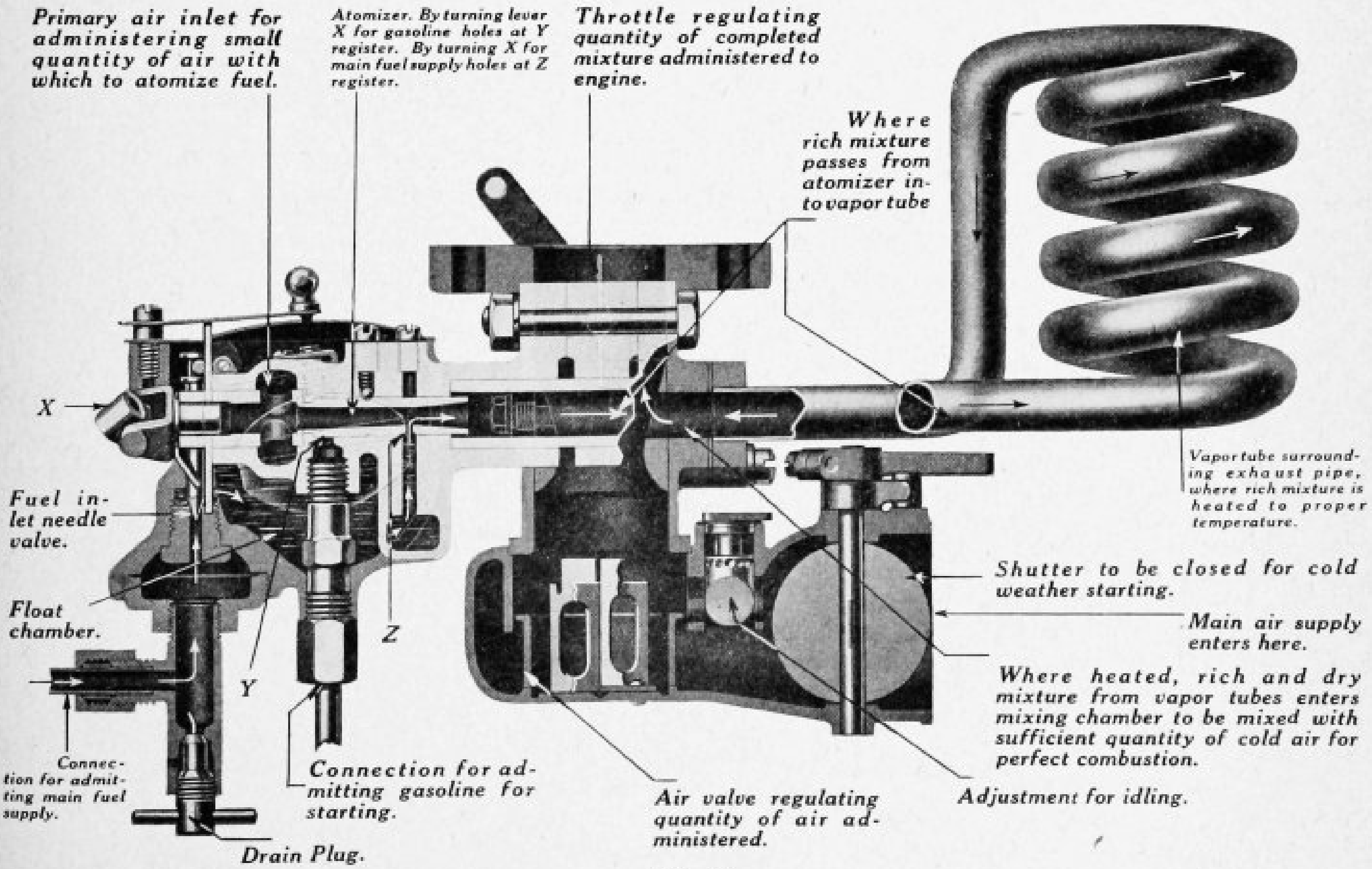


FIG. 69.

with a small amount of air entering through the primary air tube, and they are together drawn through the heated vapor tube where the fuel is completely vaporized and forms an extremely rich vapor. The rich fuel vapor then enters the mixing chamber at the choke tube. There it is mixed with the secondary air drawn through the main tube. The mixture is then in the proper proportion for perfect combustion and is sucked into the cylinder through the intake manifold. The volume of gas mixture entering the cylinder is regulated by the hand throttle.

11th. **What is the purpose of the air valve?** It is located under mixing chamber at bottom of carburetor and automatically controls the quantity of air entering the carburetor. It is so proportioned that while on its seat it admits the air necessary for idling and lifts gradually as the throttle valve is opened. It maintains the correct proportion of air to the mixture at any speed or load.

12th. **What is the purpose of the float?** It automatically controls the flow of fuel into the carburetor. The float should close the valve when the fuel reaches the proper level, indicated by a ridge cast inside the float chamber, about 1 inch below its top rim. The level must not be above this line or more than one-eighth of an inch below.

13th. **What makes float needle leak?** The flow of kerosene entering the float chamber through the fuel pipe is automatically regulated by the float valve raising and lowering on its seat. Should any particle of dirt become lodged in the seat, which prevents the valve from closing, the fuel will overflow and leak out.

14th. **How is the carburetor adjusted?** Changing the position of pointer on the atomizer to the different positions on the dial varies the amount of fuel being metered into the vapor tube. Position marked "START" gives the richest mixture, position Number 1, slightly less and so on to position Number 4, which gives the leanest mixture. In cold weather it will probably be found necessary to place pointer on atomizer to positions giving a richer mixture than used in the heat of summer.

15th. **Cleaning of atomizer:** Atomizer can be taken out by removing cotter pin, on adjustment rod and pulling out atomizer which is held in place by a compression spring and ball.

16th. **When there is water in the carburetor—what?** The presence of water in the gasoline or kerosene tank, even in small amounts, will prevent easy starting and may cause the motor to misfire and stop. As water is heavier than either gasoline or kerosene, it settles to the bottom of the tank and into sediment traps. It is advisable to frequently drain the sediment trap under carburetor and fuel tanks by removing drain plugs.

17th. **If motor runs too fast or too slow with throttle retarded—what?** (Idling at lower than governor speed.) If the motor runs too fast with throttle fully retarded, unscrew the throttle lever adjusting screw, until the motor idles at suitable speed. If the motor chokes and stops when the throttle is fully retarded the adjusting screw should be screwed in until it strikes the boss, which prevents the throttle from closing too far. When proper adjustment has been made, tighten the lock screw, so that the adjustment will not be disturbed.

18th. **Carburetion troubles:** Incorrect mixture may be due to a too rich mixture in which there is too much fuel used or a too lean mixture in which there is too much air.

The engine may be flooded from too much priming or too much unexploded gas formed from the liquid fuel drawn in. Crank engine until excess gas is exhausted.

The engine may be so cold that the gasoline or kerosene does not vaporize, or the gas is not warm enough to be ignited by the spark.

Important: Remember a leaking float or a float that is out of adjustment, demands your immediate attention and is easy to adjust. The various parts of the carburetor should be fully understood as a knowledge of adjustment of the carburetor will save you a lot of time and money in the end.

NOTE: If the motor should stop, unless it is hot, be sure and drain carburetor of kerosene and start on gasoline.

139. Summary. In the preceeding lessons I have tried to make plain the principles of carburetion, and have explained the principles and mechanical construction, and methods of regulation on a few of the carburetors which are most popular among tractor manufacturers of today. These carburetors have a wide range of mechanical construction.

While the methods of adjustment are quite different, the principles involved is the same. If the sure in the main body of the carburetor, when more than one-third of the air volume is required.

Fifth. When only one jet is adopted it must be located in the primary air passage, in the center of the choke tube, and adjusted only when one-third air volume or less is being used.

Sixth. When more than one-third of the total air volume is being used, adjustments should be made by changing the tention on the secondary air valve spring.

140. A Better Carburetor. A better carburetor is one that breaks the fuel into finer molecules and mixes them with the true proportion of air (oxegon), to carbon, and furnishes a homogenious mixture at all times, regardless of air volumes, velocity, and reasonable angularities.

141. Air Volumes. When speaking of volumes in connection with a carburetor, we mean the number of cubic inches of air taken in to the cylinder during a complete cycle, which is controlled by the throttle or governor valve. Example: Suppose the piston displacement is 500 cubic inches. By closing the throttle or governor valve, the volume of gas admitted can be diminished to 5, 10, 20, 30 or more cubic inches principle is understood as outlined in the preceding lessons, the operator will be able to adjust any carburetor with which he comes in contact regardless of its mechanical construction.

To Properly Adjust a Carburetor. To adjust a carburetor the following principles must be remembered:

First. That liquid fuels flowing through a jet will increase under an increasing negative pressure faster than the flow of air.

Second. That most carburetors have a primary and secondary air inlet, the primary equaling one-third, and the secondary two-thirds of the air capacity.

Third. The primary passage has no restrictions except the choke tube around the nozzle, and in some carburetors a choke valve. When the choke valve is closed there is a high negative pressure causing the fuel to flow from the nozzle at an excessive rate so that a rich mixture for starting is formed.

Fourth. That the air velocity through the secondary is regulated by a secondary air valve, controlled by a spring, which controls the negative presdepending upon the load, until the full piston displacement is reached. Consequently there is a varied volume according to the load.

142. Velocities. In speaking of velocities in connection with a carburetor we mean the speed at which the air passes through the carburetor which is controlled by the throttle or governor valve. With wide open throttle and governor valve the air velocity can be as high as 1,300 feet per second through the carburetor depending upon the piston speed, the displacement, and the area of the choke in the carburetor (example). The construction of the motor might be such that the air velocity is 1,000 feet per second at 800 piston feet per minute. This may be diminished by closing the throttle or governor valve to 100, 200, 300 or more feet per second depending on the load, and consequently the varied air velocitie.

143. Adjusting a Carburetor. To adjust a carburetor on principles outlined above,—namely a regulation for each speed at which we run to any considerable extent. Referring to Fig. 70 E. represents primary air opening, one-third total volume. B., C. and D. represent secondary air openings two-thirds total volume F. represents throttle valve which can be operated either by hand or governor. G. is the float chamber which surrounds the main body of the carburetor. It is equipped with a float which regulates the height of the fuel in this chamber and carries it to a level 3-16 inch below the outlet of jet H,. and is of such construction that the height of the fuel in the jet remains constant regardless of reasonable angularities.

Jet H extends up into the center of the choke tube and the size of the orfice is regulated by the needle valve A. To regulate, proceed as follows:

First. See that fuel valve under supply tank is opened and fuel is in float chamber G.

Second. Open the needle valve A several turns much more than is necessary for regular running.

Third. Increase the tention on the secondary air valves B, C and D so that they will not open at moderate speeds.

Fourth. Place the throttle F in position of A, and start the motor. If an exceedingly rich mixture is required, close the choke valve J. After the motor has started, it will be found that the mixture is too rich, and black smoke will issue from the exhaust with the motor running idle.

Fifth. Adjust the needle valve A by turning it in clockwise direction until the smoke disappears and

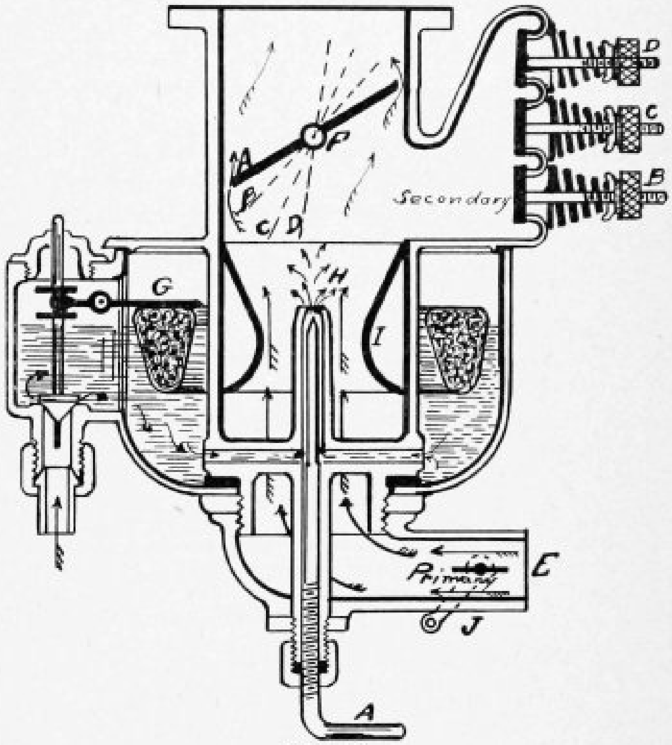


FIG. 70.

the motor runs smoothly. When the throttle is in the position of A. Assume we have 50 cubic inches of volume, and 200 feet velocity going through the carburetor to maintain 800 piston feet per minute.

Sixth. Throw in the clutch and start the tractor to the field. This will cause the governor to open the throttle F to position B and the air volume will increase to 100 cubic inches and the velocity will increase to 400. This will cause a high negative pressure in the mixing chamber around the throttle F, in order to increase the volume and velocity of air passing through the choke tube I. This causes the fuel to flow out of the jet H faster than the increasing speed of air, causing a rich mixture. Having the needle valve A regulated for idleing which we must not change, we relieve the tention on the spring of the secondary air valve B. So as to allow air to enter reducing the negative pressure in the mixing chamber and giving a true mixture when operating the tractor idle.

Seventh. Arriving at the field we drop the plows into the ground. The governor opens the throttle valve F to the position C. The air volume increasing to 200 cubic inches and 600 feet velocity. Although the secondary air valve B. is wide open, a high negative pressure is formed in the mixing chamber in order to increase the volume and velocity of air passing through the choke tube I. This causes the fuel to flow out of the jet H faster than the increase of air and results in a rich mixture. Now we have the needle valve A regulated for running the motor idle, and the secondary air valve B. regulated for operating the tractor idle. These adjustments we do not wish to change as the motor will soon return to the same volumes and velocities again. Therefore under ordinary plowing conditions with 600 foot velocity and 200 cubic inches of gas per cycle, we relieve the tension on the secondary air valve C until the smoke clears away and the motor runs smoothly with the plows in the ground.

Eight. Now having the carburetor properly adjusted for average plowing conditions, we proceed across the field until we come to a slew hill, quackgrass, or gumbo spot where the load is exceedingly heavy. Now the governor opens the throttle valve to the position D, and the air volume increasing to 250 cubic inches and 600 foot velocity per second. Although the secondary valves B and C are wide open, a high negative pressure is formed in the mixing chamber, in order to increase the volume and velocity of air passing through the choke tube I. This caused the fuel to flow out of the Jet H faster than the increased air velocity, so that a rich mixture is formed. A black smoke comes from the exhaust and we have a sluggish running motor. Having the needle valve A properly adjusted to give a true mixture when the motor is running idle, and the secondary air valve B. properly adjusted to give a true mixture when the tractor is running light, and the secondary air valve C regulated to give a true mixture under average plowing conditions. These adjustments must not be changed. Therefore we adjust the tension of the spring on secondary air valve D to secure a true mixture under severe conditions or exceedingly high volumes and velocities.

Ninth. We now have the carburetor completely adjusted to give us a true mixture at all times regardless of volumes, velocities, or angularities. If we do not have a true mixture when the motor is running idle, adjustment must be made by the needle valve A only. If we do not have a true mixture when the tractor is running light, make adjustment on secondary air valve B only. If we should not have a true mixture under average plowing conditions make adjustments on secondary air valve C only. If we do not have a true mixture at exceedingly heavy loads we should adjust the tension of the spring on the secondary air valve D only.

Fig. 70 shows a typical carburetor in principle only. You will find this principle built into the best carburetors, one regulation for each volume and velocity at which we run to any extent—although their mechanical construction may be quite different.

144. Choke Tube. The choke tube I is a restriction placed in the main body of the carburetor and around the nozzle and slightly below the nozzle, through which the primary air must pass. The function of the choke tube is to cause a negative pressure so as to cause the fuel to flow out of the nozzle. It also increases the air velocity so that it has a breaking up effect.

145. Choke Tube Too Large. This choke tube should be as large as possible so as not to decrease the power of the motor. If too large, the motor will not respond quickly to sudden changes of the throttle and can not be improved by the other adjustments. At low air velocities the motor will not run very smoothly, and will have a tendency to "load up" under a hard pull. At high air velocities the exhaust will be irregular. This "loading up" will be much worse if the manifold is too large or too cold. If there is a popping back at the carburetor when the governor or throttle valve is suddenly opened, the choke tube is too large.

146. Choke Tube Too Small. If the choke tube is too small it will prevent the motor from taking a full charge when the throttle valve is wide open. The change from one speed to the other will be very good, but the power of the motor will be decreased, on most carburetors this choke tube may be changed, if necessary. Bear in mind that when the choke is increased, more air is admitted resulting in a correspondingly less negative pressure, and a thinner mixture (the other adjustments will have to be made in their proper order).

147. Water in Carburetor. Water will not enter a nozzle through which fuel has been passing, but will form a large bubble in the float chamber, and will occasionally work up against the nozzle opening so as to prevent the fuel from flowing from the fuel chamber to the jet. This condition causes a lean mixture and a popping back at the carburetor. This popping back increases the pressure above the choke and blows the fuel out of the nozzle, and throws the water away from the opning. The water may not return to cause trouble for several hours, but it may return at any time or under any condition.

148. Dirt. Dirt will accumulate in any restricted portion of the fuel supply line. The symptoms of the accumulation of dirt is a popping back at the carburetor at exceedingly heavy loads. The popping will occur at lighter and lighter loads as the accumulation of dirt continues.

149. Rich Mixtures. When there is too large a percentage of carbon to oxygen we have an incomplete slow burning mixture, and therefore a slow sluggish running motor. If the mixture is exceedingly rich, a dense black smoke will be thrown out from the exhaust, and the combustion chamber will become badly sooted resulting in pre-ignition.

150. Lean Mixture. If the percentage of oxygen (air) becomes too great, it is termed too rare or too lean a mixture. A lean mixture is a slow burning mixture causing a blaze to remain in the combustion chamber through the power event. If exceedingly lean, the blaze continues through the exhaust event until the intake valve opens. It will light the gas in the intake manifold, sometimes causing a blaze to shoot from the carburetor. This has set many an automobile on fire.

151. Causes of Lean Mixtures.

First. Shortage of fuel in the supply tank.

Second. Stoppage by dirt in the supply pipe leading from the fuel reservoir to the carburetor at any place where a restriction is caused, especially under the float valve.

Third. Accumulation of water in the float chamber.

Fourth. Improper carburetor adjustments for the various volumes and velocities.

Fifth. Air leakage through gaskets or blow holes, and poor flange connections on intake manifold between throttle or governor valve and the motor.

152. A True Mixture. One of the most difficult engineering feats in the operation of the internal combustion motor, is the correct adjustment of the carburetor, so as to give us a corret mixture at all times regardless of volume or velocity (not too rich and not too lean). To obtain the highest efficiency, the fuel must be broken up into fine molecules, having a true proportion of oxygen to carbon, and compressed as high as possible in order that the rate of flame propagation is as instantaneous as possible.

153. Kerosene. When using kerosene as a fuel, do not change from gasoline to kerosene until the motor and circulating water is well heated. Using kerosene in a cold motor will cause condensation. Kerosene will from on the cylinder walls cutting the lubricating oil from the wall, working by the piston into the crank case and thereby destroying the lubricating value of the oil in the oiling system.

154. Intake Manifold. Too much care cannot be exercised in the selection of the intake manifold. It should be as short and direct as possible and all bends should be long easy bends. It should be designed so as to give equal distribution to all cylinders. The intake manifold should be protected from cold winds, to prevent condensation. It is not only the question of breaking up the fuels into fine molecules at the carburetor, but of delivering them in the same condition to the combustion chamber. The advantages gained by a good carburetor would be destroyed by a poorly designed intake manifold.

155. Hot Air to Carburetor. In cold weather it is necessary to use hot air to the carburetor to assist the evaporation of the fuel, especially when low-grade fuels are used. Evaporation causes a drop in temperature of about 40 degrees Fahrenheit at the nozzle in the carburetor. Hot air should be used intelligently. By heating the air we expand it, and when the air is expanded, less is taken into the cylinder, consequently there is a loss in power per cylinder volume. (42 cubic inches of gas equals one B. T. U. equals 778 foot pounds or .0236 H.-P. Cooling the air contracts it, so that more is taken into the cylinder, and resulting in more power this is why a motor in hot weather develops more power at night than in the day time.

CHAPTER IV

ELEMENTARY ELECTRICITY

156. Elementary Electricity. While we do not know what electricity is, and know but little of its exact nature, it is a matter of common knowledge that it is one of nature's prime forces, and as such is universal. All material objects, together with the air, earth, water, and clouds, are at all times electrified to a greater or less degree. The amount of electricity that a certain object possesses at any given moment depends on its electrical capacity and upon the condition of surrounding objects.

We can illustrate this by comparing electricity with air in an automobile tire. Consider first a deflated tire, it will contain a certain amount of air and there is no tendency for air to leave or enter the tire, because the air inside is of the same pressure as that outside. If we now attach a pump to the tire and begin to pump it up, more air is added and the pressure will graduallly rise.

When the tire is inflated to 75 or 100 pounds it will contain a great deal more air than at the beginning, and there will be a strain in the rubber which keeps the air from escaping. If it were electricity instead of air, the tire would be said to be highly charged.

If the tire is punctured the air will at once begin to escape and the rapidity of escape will depend on the size of the opening and the difference in pressure between the air inside and outside of the tire.

In like manner, electricity, as it really exists in nature, is in a neutral or stationary condition, and in order to get it to flow from one place to another, or to get it in motion, it is necessary to pump it up, so to speak, to a higher pressure and then provide a path through which it can flow. However, if the charge on an object is brought to a high pressure without an easy path to escape, it will gradually leak away, without giving any indication of its passing, or if the charge is suddenly raised to a high pressure it will jump in the form of a spark to another object of lower pressure. The electrical term for this pressure is potential or voltage. These terms will be explained more in detail later.

157. Ways of Developing Electricity. Electrical action can be developed in many different ways, but the most important ones come under the following named divisions:

(a) By the contact of dissimilar substances.
(b) By the application of heat.
(c) By chemical action.
(d) By magnetic induction.

The development of electricity, under the first two headings (a) and (b) are of little value in connection with our work, and we will devote no space to them here.

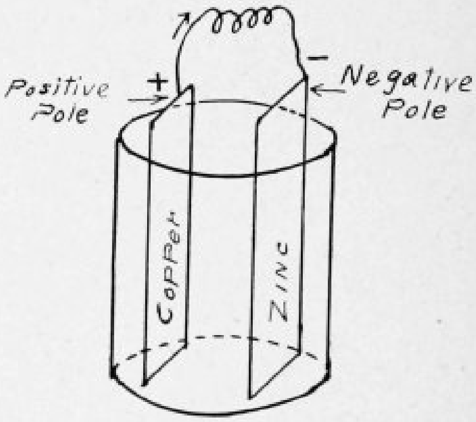


Fig 1

The development of electricity by chemical action, heading (c), includes all primary cells such as the voltaic cell and dry cells.

158. The Voltaic Cell, Fig. 1, consists of a glass or rubber jar containing sulphuric acid called electrolyte. Two plates, one of copper and the other of zinc, are placed in the acid. A difference of pressure, or potential, is produced between the plates by chemical action, and if the tops of the plates are connected by a copper wire an electrical current will flow from the copper to the zinc plate. The plates do not necessarily need to be of copper and zinc, but this pair produce the best results outside of silver, gold or platinum paired with zinc. In a dry cell, which works on the same principle as a voltaic cell, the copper plate is generally replaced by one of carbon.

The ordinary dry cell is composed of two elements, usually zinc and carbon and a liquid electrolyte. A zinc cup closed at the bottom and open at the top forms the negative electrode; this is lined with several layers of blotting paper or other absorbing material.

The positive electrode consists of a carbon rod placed in the center of the cup; the space between is filled with carbon—ground coke and dioxide of manganese mixed with an absorbent material. This filling is moistened with a liquid, generally sal-ammoniac. The top of the cell is closed with pitch to prevent leakage and evaporation. A binding post for holding the wire connections is attached to each electrode and each cell is placed in a paper box to protect the zinc of adjacent cells from coming into contact with each other when finally connected together "to form a battery."

There are three different methods of connecting or grouping the cells to form a voltaic battery:

(1) In series.

(2) In parallel.
(3) In multiple series.

In the series connections the positive terminal of the first cell is connected to the negative terminal of the second cell and the positive terminal of the second cell to the negative of the third, etc. In this method of connecting or grouping of cells, when the negative terminal of the first cell is connected to the positive terminal of the last cell by same exterior conductor, the total current produced will flow suc-

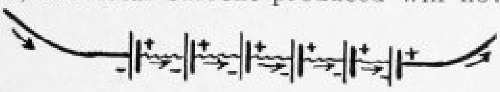


Fig. 2

cessively through each cell. This connection is illustrated in Fig. 2, and is used where a high voltage is needed and the resistance of the external circuit is comparatively high. The total voltage of the complete battery in this case is equal to the sum of the voltages of the different cells, an ordinary dry cell equals one and one-quarter volts.

Cells are connected in parallel when the positive

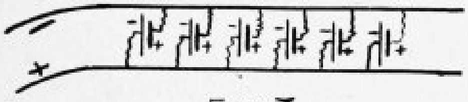


Fig 3

terminals of all the cells are connected to one main positive conductor and all the negative terminals are connected to one main negative conductor as shown by the diagram Fig. 3, only a part of the total current flowing in the main conductors will pass through each cell. This method of grouping is used when it is desired to obtain a strong current from a number of cells (when the external resistance is low) as in electro-plating.

Cells are connected in multiple series by arranging them in several groups, each group being composed of several cells connected in series, and then connecting all the groups together in parallel, as shown

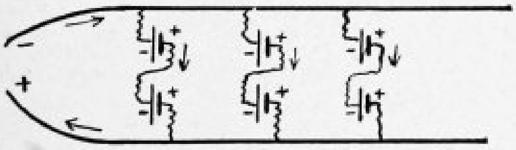


Fig 4

in the diagram, Fig. 4. This method is used where both a higher potential and a stronger current are required than any one cell of the group will give.

The other way of developing electricity, heading (d), is by magnetic induction. This is the most important method and will be discussed fully later.

159. Circuits. A circuit is a path composed of a conductor, or of several conductors joined together, through which an electric current flows from a given point around the conducting path back again to its starting point.

A circuit is broken, or open, when its conducting elements are disconnected in such manner as to prevent the current from flowing.

A circuit is closed, or complete, when its conducting elements are so connected as to allow the current to flow.

A circuit in which the earth, or ground, forms a part of the conducting path, is called an earth, or a grounded circuit.

The external circuit is that part of a circuit which is outside, or external to, the electric source.

The internal circuit is that part of a circuit which is included within the electric source.

In the case of the simple voltaic cell, the internal circuit consists of the two metallic plates, or elements, and the electrolyte; an external circuit would be a wire or any conductor connecting the free ends of the electrodes.

160. Storage Battery. A storage battery for use on automobiles is composed of rubber jars, lead plates, plate separators and electrolyte.

The jars are made of hard rubber in order that they may not be acted upon by the acid, and are so constructed that the plates rest on ribs at the bottom,

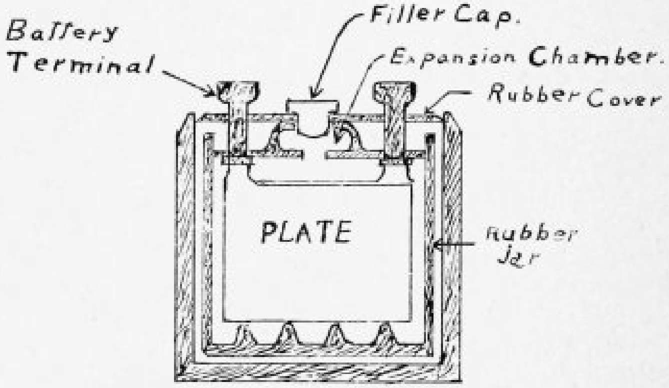


FIGURE 5

leaving about an inch space where sediment can collect without lodging between plates and short-circuiting them. Fig. 5 shows a cut through one cell of a battery.

The plates, which are about one-eighth of an inch thick, are made by first casting lead into grids. Then a composition of lead oxide, which is known as the active material, is pasted and pressed into these grids, forming plates. The active material dries and sets hard as cement. The plates then go through an electro-chemical process which turns the active material of the positive plates into brown peroxide of lead and that of the negative plates into spongy metallic lead.

The plate separators are made either of wood or of hard rubber and have grooves on the sides, up and down, to allow the electrolyte to circulate around the plates. Their purpose is to separate the positive from the negative plates, and to prevent foreign substances from lodging between the plates and cause short circuits.

The electrolyte or exciting fluid is made by mixing chemically pure sulphuric acid with distilled water in certain proportions. The gravity of the water is 1,000 and that of pure acid is 1.840. By mixing two parts of acid with five parts of water the electrolyte produced should be of about 1.300 gravity.

Electrolyte should always be mixed in an earthen vessel by first pouring in the distilled water and then adding the acid slowly, taking care to stir the solution all the time. For example, pour five gallons of distilled water into the vessel, and then add the acid as follows: Pour one quart of the acid into the water slowly and stir continuously; let this stand fifteen minutes and then add another quart in the same way. Continue this operation until the two gallons of acid have been added. Special care should be taken to use distilled water and chemically pure sulphuric acid. When the above solution is cooled, the gravity should be about 1.300. If it is above this add a little water, and if below 1.300 add a little acid. Be sure that the solution is cooled when testing the gravity.

The above statement should not be misunderstood to mean that a little acid should be added to the electrolyte in a battery when the gravity is low. Never add pure acid to a battery under any conditions, and never put new electrolyte into a batter unless you know positively that it is fully charged. If the gravity is low, fill the battery to the proper level with distilled water and put on charge until the gravity ceases to rise for about two hours. If the gravity does not come up to between 1.275 and 1.300, all or part of the old solution should be taken out and replaced by new electrolyte of 1.300 gravity. Always use distilled water for a battery, because impure water is injurious to the active material. Distilled water should be left in a glass jar or bottle well corked. Never use a tin can for this purpose.

To measure the gravity of a battery an instrument known as a hydrometer is used. It consists of a glass float loaded at the bottom and with a glass stem extending at the top upon which numbers are placed to correspond to the gravity of the liquid tested. Fig. 6 shows the position of the hydrometer under different conditions of the battery.

For convenience in testing the specific gravity of the electrolyte in a battery, the hydrometer is placed inside of a glass syringe. The electrolyte is drawn from the battery into the syringe, and after the reading is taken it is forced back into the battery again. If the battery is in good condition the gravity should be between 1.275 and 1.300.

The true gravity of the electrolyte in a storage battery can only be ascertained by charging the battery until the gravity of the solution has ceased to rise for a period of at least two hours. As a battery is being charged, the acid is forced out of the plates and mixed with the water, and the gravity of the solution increases. As a battery is being discharged, the acid leaves the water and goes into the plates, and the gravity of the solution decreases.

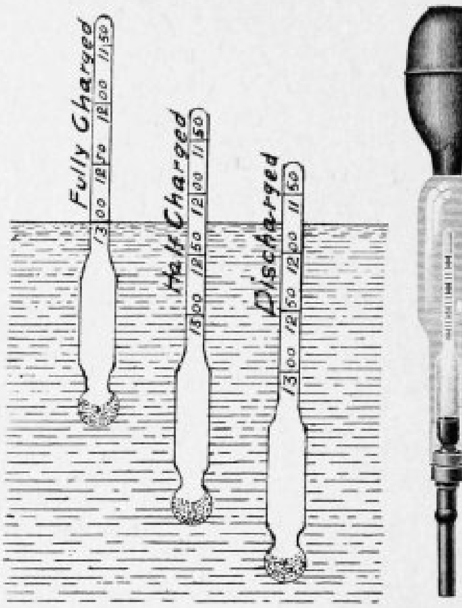


FIGURE 6

When a battery is completely, or almost completely discharged, it may be charged at a rapid rate at first, provided it does not gas. During its charge a cell should never be allowed to gas except at the finishing rate. At any other time during the charge the charging rate should be decreased as soon as the cells begin to gas.

The following are safe charging rates for any good battery. If the rated capacity of a battery is 80 ampere hours, and the gravity of the solution is below 1.150, or over 1.250, it should be charged at 5 per cent of the rated capacity or 4 amperes. If the gravity of the solution is between 1.150 and 1.250 it should be charged at 10 per cent of the rated capacity, or 8 amperes.

Fig. 7 shows a simple method of charging from

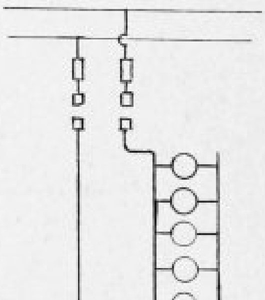


FIGURE 7

an outside source, where direct current is available. Enough lamps are placed in the circuit to get the desired amperage through the battery.

Never take a reading of the gravity of a cell immediately after adding water. Allow the cell to charge for 15 or 20 minutes so that the water will have time to become thoroughly mixed with the acid of the cell.

When the charge of a storage battery is nearly complete, each cell should give from 2.5 to 2.6 volts and a battery of 3 cells, 7.5 volts. When the charging is ceased the voltage will go back to 2.2 volts for each cell, or 6.6 volts for the three-cell battery.

Distilled water should be added to a battery in use at least twice a month. In cold weather never add water to a battery and let it stand in a cold place unless it has been given a charge after the water was added. Water is lighter than electrolyte and will remain on the top and freeze if not mixed with the electrolyte.

A battery fully charged will not freeze under ordinary temperatures, but when it is completely discharged its freezing point is considerably above zero.

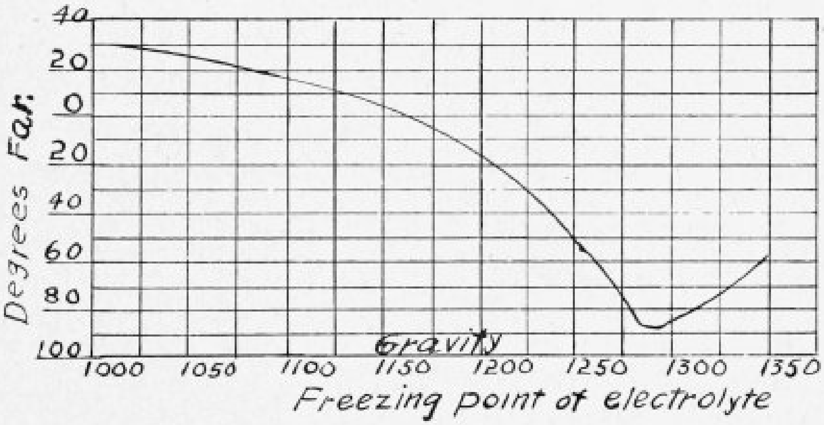


FIGURE 8

Fig. 8 shows a curve by which the freezing point of electrolyte of any specific gravity can be easily found.

If the terminals of a storage battery show signs of corrosion, this corrosion should be removed at once. It is a greenish substance and if left on the terminals for any length of time, it will cause poor contacts and the battery will be hard to charge and will show weakness even if it is not discharged. All loose parts should be taken off and cleaned in a strong solution of cooking soda and water. Place the parts in the soda solution for half an hour and then clean with a stiff brush, removing all the corrosion. Also clean the terminal parts of the battery, but be careful not to let the soda solution get into the battery.

When all parts are clean, wipe them off with a clean cloth and apply a coat of vaseline. If the terminals are kept coated with vaseline corrosion will not take place.

161. Magnetism. Magnets are substances which have the property of attracting pieces of iron or steel, and the term magnetism is applied to the cause of this attraction. Other metals besides iron and steel, such as nickel, cobalt and magnese are also magnetic, while copper, aluminum, zinc and other metals cannot be magnetized at all. Iron and steel, however, are the only metals which are used as magnets commercially. The different kinds of these metals also vary greatly in their ability to hold their magnet properties after being magnetized; for instance, a piece of soft iron will remain magnetized only while it is in contact with another magnet, and a piece of hard steel will remain magnetized indefinitely.

All material substances are supposed to be composed of minute particles called molecules. In a magnetic substance like iron and steel, each one of these molecules is a small magnet in itself, but all of these molecules are jumbled up in such a manner that very few of them have their north and south poles in the same direction. When the molecules or small magnets are in this mixed up condition, their magnetism is not noticed; but when the piece of steel is magnetized, a number of these small magnets are turned with their north pole in one direction, and their south poles in the opposite direction, causing them to pull together to produce a magnetic pull. The strength of a magnet depends on the number of molecules or small magnets turned in the same direction.

162. Permanent and Temporary Magnetism. Magnetism exists in a natural state in an ore iron which is known in chemistry as magnetic oxide of iron, or magnetite. This magnetic ore was first found by the ancients in Magnesia, a city in Asia Minor; hence substances possessing this property have been called magnets. It was also discovered that when a small bar of this ore is suspended in a horizontal position by a thread it has the property of pointing in a north and south direction. From this fact the name lodestone—leading stone, was given to the ore

When a bar or needle of hardened steel is rubbed with a piece of lodestone, it acquires magnetic properties similar to those of the lodestone, without the latter losing any of its own force. Such bars are called artificial magnets.

Artificial magnets which retain their magnetism for a long time are called permanent magnets.

A bar of soft steel treated in the above manner, which would retain its magnetism but a short time, would be called a temporary magnet.

The common form of artificial, or permanent magnet is a bar of steel bent into the shape of a horseshoe and then hardened and magnetized. A piece of soft iron called an armature, or a keeper, is placed across the two free ends, which helps to prevent the steel from losing magnetism. Fig. 9.

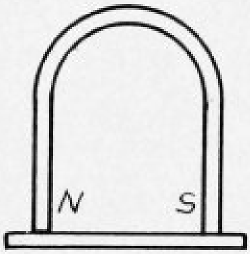


FIGURE 9

If a bar magnet is dipped into iron filings, the filings are attracted towards the two ends, and adhere there in tufts; while toward the center of the bar half way between the two ends, there is no such tendency.

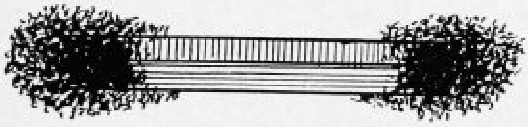


FIGURE 10

See Fig. 10. That part of the magnet where there is no apparent magnetic attraction is called the neutral line; and the parts around the two ends where the attraction is greatest are called poles.

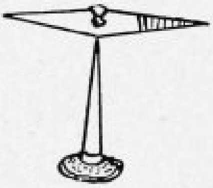


FIGURE 11

A compass consists of a magnetized steel needle, Fig. 11, resting upon a fine point so as to turn freely in a horizontal plane. When not in the vicinity of other magnets or magnetized iron, the needle will always come to rest with one end pointing towards the north and the other towards the south. The end pointing northward is the north seeking pole, or simply the north pole, and the opposite end is the south seeking pole, or south pole. This polarity applies as well to all magnets.

If the north pole of any magnet is brought near the south pole of another magnet, attraction takes place; but if two north poles or two south poles are brought together they repel each other. In general like magnetic poles repel one another, unlike poles attract one another.

The earth is a great magnet whose magnetic poles coincide nearly, but not quite, with the geographical north and south poles. A freely suspended magnet, therefore, will always point in an approximately north and south direction. It is impossible to produce a magnet with only one pole. If a long bar magnet is broken into any number of parts, each part will still be a magnet, and have two poles, a north and south one.

163. Magnetic Field. The space surrounding a magnet in which any magnetic substance will be attracted or repelled is called its magnetic field, or simply its field. Magnetic attractions and repulsions are assumed to act in a definite direction and along imaginary lines called lines of magnetic force, or

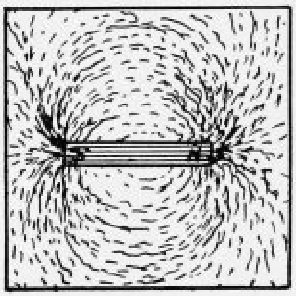


FIGURE 12

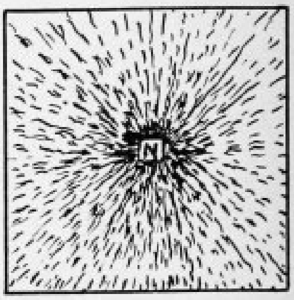


FIGURE 13

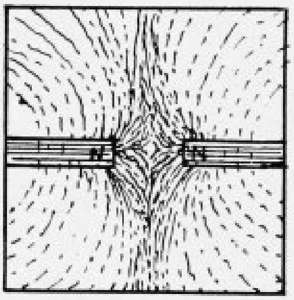


FIGURE 14

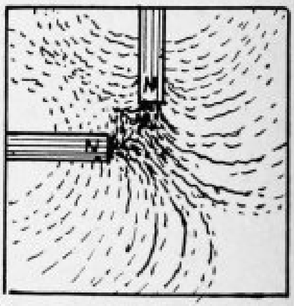


FIGURE 15

simple lines of force, and every magnetic field is assumed to be traversed by such lines of force, in fact, to exist by nature of them.

The direction of the line of force in any plane can be shown by placing a paper in a magnetic field and sprinkling iron filings over the paper. Figures 12, 13, 14 and 15 show the results of such experiments.

As seen from the figure, the lines of force never intersect each other, but they are crowded out of their original direction when two like poles are brought together, until they coincide in direction with those opposing and form a resultant field.

The amount or quantity of magnetism is expressed by the total number of lines of force contained in the magnetic circuit.

Magnetic density is the number of lines of force passing through a unit area measured perpendicular to their direction.

164. Electromagnetism. If a conductor be placed parallel to the magnetic axis of a compass needle, and a current passed through the conductor in either direction, the needle will tend to place itself at right angles to the conductor, as shown by arrows in Fig. 16; or, in general, an electric current and a magnet exert mutual force upon each other. As stated before, the space surrounding the conductor is a magnetic field. If the conductor is threaded up through a piece of cardboard, and iron filings are sprinkled on the cardboard, they will arrange themselves in concentric circles around the conductor, as represented in Fig. 17. This effect will be observed throughout the entire length of the conductor; and is caused entirely by the current. In fact, every conductor conveying a current of electricity can be imagined as completely surrounded by a sort of magnetic whirl, the magnetic density decreasing as the distance from the current increases. See Fig. 18.

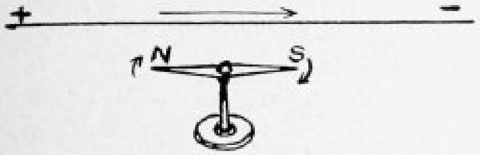


FIGURE 16

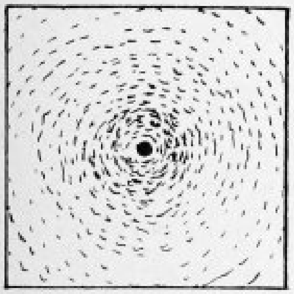


FIGURE 17


FIGURE 18

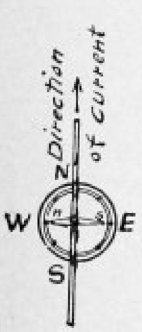


FIGURE 19

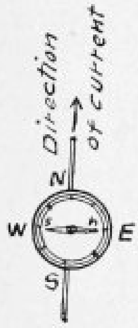


FIGURE 20

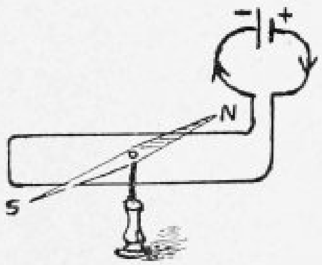


FIGURE 21

If the current in a horizontal conductor is flowing towards the north, and a compass is placed under the conductor, Fig. 19, the north pole of the needle will be deflected towards the west; by placing the compass over the wire, Fig. 20, the north pole of the needle will be deflected towards the east. By reversing the direction of the current in the conductor, the needle will point in the opposite direction in each case, respectively.

If the conductor is placed over the needle, and then bent back under, it forming a loop as shown in Fig. 21, the tendency of the current in both top and bottom portions of the wire is to deflect the north pole of the needle in the same direction.

From these experiments, knowing the direction of current in the conductor, the following rule is deduced for the direction of the lines of force around the conductor:

Rule:—If the current is flowing in the conductor away from the observer, then the direction of the lines of force will be around the conductor in the direction of the hands of a watch.

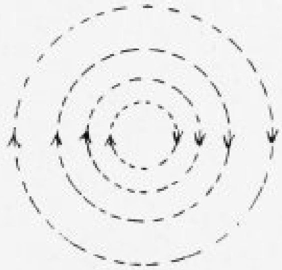


FIGURE 22

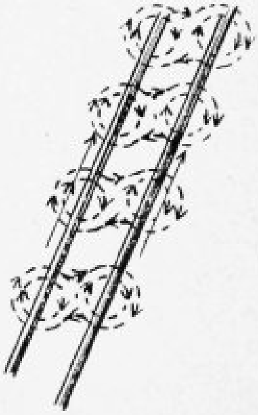


FIGURE 23

The direction of the lines of force around a conductor is indicated in Fig. 22, where the current is assumed to be flowing downwards, that is, piercing the paper.

Two parallel conductors, both transmitting currents of electricity, are either mutually attractive or repellant, depending upon the relative direction of their currents. If the currents are flowing in the same direction in both conductors, as represented in Fig. 23, the lines of force will tend to surround both


FIGURE 24

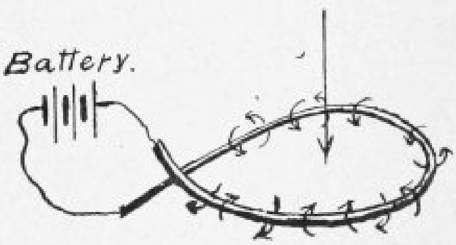


FIGURE 25

conductors and contract, thus attracting the conductors. If, however, the currents are flowing in opposite directions, as in Fig. 24, the lines of force lying between the conductors will have the same direction, and, therefore, repel the conductors.

If the conductor carrying the current is bent into the form of a loop, as in Fig. 25, then all the lines of force around the conductor will thread through the loop in the same direction. By bending the conductor into a long helix of several loops, the lines of force around each loop will coincide with those around the adjacent loops, forming several long lines of force which thread through the entire helix, entering at one end and passing out of the other. The same conditions now exist in the helix as exist in a bar magnet. i. e., the lines of force pass out from one end and enter the other. In fact, the helix possesses a north and a south pole, a neutral line, and all the properties of attraction and repulsion of a magnet. If it is suspended in a horizontal position and free to turn, it will come to rest pointing in a north and south direction.

A helix made in this manner, around which a current of electricity is circulating, is called a solenoid.

The polarity of a solenoid, that is, the direction of the lines of force which thread through it, depends upon the direction in which the conductor is coiled, and the direction of the current in the conductor. To determine the polarity of a solenoid, knowing the direction of the current:

Rule:—In looking at the end of the helix, if it be so wound that the current circulates around the helix in the direction of the hands of a watch, that end will be a south pole; if in the other direction, it will be a north pole.

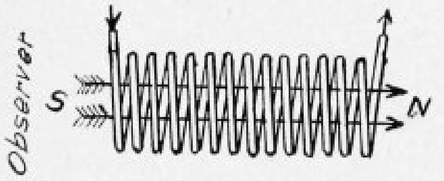


FIGURE 26

Fig. 26 represents a conductor coiled in a right-handed helix. If the current starts to flow from the end where the observer stands, that end will be a south pole and the observer will be looking through the helix in the direction of the lines of force. The polarity of a solenoid can be changed by reversing the direction of the current in the conductor.

It has been stated that when a magnetic substance is brought into a magnetic field, the lines of force in that field crowd together, and all try to pass through that substance; in fact, they will alter their circular shape, and extend a considerable distance from their original position in order to pass through it. A magnetic substance, therefore, offers a better path for the lines of force than air, or other non-magnetic substances.

The facility afforded by any substance to the passage through it of lines of force is called magnetic permeability, or, simply, permeability.

The permeability of all non-magnetic substances, such as air, copper, wood, etc., is taken as 1, or unity. The permeability of soft iron may be as high as 2,000 times that of air. If therefore, a piece of soft iron be inserted into the magnetic circuit of a solenoid, the number of lines of force will be greatly increased; and the iron will become highly magnetized.

A magnet produced by inserting a magnetic substance into the magnetic circuit of a solenoid is an electro-magnet, and the magnetic substance around which the current circulates is called the core. See Fig. 27. The solenoid is generally termed the magnetizing coil.

In the ordinary form of electro-magnet, the magnetizing coil consists of a large number of turns of insulated wire—that is, wire covered with a layer or coating of some non-conducting or insulating material, usually silk or cotton; otherwise, the current

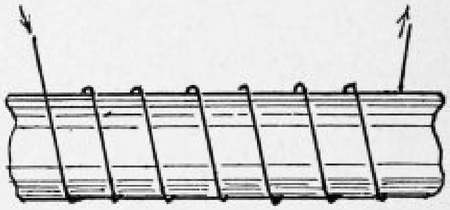


FIGURE 27

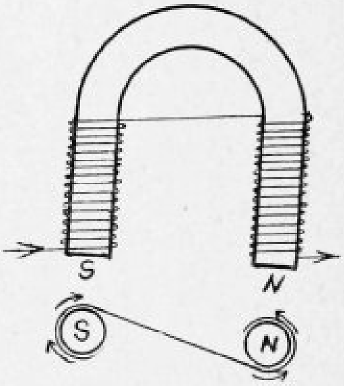


FIGURE 28

would take a shorter and easier circuit from one coil to the adjacent one, or from the first to the last coil through the iron core without circulating around the magnet.

The most convenient form of electro-magnet for a great variety of uses is the horseshoe, or U-shaped electro-magnet, Fig. 28. It consists of a bar of iron bent into the shape of a horseshoe, with straight ends, and provided with two magnetizing coils, one on each end of the magnet. The two ends which are surrounded by the coils are the cores of the magnet, and the arcshaped piece of iron joining them together is known as the yoke of the magnet.

165. Electrical Units. For simplicity we can compare electricity flowing through a conductor to water flowing in a pipe, but it must be remembered that the two are similar in action only and are not alike in any other way. Imagine a water pump with a bent pipe connecting both inlet and outlet at the pump, as shown in Fig. 29.

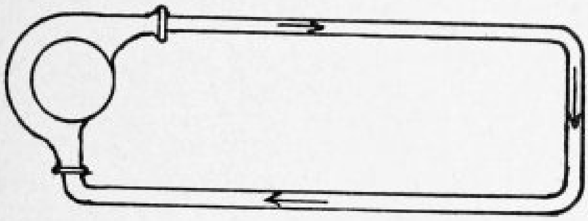


FIGURE 29

If the system is filled with water and the pump started water will flow from the pump through the pipe and back to the pump again. The pump in this case takes the place of the battery or the generator in the electric circuit.

The faster the pump is run the higher the pressure on the outlet side of the pump and the more water will be flowing through the pipe. It will also be noticed that the pipe will offer a considerable resistance to the flow of the water, and the resistance will be greater the smaller the pipe, and consequently less water will flow through a small pipe than through a big one at the same pressure.

In like manner in the electrical circuit the volume of current flowing depends upon the pressure at the battery or generator and on the size of the conductor forming the circuit. Increasing the pressure will increase the amount of current flowing through a given circuit but the resistance to its flow will also increase.

The resistance offered to the flow of current varies with different conditions and also with the temperature of the conductor.

The three principal units used in practical measurement of electricity are:

(a) Ampere.
(b) Volt.
(c) Ohm.

The ampere is the unit denoting the rate of flow of an electric current and may be compared to gallons per minute in the case of water flowing through a pipe.

The volt is the unit of pressure or electrical potential, and may be compared to the pounds of pressure in comparison with water. The electrical potential is often called electromotive force, E. M. F., or simply E.

The ohm is the unit of restistance. This unit is used to measure the resistance offered to the flow of electric current through different conductors.

These units bear a certain relation or ratio to each other and this is expressed by what is called Ohm's Law.

Ohm's Law:—The strenght of an electric current in any circuit is directly proportional to the electromotive force developed in that circuit and inversely proportional to the resistance of the circuit: i. e., it is equal to electromotive force divided by the resistance. Ohm's Law is usually expressed algebraically, thus:

$$\text{Strenght of current, equals } \frac{\text{electromotive force}}{\text{resistance}}$$

If the electromotive force (E) is expressed in volts and the resistance (R) in ohms, the formula will give the strenght of current (I) directly in amperes: thus:

$$I = \frac{E}{R}$$

168. Electro-Magnetic Induction. It has been shown that an electric current circulating around a coiled conductor produces lines of force which thread through the coil, which enters at one end and leaves at the other end. As long as the current in the coil remains at a certain strength, the lines of force have direction and position only; unless influenced by some

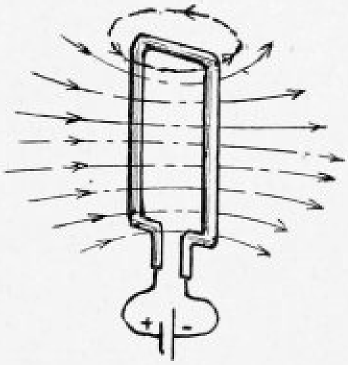


FIGURE 30

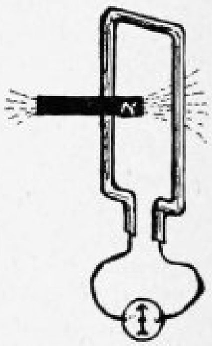


FIGURE 31

exterior magnetic substance, they do not increase or diminish in number, or change their position relatively to the coil. Fig. 30 shows such a coil around which a current is flowing from the battery. Suppose the battery was disconnected from the coil and a gal-

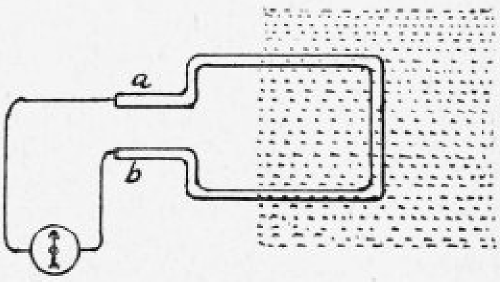


FIGURE 32

vanometer for detecting small currents is inserted in its place. A magnetic pole suddenly thrown into the coil, as represented in Fig. 31, will cause a deflection of the galvanometer needle; the needle, however, will return to its original position just as soon as the magnet comes to a rest. Taking the magnet away from the coil also causes a deflection of the needle, but in the opposite direction. In one case a momentary current is induced in the circuit, as shown by the deflection of the galvanometer needle, while the magnet is being inserted into the coil; this current immediately subsides when the magnet ceases to move. In the other case the same effects are produced, with the exception that the current induced in the coil flows in an opposite direction to that in the first instance.

These induced currents are caused by a change in the number of lines of force which pass through the coil. In passing into or out of the coil, the lines of force from the magnet set up an E. M. F. in that portion of the conductor in which the number of lines

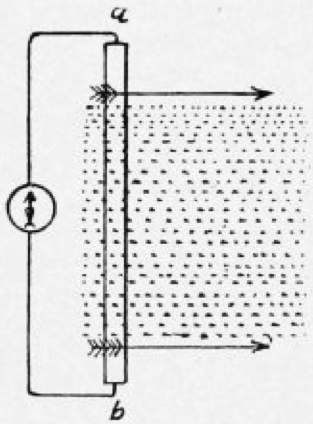


FIGURE 33

of force changing, and this E. M. F. tends to send a current through the circuit.

In place of a small magnetic pole, we will suppose that the coil was quickly inserted into a large uniform magnetic field where all lines of force are parallel to one another. Fig. 32 represents a cross-sectional view of this kind of a field. The dots represent the ends of the lines of force; their direction is assumed to be downwards, piercing the paper; or, in other words, the observer is looking along the lines of force towards the face of a south magnetic pole. As the coil enters the magnetic field with its plane at right angles to the lines of force, a current will be induced in the coil and the galvanometer needle will be deflected; this induced current is produced by a change in the number of lines of force that pass through the coil, as in the former case. Taking the coil away from the magnetic field will also cause a current in the circuit, but it will deflect the galvanometer needle in an opposite direction, showing that the current in the circuit is reversed.

If the coiled conductor be straightened out, forming one long conductor and then moved across the magnetic field at right angles to the lines of force, as shown in Fig. 33, a current will be generated in the circuit. The current will, however, subside immediately when the motion stops, whether the conductor is in the magnetic field or otherwise. If the conductor be moved in the magnetic field, with its length parallel to the lines of force, there will be no current generated in the circuit. From these two experiments the following principle is deduced: When a conductor is moved across a magnetic field so that it cuts the lines of force, an E. M. F. is generated which tends to send a current through that conductor.

There are three methods of producing an electromotive force by induction in a coiled conductor; namely, by electro-magnetic induction, by self-induction, and by mutual induction.

In electro-magnetic induction, the change in the number of lines of force that pass through the coil is due to some relative movement between the coil and a magnetic field; as, for example, by thrusting a magnet into the coil or withdrawing it; or, by suddenly putting the coil into a magnetic field with its plane at right angles to the lines of force.

In self induction the change in the number of lines of force is caused by sudden changes in a current which is already flowing through the coil itself, and is supplied from some outside force. This outside current produces a magnetic field in the coil, and so long as the strength of the current remains steady, there is no change in the number of lines of force which pass through the coil. If the strength of the current is increased suddenly, a change in the number of lines of force occurs; the change in turn induces an electromotive force in the conductor, which opposes the original current in the coil and tends to keep the current from rising. Its action is similar to that which would take place if some extra resistance were suddenly inserted into the circuit at the instant the strength of the current is increased. The original current eventually reaches its maximum strength in the coil as determined by Ohm's law, but its rise is not instantaneous; it is retarded to a certain extent by this induced electromotive force. If, on the other hand, the strength of the original current is allowed to decrease suddenly, another change is produced in the lines of force that pass through the coil; this new change induces an electromotive force in the coil that acts in the same direction as that of the original current and tends to keep it from falling. As in the former case, however, the original current will eventually drop to its minimum strength, as determined by Ohm's law, but it will drop gradually, and a fraction of a second will elapse before it becomes constant.

In mutual induction, two separate coiled conductors, one conveying a current of electricity, are placed near each other so that the magnetic circuit produced by the one in which the current flows is enclosed by the other, as shown in Fig. 34, where the current circulates around the coil, P, when the circuit is closed at key b. The coil P is called the Primary or Exciting Coil; the other coil is the Secondary Coil.

Any quick change in the strength of the current circulating around the primary coil, as, for instance, breaking the circuit at b, produces a corresponding

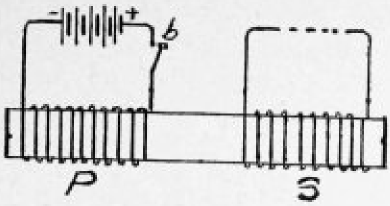


FIGURE 34

change in the number of lines of force in the magnetic circuit, which passes through both coils; and, hence, an electromotive force is induced in the secondary coil. If the primary circuit is completed at b, and the current tends to rise in that coil, the electromotive force induced in the secondary coil causes a current to circulate around in it in the opposite direction to the current in the primary coil. If, on the other hand, the circuit at b is opened suddenly and the current in the primary decreases, the induced electromotive force in the secondary causes a current to circulate around in it in the same direction as the current in the primary coil.

The direction of an induced current in a coil depends upon the direction of the lines of force in the coil, and whether their number is increasing or diminishing. If these two facts are known, the direction in which the current circulates around the coil is determined by the following rules:

Rule:—If the effect of the action is to diminish the number of lines of force that pass through the coil, the current will circulate around the coil in the direction of the movement of the hands of a watch as viewed by a person looking along the magnetic field in the direction of the lines of force; but if the effect is to increase the number of lines of force that pass through the coil, the current will circulate around in the opposite direction.

If in the diagram, Fig. 32, when the coil is inserted into the magnetic field, thereby increasing the number of lines of force that pass through the coil, the current circulates from b around the coil to a, and thence through the galvanometer to b again; when the coil is withdrawn and the number of lines diminishes, the current circulates in the opposite direction; that is, from a, around the coil, to b, and thence, through the galvanometer, to a again. That end of the coiled conductor from which the current flows to the external circuit, as from a through the galvanometer, in the first case, is the positive pole or terminal of the coil; in the second case, b is the positive pole or terminal.

Referring to the straight conductor in which a current is generated by moving it across a magnetic field at right angles to the lines of force, the direction of the current in the conductor depends upon the relation of the direction of the lines of force to that of the moving conductor. The conductor must necessarily be moved across the magnetic field at some angle to the lines of force, and the current generated in the conductor will tend to flow at right angles to the lines of force and at right angles to the direction in which the conductor is moving. In Fig. 33, if the conductor is moved from left to right across the lines of force, the current generated in it will tend to flow upwards through the conductor; that is, from b to a through the conductor, then from a to b through the galvanometer. If the conductor is moved in the opposite direction, that is, from right to left, the current in the conductor will tend to flow in a reversed direction, that is, from a to b through the conductor and from b to a through the galvanometer. A convenient method for remembering the direction of a current generated in a straight conductor, when that conductor is moved in a magnetic field at right angles to the lines of force, is as follows:

Rule:—Place thumb, forefinger, and middle finger of the right hand so that each will be perpendicular to the other two; if the forefinger points in the direction of the lines of force, and the thumb points in the direction towards which the conductor is moving, then the middle finger will point in the direction towards which the current generated in the conductor tends to flow.

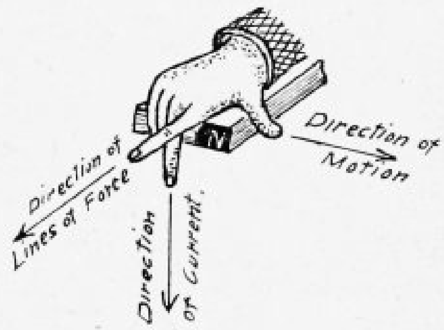


FIGURE 35

For instance, in Fig. 35, if a vertical conductor be moved across the front of the north pole N of the magnet, in the direction towards which the thumb points, the current generated in the conductor will flow downwards; or in the direction towards which the middle finger is pointing.

The summary of these electromagnetic induction experiments can be stated as follows: Electromotive forces are generated in a conductor moving in a magnetic field at right angles to the direction of the lines of force, or are induced in a coiled conductor when a change occurs in the number of lines of force which pass through the coil.

169. Principles of mechanical magnetic induction. Mechanical magnetic induction is often used where a small amount of electric currant is required. Where a constant output is required the magnetic field is furnished by permanent magnets, called field magnets. These magnets are placed over a set of pole pieces between which an armature rotates. The armature consists of an iron core which furnishes an easy path over which the magnetic lines pass. If this armature is constructed of cast iron and the proper permanent magnets are supplied, the magnetic field will consist of about 60,000 lines of force per square inch. If the armature is constructed of cast steel the line of force will equal about 70,000 per square inch. And if the armature is constructed of fine laminations of the softest Norway sheet iron, rivited together, the lines of force passing between the pole pieces would be approximately 120,000 lines per square inch. The armature is supported by a shaft called the armature shaft, which revolves on suitable bearings.

When the armature stands parallel to the lines of force, the lines travel across the armature at their own leisure, as shown in Fig. 36. When the armature is revolved and the path is being reduced, as shown in Fig. 37, the lines increase their speed, until the armature assumes a position at direct right angles to the lines of force. Then the lines reverse and enter the opposite end of the armature, see Fig. 38, always traveling from the north to the south pole or from positive to negative. The faster the armature is rotated the faster the lines of force travel.

170. Armature winding. By winding an insulated copper wire around this armature, (as shown in Fig. 39—40 and 41), and connecting the two terminals, and at the same time rotating the armature from a position parellel to the lines of force to one at right angles to them, we generate an electric current in the coil. The highest voltage is generated when the lines are traveling fastest, that is, when the armature stands at a position of about 45 to the lines of force as shown in Fig. 40 and 41, in Fig 40 the lines of force are traveling through the coil in one direction, and in Fig. 41 in an opposite direction, thus producing an alternating current.

The current travels first in one direction and then in the other like the balance wheel of a watch, see Fig. 42. (This is known as the shuttle type armature.)

171. The stationary coil principle. When the winding is stationary and a strong magnetic field is made to alternate, first in one direction and then in the other, through a soft iron core passing through the center of the winding, an electric current is generated in the coil. The core is extended on both sides of the winding to form rotors which revolve between the magnetic poles, so as to change the speed and the direction of the lines of force. The sudden change of the magnetic field through the winding induces a current in the stationary coil, see Fig. 43. By revolving the rotor with this wing construction we cause the magnetic lines to travel through the stationary coil, first in one direction and then the other, inducing an alternating current in the coil.

CHAPTER V

IGNITION

172. Ignition. Ignition System. While it is necessary to obtain a correct mixture of gas and air in order that the motor shall run correctly and economically, it is also necessary to have this mixture ignited at the proper time.

It is necessary to heat the compressed charge in the cylinder in order to ignite it. An electric spark is used for igniting the charge on practically all types of gas motors at the present time. Although in the past other forms of ignition apparatus to have been in vogue, they have been superseded by electrical apparatus, and there are very few other types of ignition equipment in use at present.

The electric systems of ignition are divided into two classes called Jump Spark, and Make and Break or Butt Spark. Jump Spark is also sometimes called High Tension Ignition; the Make and Break or Butt Spark, Low Tension Ignition.

The Jump Spark is used on the majority of motors, because the Jump Spark system is much more easily applied on a motor and is more efficient. Both Make and Break and Jump Spark systems are furnished for operation by Battery or Magneto or a combination of Magneto and Battery.

In the Make and Break system two contact points meet in the cylinder and are separated by a mechanical device arranged to separate the points at the proper time to ignite the charge. In the Jump Spark the two points are stationary and are separated by an air gap generally set at 1-32 of an inch.

The electric spark jumps across this gap at the proper time to ignite the charge.

Before going into the details of the operation of the two systems, it will be necessary to cover the electrical principles upon which they operate.

173. The Electric Current. An electric current can easily be compared to a stream of water. The pound pressure which is the force behind a stream of water may be compared to the voltage or force of the electric current. The quantity of water in the stream, measured in gallons or barrels, is to be compared with the Amperes, or the quantity of electricity flowing in a circuit.

In order to cause the electric spark between the points of the Make and Break system, it does not require the pressure of voltage required to force the electricity to jump across the gaps between the two points as in the Jump Spark system.

Air has great resistance to electricity. Laboratory tests show that it requires a voltage of 60,000 volts to cause an electric spark to jump a gap of one inch in the air, also that it requires four times the volume to jump the same gap in a motor cylinder with the mixture compressed for firing.

With the Make and Break system, however, as the air gap between the two points is opened mechanically, the electricity flows across from one point to the other rather than jumping across an opening which is already set, making a high voltage unneccessary.

Special apparatus is necessary to produce the high voltage required for the Jump Spark system, and to direct it to the proper spark plug on a multiple cylinder motor at the proper time.

The current obtained from the usual number of dry cells and generated by the usual magneto for the service is of a voltage of from 8 to 15 volts: an electrical principle called induction is used to raise this voltage to the 15,000 volts necessary for jump spark system.

174. The Induction Coil. The induction coil is a coil for stepping from a low to a high voltage consisting of three elements, a soft iron core, a primary winding, and a secondary winding. When an electric current is flowing in a conductor (wire) a magnetic field is set up around the wire.

A piece of iron brought into this field will become magnetized: the strength of the magnetism in the iron being in proportion to the amount of current in the wire. In the same way a current of electricity will be set up in a wire that is placed in a magnetic field, if by any reason whatsoever a sudden change takes place in this field.

For the jump spark system, a coil called an induction coil is made up which uses this principle. A core which is composed of a bundle of soft iron wire (No. 19), forming a bundle of approximately ⅝ inch in diameter and 6 inches long, is wound over with two or three layers of rather heavy cotton insulated copper wire of about the size of bell wire. This winding is called the primary winding.

175. The Core. The core is made of exceedingly soft iron wire, so that it is possible to establish and de-establish a magnetic field instantly.

The Primary Winding. The primary winding is of a rather coarse wire, wound around the soft iron core, well insulated from it electrically but not magnetically. When a current of electricity flows through this coil, it magnetizes the soft iron core and sets up a magnetic field around the secondary winding.

176. Secondary Winding. Over the primary winding, but well insulated from it is wound a second winding of fine wire. The secondary winding must contain several thousand more turns than the primary. It is therefore necessary to use as fine a wire as is substantial for this purpose. If the core is magnetized and demagnetized rapidly, it degenerates or induces an electric current in the second or secondary winding.

The voltage of the current induced in the secondary will be in direct proportion to the voltage in the primary circuit as the number of turns of wire in the primary is compared to the number of turns in the secondary winding. That is, if the primary current was six volts and there were double the number of turns in the secondary than in the primary, the voltage of the secondary would be 12 volts. Enough more turns are put in the secondary to induce a sufficiently high voltage to jump the space between the plug points in the motor cylinder under compression, usually 15,000 volts.

To magnetize and demagnetize the core rapidly, a vibrator is installed on the usual form of jump spark coil which is operated automatically by the electric current and which breaks the primary circuit rapidly, causing the current to flow and stop, flowing through the primary winding. See Fig. 36.

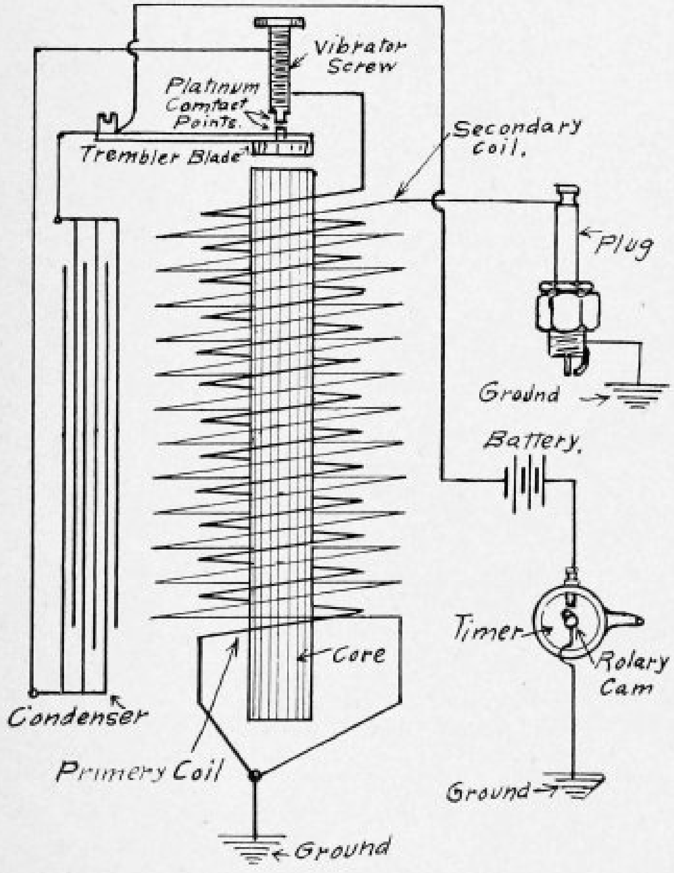


FIGURE 36

When operated in connection with a magneto, the vibrator is replaced by the contact points in the breaker, accomplishing the same results. See Fig. 37. Some jump spark magnetos are made up with the

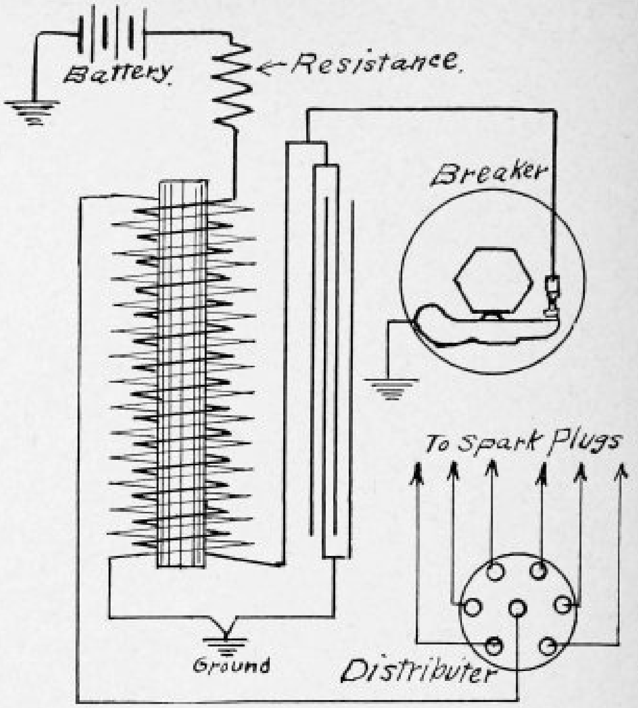


FIGURE 37

induction coil built into the magneto, others have the induction coil separate from the magnetos. The former type are generally called High Tension magnetos, the latter, Low Tension.

177. The Condenser. A condenser is a device used to absorb electric current as a sponge absorbs water. It is made of thin sheets of tinfoil insulated one from the other by paraffin paper. It is divided into two halves, one-half being connected to the wire running to timer points and the other half connected to the ground wire.

Its function is to absorb electric current and prevent the current from jumping across the gap formed by the timer points when open, causing an arc. This is necessary because if the current jumped the gap it would flow across the timer to the ground screw and become destructive to the timer points. The condenser is also a drain on the electric system when the points are together.

178. Battery Ignition—Vibrating Induction Coil. Fig. 36 shows a simple battery ignition system for a one-cylinder motor. The induction coil consists of a soft iron core around which both a coarse and a fine winding is wound. At one end is a vibrator for making and breaking the primary circuit. The vibrator is used for the purpose of completing the electrical circuit at the point when the spark is needed. The other parts are clearly shown in the figure.

179. Explanation of the Vibrator Coil. When the vibrator contacts are closed a current flows from the battery through the coarse winding of the coil, the primary winding, then through the ground and timer back to the battery again. This cur-

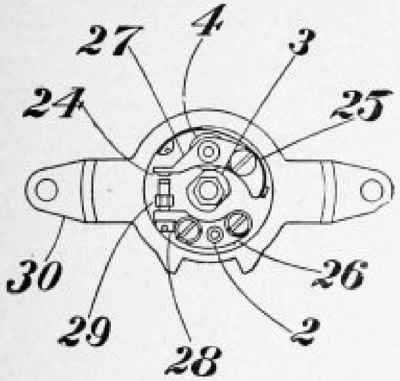
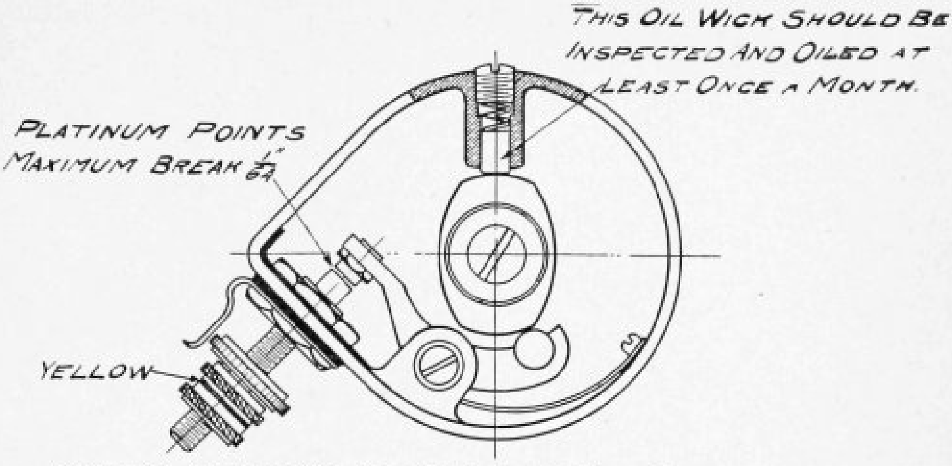
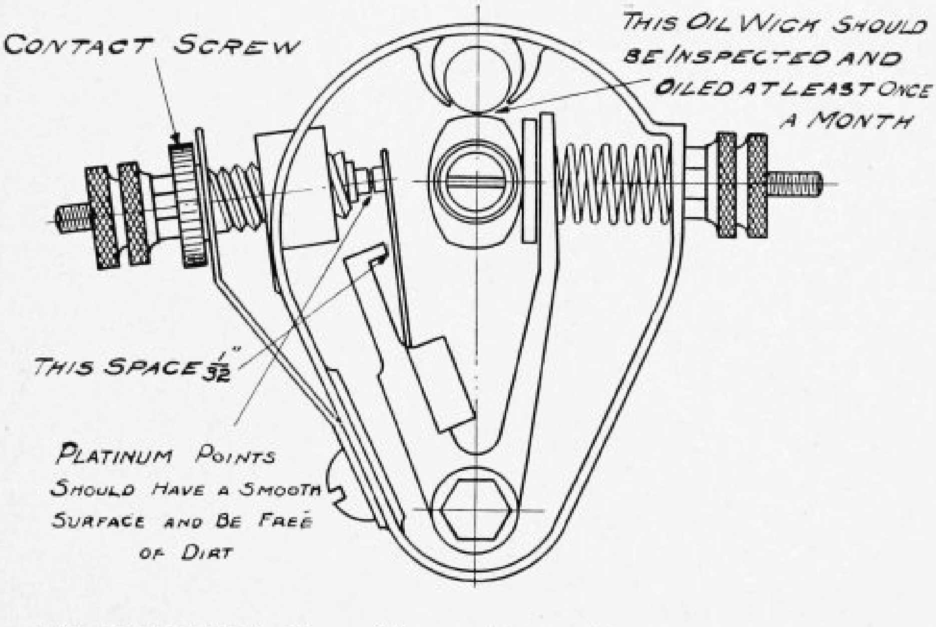


FIGURE 38



TYPE R D CAM HOUSE SHOWING THE ONLY ADJUSTMENT ON THE REMY MAGNETO

FIGURE 39



TYPE S T OR L CAM HAUSE REMY MAGNETO

FIGURE 40

rent magnetizes the soft iron core, which attracts the vibrator and breaks the circuit. As the circuit is broken the current rushes into the condenser and is absorbed, presenting an arc at the contact points. The magnetic field suddenly dies down, and the rapid retreat of the magnetic lines induces a current of high voltage in the secondary winding, causing a spark to jump at the plug. The attraction of the core on the vibrator also ceases, and it is brought back by spring action into the original position closing the contact points again, and the action is repeated. The vibration continues and sends a shower of sparks across the points of the spark plug until the brush of the timer leaves the segments, thus breaking the circuit.

In modern battery systems the vibrating methods with a timer are seldom used, but are replaced by a set of contact points mechanically operated by a cam so as to suddenly break the circuit at the time the spark is needed at the spark plug, thus producing a unit spark the same as a magneto. The mechanical construction of the breaker differs with the various systems, but the working principle is the same in each case. Fig. 37 shows the arrangement of the wiring.

180. Breaker Box. The breaker box is a mechanical switch or interruptor consisting of the breaker box proper, control lever for advance and retard, breaker bar arm and spring, platinum tipped screws or contact points, cam and cam roller, and insulated binding post.

The function of the breaker box is to open and close the primary circuit by making or breaking contact at the platinum points so that the current may be

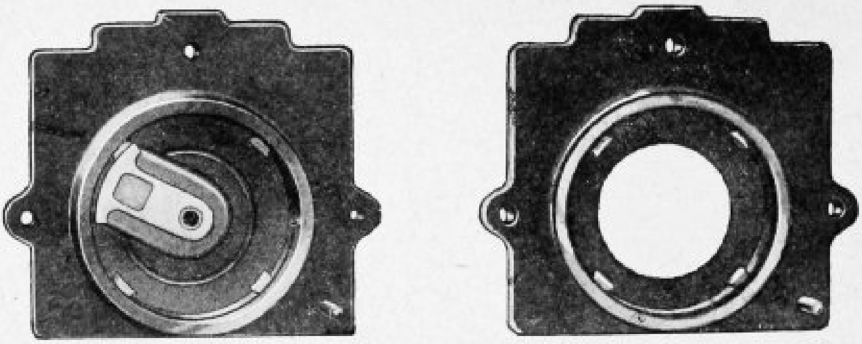


FIGURE 41

delivered a the spark plug a the time the ignition should take place.

The contact points are operated by a cam on the end of the armature shaft. These points should be separated 1-64 inch. Breaker boxes are manufactured in a wide range of mechanical construction, as shown in Fig. 38, 39 and 40.

Referring to Fig. 38, No. 2 is the insulated binding post. No. 3 is the cam on the end of the armature shaft. No. 4 is the cam roller, No. 24 is the breaker arm bar equipped with one of the platinum points. No. 25 is a flat spring to hold the cam roller on the cam and bring the points together when the cam will permit. No. 26 is the insulated breaker arm which is held stationary to the breaker box proper. No. 24 is the platinum tip brazed to the breaker arm 27, No. 29 is a platinum tipped screw, on the insulated breaker, arm 26, and is adjustable. The standard space between these points when open is 1-64 inch. No. 30 is the control lever for advancing and retarding the time the platinum points separate.

181. The Distributor. The distributor is a mechanical device for distributing the high tension current from one cylinder to the other in the order of ignition The distributor consists of a distributor brush or disc, center high-tension binding post, a distributor housing with segments depending on the number of cylinders and are equally spaced. There is a binding post for each segment, there is also a distributor gear and shaft.

It is the function of the distributor brush to make contact with the different segments so that the high tension current will be distributed to the proper spark plug in the order of ignition on a multiple cylinder motor. See Fig. 41.

182. Principles of Operation of the Ordinary Magneto. Practically all magnetos use permanent steel magnets to produce a magnetic field, and these magnets are called field magnets.

The field magnets are placed over a set of pole pieces between which the armature rotates.

The armature consists of an iron core which affords an easy path over which the magnetic lines travel. As the armature rotates the path is cut off, causing the lines to increase their speed. See Fig. 42.

There are two methods employed in the construction of magnetos, for utilizing these magnetic lines to generate electromotive force (E. M. F.). In some magnetos the armature is wound with insulated copper wire. When the armature is rotated the wire loops cut through the magnetic lines of force, and

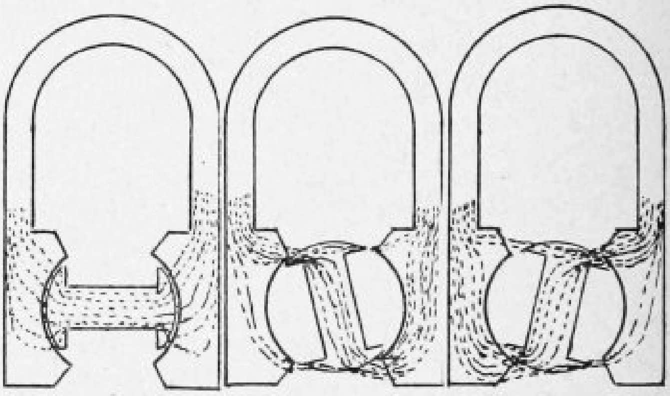


FIGURE 42

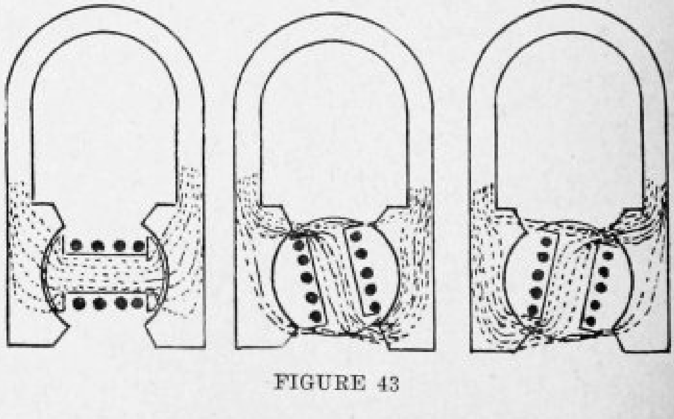


FIGURE 43

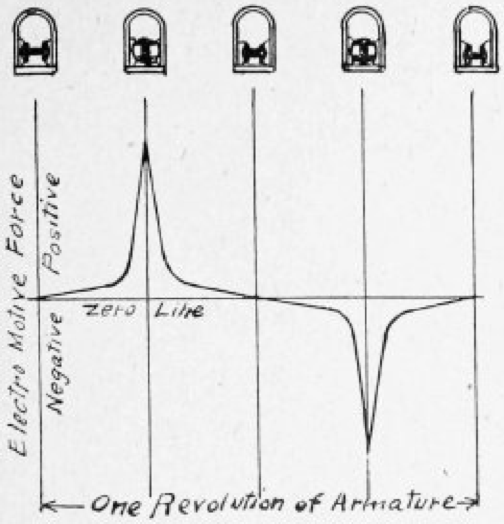


FIGURE 44

a current is generated in them. The iron core is used for the purpose of increasing the lines of force passing between the pole pieces. The iron core with the coils of wire on it is called the armature winding. Fig. 43 shows the direction in which the lines of force pass through the core of the winding at any position.

The first half the revolution the lines of force is passing through the coil in one direction; and the second half in the opposite direction; this reversal causes a current to be generated in the armature winding; first traveling in one direction and then in the other, producing an alternating current. See Fig. 44 showing the direction of current flow through the coil at any position of the armature.

183. The Induction Principle. Some magnetos work on what is known as the inductor principle. In this type of magneto the winding is stationary and a strong magnetic field is made to alternate. first in one direction and then in the other, through a soft iron core passing through the center of the winding. The core is extended on both sides of the winding to

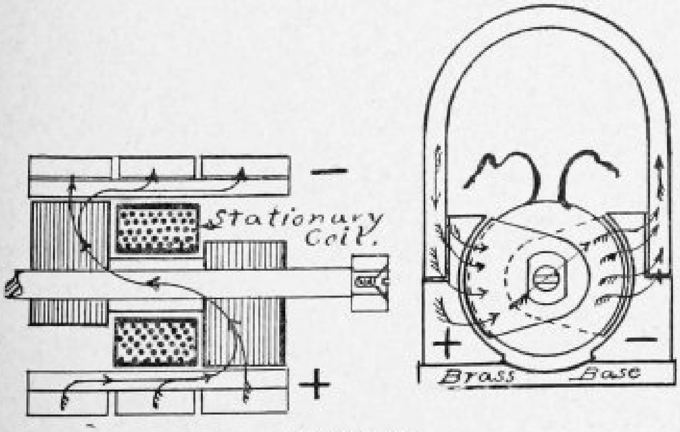


FIGURE 45

form rotors which revolve between the poles, so as to change the direction of the lines of force. The sudden change of the magnetic field around the winding induces a current in its primary coil. See Fig. 45, also producing an alternating current in the coil.

184. The Magneto. A magneto is a mechanical device for generating electric current by mechanical magnetic induction, and is equipped with permanent magnets, thereby it derives its name magneto. These magnetos are divided in two classes:

First the shuttle type, where the winding is placed over the armature. By rotating the armature the line of force travels at a high rate of speed, exciting and generating a current in the coil.

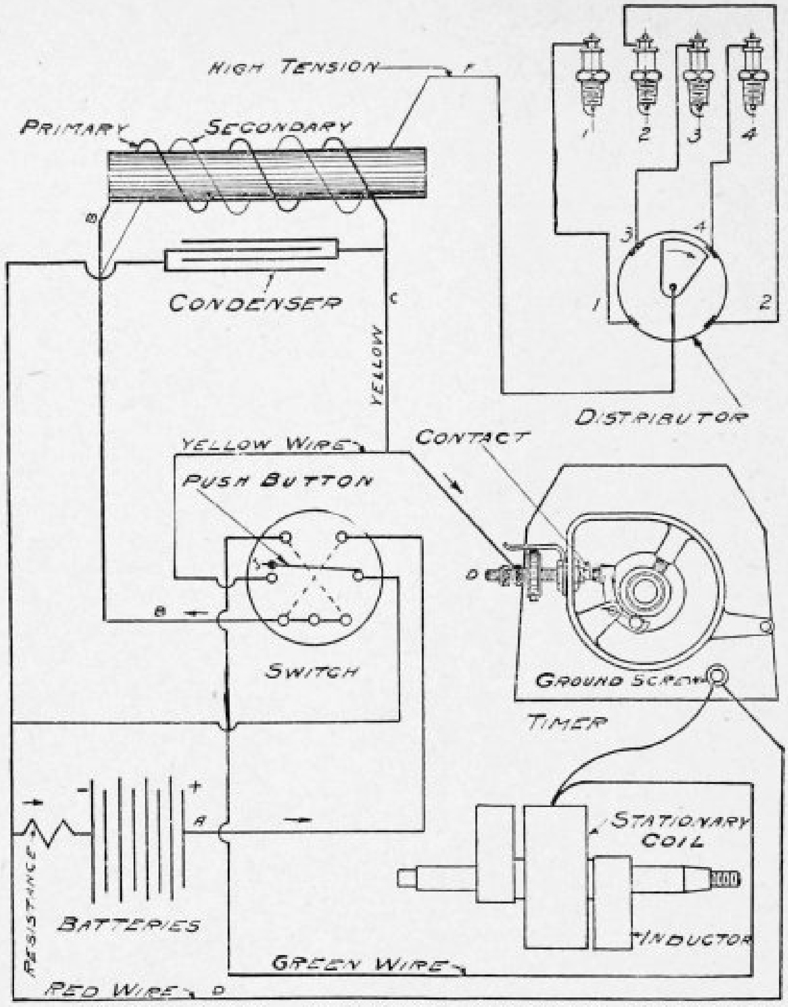
Second the induction type, where the coil remains stationary, and a rotor is used which, when revolved, causes the magnetic lines to travel at a high speed through the stationary coil, generating a current in the coil. These magnetos generate an alternating current equal to 10 volts and 20 amperes, or about the capacity of eight ordinary dry cells.

In these magnetos one end of the coil is grounded, while the other end is well insulated. It leads to the ignition switch, from the ignition switch through the induction coil back to the insulated post on the breaker box. When the contact is closed, the current flows through to ground, and back to the coil, completing the circuit.

185. The Low Tension Magneto. The low tension magneto is built on either of the two above named principles, and are wound to generate a current equal to 10 volts and 20 amperes. In the magneto where the coil is wound on the armature, one end of the coil is grounded, and the other end is well insulated leading to a collector ring and is taken off of the collector ring by a brush and passes through a conductor to the induction coil through the primary winding and back to the insulated post on the breaker box. When the contact points come together the current passes through to the ground which completes the circuit. This is a strictly low tension magneto, and requires an induction coil to step up the current to proper voltage. To jump the gap at the spark plug, it is also necessary to use a battery for starting. A wiring diagram for low tension magneto and battery is shown in Fig. 46.

186. Explanation of Low Tension Diagram. See Fig. 46. When starting on a low tension magneto, first throw switch onto the batteries. The current leaves the positive side of the batteries, travels up to the switch, across the switch and up to the primary coil. This magnetizes the soft iron core, which sets up a magnetic field around the secondary winding. The current travels through the yellow wire down to the insulated post on the breaker box, when contact points are closed it flows through to ground, back through ground wire to the battery, thus completing the circuit.

Now, when the cam in the breaker box turns so that the contact points separate, this circuit is broken, and the current rushes back through the yel-



WIRING PLAN FOR REMY MAGNETO - TYPE RF CIRCUIT
DUAL SYSTEM FOUR CYLINDERS

FIGURE 46

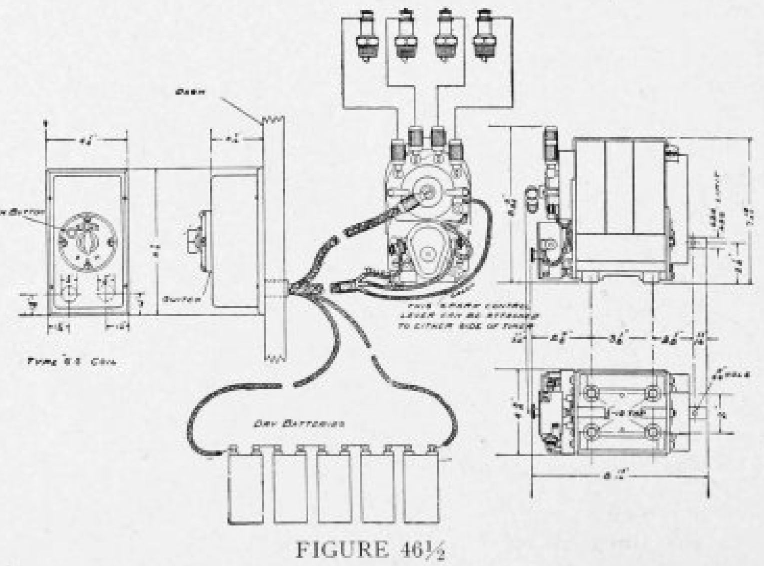


FIGURE 46½

low and ground wires to the condenser, which absorbs the current and prevents it from arcing across contact points. The soft iron core immediately loses its magnetism, and the rapid retreat of the magnetic lines excites the secondary winding, and generates a high tension current of 15,000 volts. This current flows through the high tension cable to the center of the distributor, through the distribution brush to the segment corresponding to the cylinder under compression, from there to the spark plug, jumps the gap so as to cause ignition of charge, and travels through the cylinder walls to ground screw. From there it travels back through the battery up to the switch and back to secondary coil, thus completing the circuit.

As soon as sufficient motion has been imparted to the magneto to generate a current, throw the switch from the battery to the magneto. The current then leaves the stationary coil, follows the green wire to the switch, across the switch to the primary winding. This magnetizes the soft iron core, which sets up a magnetic field around the secondary winding. The current travels through the yellow wire to the insulated post on the breaker box, when the contact points are closed the current travels through the ground and back to the stationary coil in the magneto, completing the circuit.

When cam in breaker box separates the contact points, the current rushes back through the yellow and ground wire to the condenser. The condenser absorbs the current, and the soft iron core instantly loses its magnetism. The rapid retreat of the magnetic lines excites the secondary winding and sets up a high tension current of 15,000 volts, which travels through the high tension cable to center of the distributor, through distributor brush to segment corresponding to cylinder under compression, up to spark plug in the cylinder, jumps the gap in the plug, so as to ignite the charge, travels through the cylinder walls to ground screw and back to secondary winding in the induction coil, thus completing the circuit.

187. Atwater Kent System of Battery Ignition. The Atwater Kent system consists of three parts:

1. The Unisparker, which combines the special form of contact maker which is the basic principle of this system and a high-tension distributor.

2. The Coil, which consists of a simple primary and secondary winding, with condenser—all imbedded in a special insulating compound. The coil has no vibrators or other moving parts.

3. The Ignition Switch.

The Atwater Kent system is manufactured in two forms, Type "K-2," with Automatic Spark Control, and Type "H," for use in connection with the regular spark lever. The electrical and mechanical features of the two systems are identical, except that in the Type "H" system the automatic spark control governor is omitted.

188. The Principle of the Atwater Kent System. The operation of the Unisparker is shown below. This consists of a notched shaft, one notch for each cylinder, which rotates at one-half the motor speed; a lifter or trigger which is pulled forward by the rotation of the shaft, and a spring which pulls the lifter back to its original position. A hardened steel latch and a pair of contact points complete the device.

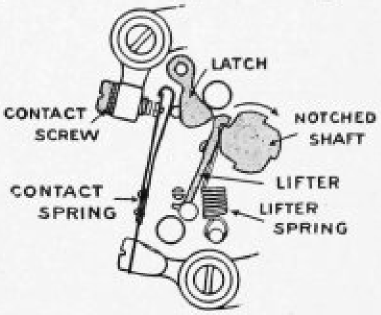


FIGURE 47

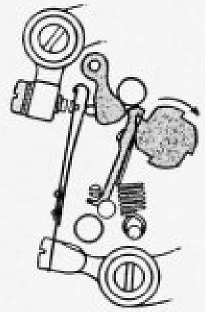


FIGURE 48

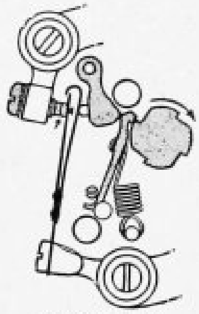


FIGURE 49

FIGURE 50

Figures 47, 48, 49 and 50 shows the operation of the contact-maker very clearly. It will be noted that in Figure 47 the lifter is being pulled forward by the notched shaft. When pulled forward as far as the shaft will carry it (Fig. 48), the lifter is suddenly pulled back by the recoil of the lifter spring. In returning, it strikes against the latch, throwing this against the contact spring and closing the contact for a very brief instant—far too quickly for the eye to follow the movement (Fig. 49).

Fig. 50 shows the lifter ready to be pulled forward by the next notch.

Note that the circuit is closed only during the instant of the spark. No current can flow at any other time, not even if the switch is left "On" when the motor is not running.

Note that no matter how slow or how fast the shaft is turning, the lifter spring will always pull the lifter back at exactly the same speed, so that the operation of the contact, and therefore the spark, will always be the same, no matter how fast or how slow the motor is running.

The contact points are adjustable only for normal wear. All other parts of the contact maker are of glass-hard steel and are not subject to wear They will outlast the motor because they move but a very short distance, do very little work, and the wear is reduced to a minimum.

per part of the Unisparker, the high-tension current from the coil is conveyed by the rotating distributor block, which seats on the end of the Unisparker, to each of the four spark plug terminals in the order of firing.

An important advantage which the Atwater Kent distributor possesses is the fact that there are no sliding contacts or carbon brushes, the distributor blade being so arranged that it passes close to the spark plug terminal without quite touching, thus permitting the spark to jump the slight gap, and eliminating all wear and trouble due to sliding contacts.

189. Direction of Rotation. The Type "K-2" Unisparker is manufactured only for clock-wise rotation when looking down on the top of the distributor. In other words, the distributor block on the top of the shaft should rotate the same as the hands of a clock.

The Type "H" system, without the automatic spark control, is made for either rotation. It should be understood, however, that a given Type "H" Unisparker will not operate in both directions, but only in the direction for which it is specified.

190. Wiring. The wiring of the Atwater Kent system is very simple, and is shown in the two diagrams, Figures 51 and 52. Figure 51 shows the connections when the reversing switch and Underhood coil are used. Figure 52 shows the connections when using plate or kick switch coil. The wiring of both the Type "K-2" and "H" systems is the same.

For the primary or battery circuits, use well insulated and braided primary wire, and see that it is protected against rubbing or abrasion wherever it comes in contact with metal. Where the lighting and starting battery is used for ignition, two wires from the ignition system should run directly to the battery terminals. They should not be connected in on any other branch circuit.

The contact-maker of the Unisparker is connected to the coil by means of a length of twisted double conductor cord, furnished with the outfit. Do not, under any conditions, use separate wires for this connection.

The high-tension wiring from the distributor to the coil and plugs should be the best possible grade of secondary wire 5-16 inch in diameter outside of insulation. It is recommended that the connections between the spark plugs and the distributor be left until the Unisparker is "timed" so that the proper distributor points can be connected up in the correct order of firing.

In making these connections, the high-tension wire is bared for a space of about 1⅛ inches, and passed through the hole in the secondary terminal. The end of the wire is then twisted back on itself for one turn, so that the end will not project beyond the diameter of the insulation. It will be found that when the terminal cover is screwed down the secondary wire will be tightly held. These terminals should be

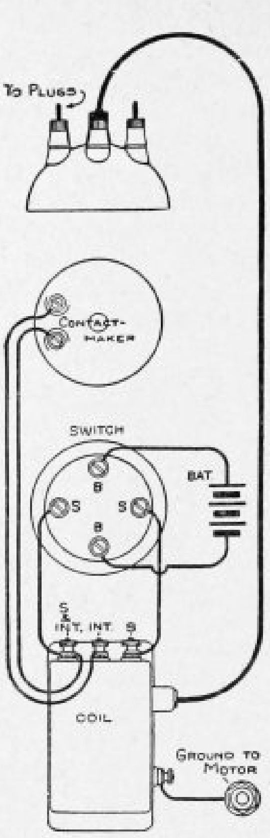


FIGURE 51

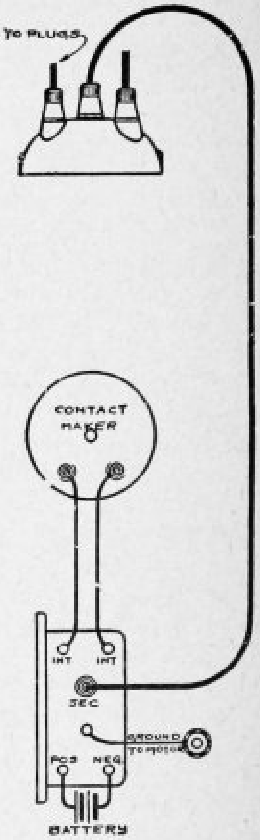


FIGURE 52

screwed down with the fingers—do not use pliers. The wires should never be soldered to the brass posts.

191. Battery. Current for the Atwater Kent system is usually supplied by the battery. Be sure that the standard voltage of the electrical system is the same as that marked on the coil.

If a special battery is used for ignition only we recommend a set of ordinary dry cells, connected six in series.

Note: Two sets of six cells each connected in series multiple will give three times the life of a single series.

If storage battery is used, the current consumption will be found to be negligible—less than one-tenth that consumed by other battery ignition systems. If dry cells are used, see that they are insulated from each other and from the sides and bottom of the battery box by wood or fibre battens or partitions. The strawboard covers on dry cells have little, if any, insulating value when damp. See that cells are packed so that the connections cannot jar loose.

192. Setting and Timing the Type "K-2" Unisparker (No Spark Control Lever Being Used). The Type "K-2" Unisparker should be installed so as to allow a small amount of angular movement for the initial timing adjustment. In other words, the socket into which the Unisparker fits should be provided with a clamp which will permit the Unisparker to be turned and locked rigidly in any given position.

In timing, the piston in No. 1 cylinder should be raised to dead center, then, with the clamp which holds the Unisparker loose, the Unisparker should be slowly and carefully turned backwards or counterclockwise (contrary to the direction of rotation of the timer shaft) until a click is heard. This click happens at the exact instant of the spark. At this point, clamp the Unisparker tight, being careful not to change its position.

Now remove the distributor cap, which fits only in one position, and note the position of the distributor block on the end of the shaft. The terminal to which it points is connected to No. 1 cylinder. The other cylinders in their proper order of firing are connected to the other terminals in turn, keeping in mind the direction of rotation of the timer shaft.

When timed in this manner the spark occurs exactly on "center" when the motor is turned over slowly. At cranking speeds the governor automatically retards the spark for safe starting, and as the speed increases, the spark is automatically advanced, thus requiring no attention on the part of the driver.

Note: If spark lever is used in conjunction with the Type "K-2" Unisparker, proceed the same as for Type "H" except that the spark control levers should be arranged so that the Unisparker moves not more than ½ inch from the full retard position to the full advance.

193. Setting and Timing the Type "H" Unisparker. The first operation in timing the Type "H" Unisparker is to crank the motor until the piston of No. 1 cylinder is on high dead center between the compression and power strokes.

The Unisparker is then placed on the shaft, the advance rod from the steering post being connected to the lug on the side of the Unisparker, which is provided for that purpose.

The position of the spark advance lever on the steering wheel sector should be within ½ inch of full retard, and the connecting levers should be such as to give the Unisparker a movement of at least 45° to 60° for the full range of spark advance.

After the spark lever is connected up and the Unisparker is in position, it should be left loose at the driving gear, and, with the motor on dead center as above directed, the shaft of the Unisparker should then be turned forward or in the same direction as that in which the timer shaft normally rotates, until a click is heard, at which point it should be set by tightening the driving connection.

The Unisparker being properly set, the next thing to do is to get the secondary wires leading to the right plugs. To do this, remove the distributor cap and note the terminal to which the distributor block points. This will be the proper terminal for No. 1 cylinder. The other terminals will then be wired up according to their firing order.

194. Adjustment. The only parts of the Atwater Kent system which are adjustable are the contact points. These are adjustable only for natural wear (The initial adjustment made at the factory should be good for several weeks of service.)

195. Contact Points. The normal gap between the contact points is from .010 inch to .012 inch—never closer.

The contact points are made of purest tungsten, which is many times harder than platinum-iridium.

When contact points are working properly, small particles of tungsten will be carried from one point to the other, sometimes forming a roughness and a dark gray color on their surfaces. This roughness does not in any way affect the proper working of the points, owing to the fact that the rough surfaces fit into each other perfectly. However, when it becomes necessary to take up the distance between these points due to natural wear, it is advisable to remove both contact screw and spring contact arm, and with a new fine file dress down the high spots. This makes it possible to obtain a more accurate adjustment and eliminates any danger of high points on either contact touching each other when system is at rest.

Please bear in mind that these contacts are very hard to file and that it is necessary to remove only a very small amount of metal. Please also remember that although the contact surfaces may be very rough they are probably in perfect working condition, the dark gray appearance being the natural color of the tungsten.

196. Oiling—Important! The other parts of the contact maker—the latch, lifter, lifter-spring and notched shaft—are not adjustable, and are not subject to wear if they are cleaned and oiled at intervals of a few weeks. Take care to avoid getting oil on the contact points.

Caution: Do not think that these parts do not work properly because you cannot see their movement, which is far too quick for the eye to follow. The contact maker of the Unisparker may be likened to a watch, which, because of the small size and extreme accuracy and hardness of its moving parts, is subject to little or no wear even after many years of service. Both the latch and lifter are of glass-hard steel and move only a short distance for each operation. Under no circumstances should they be altered in shape, nor should the tension or setting of the springs be changed. These are set right at the factory, and are the result of years of painstaking standardization.

197. Testing. If motor misses without regard to speed, test each cylinder separately by short-circuiting the plug with a screw driver, allowing a spark to jump. If all cylinders produce a good, regular spark, the trouble is not with the ignition system.

If any one cylinder sparks regularly, this will indicate that the system is in working order so far as the Unisparker and coil are concerned, and the trouble is probably in the high-tension wiring between the distributor and plugs or in the plugs themselves. Examine carefully the plugs and wiring. Leaky secondary wiring is frequently the cause of missing and back-firing.

Frequently when high-tension wires are run from the disributor to the spark plugs through metal or fibre tubing, trouble is experienced with missing and back-firing, which is due to induction between the various wires in the tube. This trouble is especially likely to happen if the main secondary wire from the coil to the center of the distributor runs through this tube with the spark plug wires.

Wherever possible, the distributor wires should be separated by at least ½ inch of space and should be supported by brackets or insulators rather than run through a tube. In no case should the main distributor wire be run through a conduit with the other wires.

If regular sparking is noted at all plugs, examine first the battery and connections therefrom. If the trouble commences suddenly, it is probably due to a loose connection in the wiring. If gradually, the batteries may be weakening or the contact points may require attention. See that contacts are clean and bright, and also that the moving parts are not gummed with oil nor rusted.

Note: Do not attempt under any condition to alter any of the parts of this system. Every part is exactly right in shape; every spring has the proper tension. Do not let the fact that the contact is made and broken so quickly that the movement cannot be followed by the eye cause any misapprehension. Do not alter or tamper with any of the parts.

The systems outlined above are typical ignition systems, but in many cases the magneto has been replaced by a direct current generator. This generator furnishes the current for the ignition and lighting system, and also charges the storage battery, which furnishes the current for the starting motor.

The High Tension Magneto. The high tension magneto operates practically on the same principle above described, except that the induction principle used in the induction coil is utilized in the magneto in its self for stepping the low voltage up to a high voltage, necessary to jump the gap at the plug. The magneto proper generates an alternating current of 10 volts and 20 amperes, which forms a circuit through the contact points. When this circuit is complete it magnetizes the armature or rotor, setting up a secondary magnetic field around the secondary winding, which is wound over the armature winding, or the stationary winding. When the contact points separate, the current rushes into the condenser and is absorbed, tearing down the secondary magnetic field, exciting the secondary winding and generating a high tension current. It is led to the center of the distributor, through the brush to the segment corresponding to the cylinder under compression, through the high tension cable to the spark plug, it jumps the gap at the plug to ground, and returns back through ground to the secondary winding completing the circuit. The following pages are a description of the high tension magnetos most extensively used today.

The Impulse Starter. The impulse starter is a mechanical device, placed between a large heavy duty

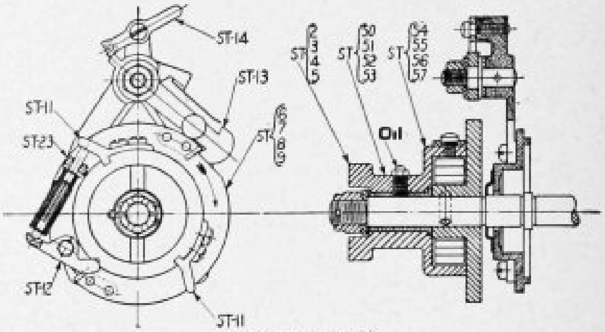


FIGURE 52½

motor, and the magneto, so constructed as to hold the magneto stationary until one cylinder is brought to dead center, then automatically tripped, with a heavy clock spring arrangement, the magneto is revolved at a high rate of speed, causing a hot spark for starting although cranking slowly. All tractor magnetos are equipped with this impulse starter, sometimes called a starting coupling.

198. Instructions for Bosch High Tension Magnetos—DU Types. The Bosch Magnetos, Types DU1, DU2, DU3, DU4, and DU6, are of the high tension series, and are used respectively on one, two, three, four, and six-cylinder motors used in motor car, marine, tractor and stationary service.

The type DU magnetos are usually employed as sole ignition on a motor, or, in some cases, in connection with a battery system operating on a separate set of spark plugs. The Du magnetos, without alteration, are also employed to provide battery and magneto ignition on one set of spark plugs, this being accomplished by means of the Bosch Vibrating Duplex Ignition System.

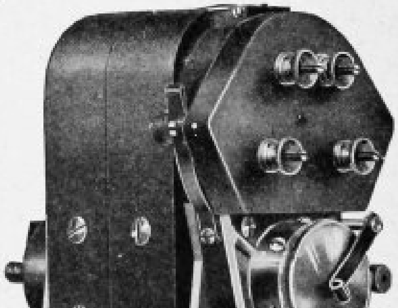


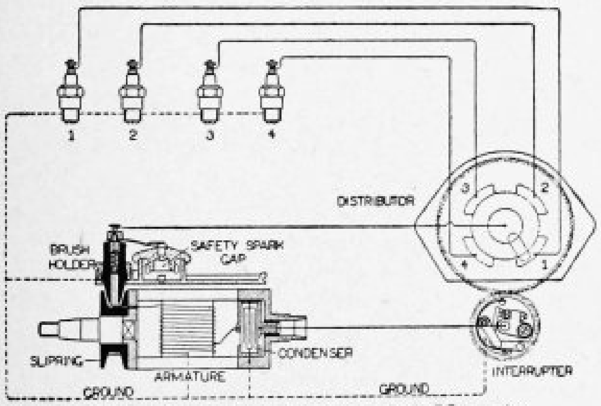
FIGURE 53

Generation of Current. Like other Bosch High Tension Magnetos, the types DU generate their own high tension current directly in the magneto armature (the rotating member of the magneto), without the aid of a separate step-up coil, and have their timer and distributor integral. See Fig. 53.

The armature winding is composed of two sizes of wire, one size comparatively heavy and the other very fine. The heavy wire, constitutes the primary or low tension circuit; and the very fine wire the secondary or high tension circuit.

The rotation of the armature between the poles of strong permanent magnets sets up or induces a current in the armature primary circuit, and this is further augmented at regular intervals in the rotation of the armature shaft by the abrupt interruption of the primary circuit by means of the magneto interrupter. At the opening of the primary circuit, the resulting discharge of current from that circuit induces a current of high voltage in the armature secondary circuit. The high tension current thus created is collected by the slipring on the armature and passed through the slipring brush, then to the various magneto distributor terminals, each of which is connected by cable to the spark plug in its respective cylinder. The operation of the instrument will be more clearly understood from a study of the complete circuits, primary and secondary, which follow:

199. Primary or Low Tension Circuit. The beginning of the armature primary circuit is in metallic contact with the armature core, and the end of the armature primary circuit is connected, by means of



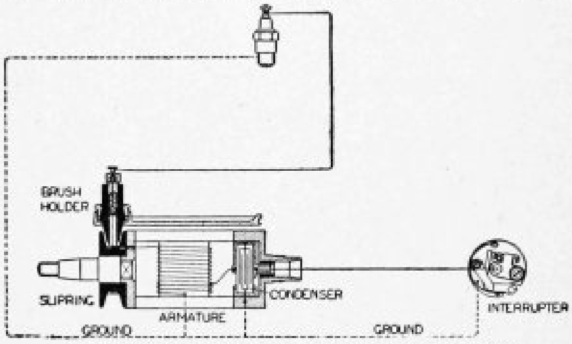
Circuit Diagram Type DU4 Bosch Magneto

FIGURE 54

the interrupter fastening screw, to the insulated contact block supporting the long platinum contact on the magneto interrupter. The interrupter lever, carrying a short platinum contact, is mounted on the interrupter disc which, in turn, is electrically connected to the armature core. The primary circuit is completed whenever the two platinum interrupter contacts are separated. The separation of the platinum contacts is controlled by the action of the interrupter lever as it bears against the steel segments secured to the inner surface of the interrupter housing; the types DU1 and DU4-2, 360°, are each provided with but one interrupter segment, while all other DU types have two such segments. See Fig. 54.

The high tension current is generated in the secondary circuit only when there is an interruption of the primary circuit, the spark being produced at the instant the platinum interrupter contacts separate.

200. Secondary or High Tension Circuit. The armature secondary circuit is a continuation of the armature primary circuit, the beginning of the secondary being connected to the primary, while the end of the secondary is connected to the insulated



Circuit Diagram Type DU1 Bosch Magneto

FIGURE 55

current collector ring, or slipring, mounted on the armature just inside the driving shaft end plate of the magneto. This form applies in all DU types except the DU1 two-spark magneto. See Fig. 55.

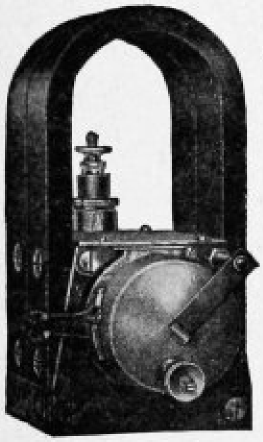
201. In Types DU4-2, DU3, DU4, and DU6, the slipring brush, which is held in contact with the slipring by the brush holder at the shaft end of the magneto, receives the high tension current collected by the slipring, and, by means of the connecting bar under the arch of the magnets, passes the current to the metal contact in the center of the distributor plate. From the latter point the high tension current passes to the distributor brush, which is held in a brush holder mounted on the distributor gear, and consequently rotates with the gear.

Metal segments are imbedded in the distributor plate; and as the distributor brush rotates, it makes contact successively with the segments in the distributor plate.

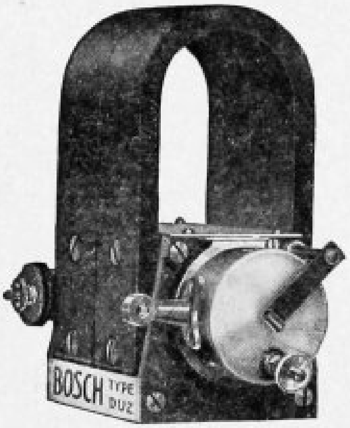
The segments in turn are connected with the terminal studs on the face of the distributor plate, and the latter are connected by cables to the spark plugs in the various cylinders. In the cylinders, the high tension current produces a spark which causes ignition and then returns through the engine to the magneto armature, thus completing the circuit.

In Type DU2, the slipring groove is provided with a sectional metal segment, and the end of the armature secondary circuit is connected to this segment. The metal segment acts not only as a current collector, but also as a high tension distributor; for, at every 180° revolution of the armature, the segment alternately comes into contact with, and delivers high tension current to, one of the two slipring brushes which are horizontally mounted in the brush holders on opposite sides of the shaft end plate. High tension cables from the brush holder terminals connect the slipring brushes with the spark plugs in the cylinders.

In Type DU1, Single-Spark, for one-cylinder motor, no distributor is required; and the high tension current from the armature secondary circuit is passed by the slipring to a single brush, which is supported



Bosch Magneto Type DU1
FIGURE 56



Bosch Magneto Type DU2
FIGURE 57

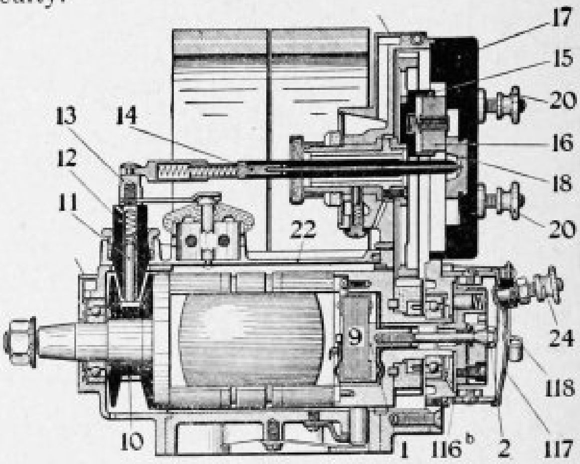
by a brush holder at the shaft end of the magneto. A high tension cable between the brush holder terminal and the spark plug in the cylinder completes the secondary circuit. See Fig. 56.

In Type DU1, Two-Spark, the armature secondary circuit is insulated from the armature primary circuit; and the two ends of the secondary are connected to two sectional metal segments, diametrically opposite on a single slipring. Two slipring brushes are provided which, as in the type DU2, are horizontally mounted in brush holders on opposite sides of the shaft end plate; during that portion of the armature rotation when high tension current is being delivered, each of the two slipring segments will be in contact with one of the brushes. The secondary circuit is completed by a high tension cable from each brush holder terminal to a spark plug, and a spark will pass at both plugs simultaneously. See Fig. 56-57.

202. Safety Spark Gap. In order to protect the armature and other current carrying parts, a safety spark gap is provided.

Unde ordinary conditions, the current will follow its normal path to the spark plug; but if for any reason the electrical resistance in the secondary circuit is increased to a high point, as when a cable becomes disconnected or a spark plug gap too wide, the high tension current will discharge across the safety gap.

The current should never be allowed to pass across the safety spark gap for any length of time, and if the motor is operated on a second or auxiliary ignition system, the magneto must be grounded in order to prevent the production of high tension current. The snapping sound, by which the passage of the current across the safety gap may be noted, should always lead to an intermediate search for the cause of the difficulty.



Longitudinal Section of DU4 Magneto
FIGURE 58

1. Brass plate for connecting the end of armature primary circuit.
2. Fastening screw for magneto interrupter.
9. Condenser.
10. Slipring.
11. Slipring brush.
12. Slipring brush holder.
13. Cap nut for slipring brush holder.
14. Connecting bar.
15. Distributor brush holder.
16. Distributor brush.
17. Distributor plate.
18. Central distributor contact.
20. Terminal nut for distributor plate.
22. Dust cover over armature.
24. Terminal nut for grounding terminal.

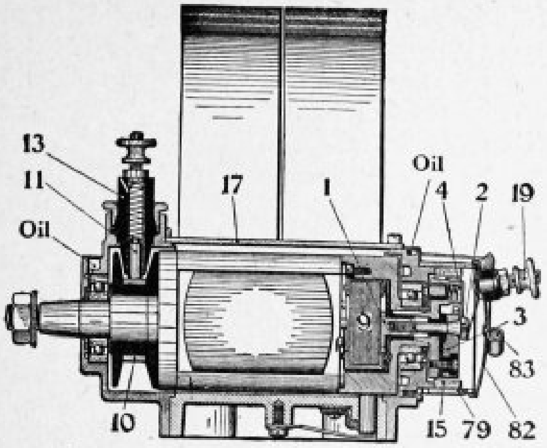
116b. Interrupter housing and timing arm.
117. Cover for interrupter housing.
118. Contact spring for grounding terminal.

The above numbers apply only to the section illustration, Fig. 58.

203. In Types DU4-2, DU3, DU4, and DU6, the safety spark gap is arranged on the dust cover over the armature, and consists of two short pointed electrodes supported a short distance from each other. One electrode is set on the dust cover itself and inclosed by a metal and wire gauze housing; while the other, or insulated electrode, is set in the center of the steatite cover of the safety spark gap housing and connected into the secondary circuit of the magneto.

204. In Types DU1 and DU2, the safety spark gap consists of a short pointed wire projecting from the armature insulating material, the end of this wire extending to within a short distance of the armature cover at the driving shaft end. See Fig. 59.

205. Timing Range. The magneto interrupter housing is arranged so that it may be rotated through an angle of 35° with respect to the armature shaft. The movement of this housing in one direction or the other causes the interrupter lever to strike the steel segments earlier or later in the revolution of the



Longitudinal Section of DU1 Magneto

FIGURE 59

armature, the spark occurring correspondingly earlier or later in the stroke of the piston.

The spark can be advanced by moving the interrupter housing by means of the timing control arm in the direction opposite the rotation of the armature, and can be retarded by moving the interrupter housing in the same direction as the rotation of the armature. The armature rotation is indicated by the arrow on the oil well cover at the driving shaft end of the magneto.

206. Cutting Out the Ignition. Since high tension current is generated only on the interruption of the primary circuit, it is evident that in order to cut out the ignition it is necessary merely to divert the primary current to a path which is not affected by the action of the magneto interrupter. This is accomplished as follows:

An insulated grounding terminal is provided on the cover of the magneto interrupter housing with its inner end, consisting of a spring with carbon contact, pressing against the head of the interrupter fastening screw. The outer end of the grounding terminal is connected by low tension cable to one side of a switch; and the other side of the switch is grounded by connecting another cable between it and the engine or chassis.

1. Brass plate for connecting the end of armature primary circuit.
2. Fastening screw for magneto interrupter.
3. Contact block for magneto interrupter.
4. Magneto interrupter disc.
5. Long platinum screw.
6. Short platinum screw.
7. Long flat spring for magneto interrupter lever.
8. Magneto interrupter lever.
9. Condenser.
10. Slipring.
11. Slipring brush.
13. Slipring brush holder.
15. Steel segment for interrupter housing.
17. Dust cover over armature.
19. Terminal nut for grounding terminal.
79. Interrupter housing and timing control arm.
82. Cover for interrupter housing.
83. Spring for holding interrupter housing cover.

The above numbers apply only to the sectional illustrations Fig. 58-59-59½.

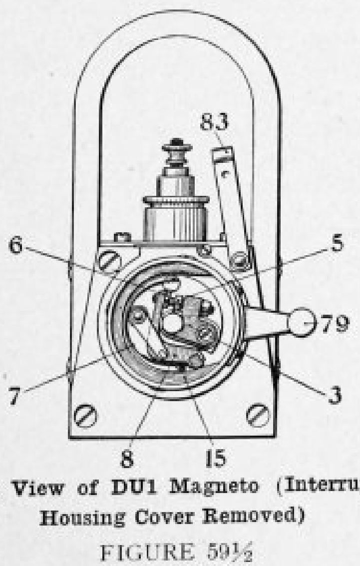
When the switch is open, the primary current follows its normal path across the platinum interrupter contacts, and is interrupted at each separation of these contacts. However, when the switch is closed, the primary current passes from the head of the interrupter fastening screw to the carbon contact of the grounding terminal, and thence through the switch to the motor and back to the magneto; and as the primary current remains uninterrupted when following this path, no ignition current is produced.

207. Care and Maintenance. Aside from keeping the magneto clean externally, practically the only care required is the oiling of the bearings. Of these, there are two ball bearings supporting the armature; and, in the types with gear-driven distributor, a single plain bearing supporting the shaft of the distributor gear.

Any good, light machine oil may be used for this purpose (never cylinder oil); and each of the bearings should receive not more than two or three drops about every 80 hours running, applied through the oil ducts under the covers marked "Oil," located at both ends of the magneto.

The interrupter is intended to operate without lubrication; and as oil on the platinum interrupter contacts will prevent good contact and cause sparking and burning, as well as misfiring, care should be exercised to prevent the entrance of oil to these parts.

208. Starting the Motor. When cranking a motor equipped with a DU magneto as sole ignition, the spark lever should be fully retarded if the magneto is of the Model 5 or Model 6 construction (most of the DU1 and DU2 magnetos are of these models); but should be slightly advanced with all other models. In the latter case, if the magneto has been timed according to instructions, the spark lever may be safely advanced about one-third, or even one-half on starter equipped motors; and in this position will permit easier starting (see also "Plug Gap Too Wide").



Rear View of DU1 Magneto (Interrupter Housing Cover Removed)

FIGURE 59½

209. Kingston Model "O' Magneto. Kingston Model "O" enclosed type magneto is a self-contained high tension magneto. It is dust and waterproof, being designed particularly to eliminate the dust and oil nuisance which is so general in some lines of service, particularly on tractors and trucks. See Fig. 60.

Fully 75 per cent of all Kingston magnetos are sold equipped with the Kingston Automatic Impulse Starter—the only absolutely automatic starter on the market (fully covered by U. S. and foreign patents). It requires no attention whatever on the part of the operator, coming into service at very low speed and cutting out automatically when the motor speeds up again. This feature elminates the need of batteries, and measures a positive hot spark for starting purposes.

210. Connecting Magneto to Motor. Model "O" magneto must be secured to the base on motor with cap screws, and in no case should clamps be used. The use of clamps to secure magneto to base on motor causes magneto cover to become distorted, thereby rendering it useless as a dust or waterproof cover. The magneto should not be bolted to an iron or steel base; brass or aluminum should be used. If impossible to do this, and the magneto must rest on an iron base, brass cap screws must be used to hold it. If not, the magnetism will pass around the armature, thus destroying the efficiency of the magneto. Care must be taken that the cap screws used to fasten it are not too long; for if the brass washers at the top of the screw holes are forced out of position they are liable to do serious damage to the armature. Care must be taken in connecting the magneto to the motor

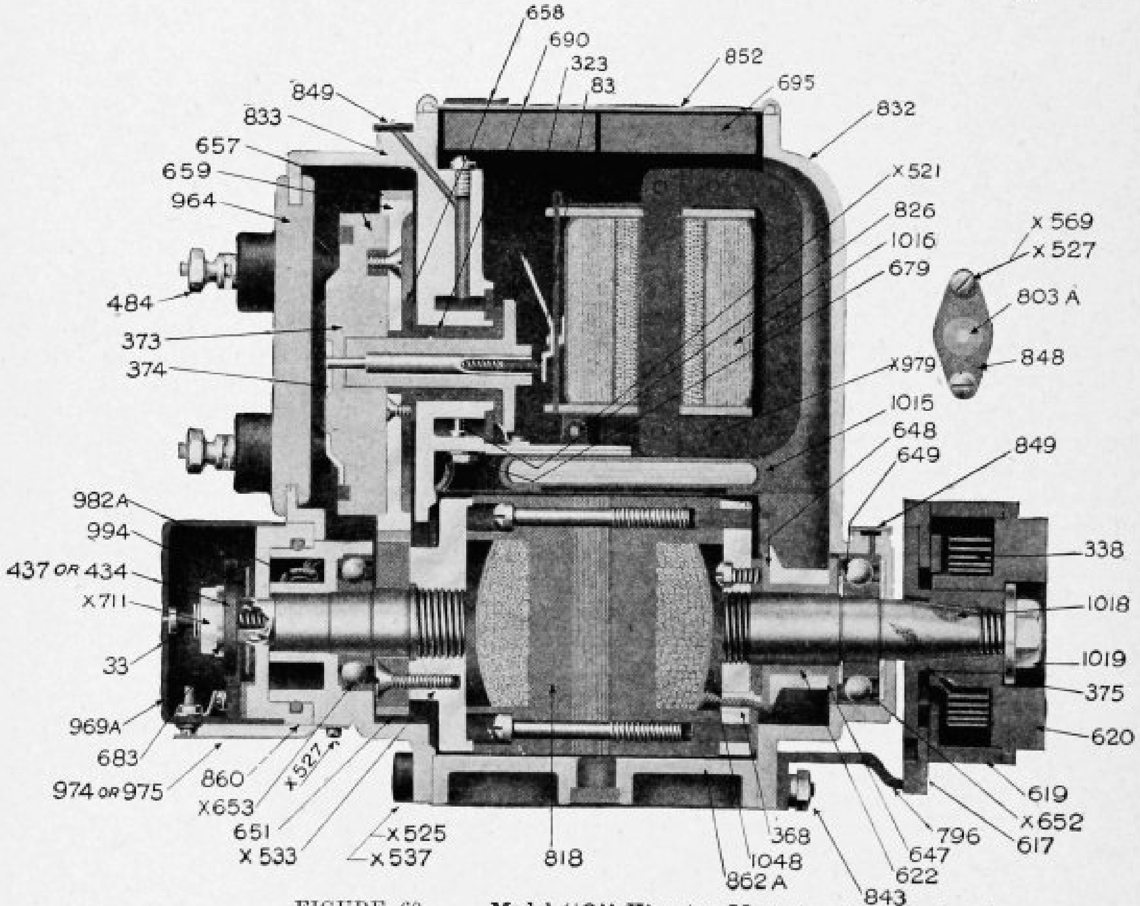


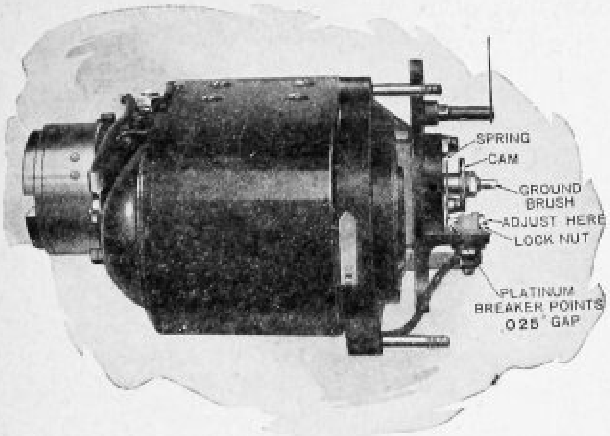
FIGURE 60 **Model "O" Kingston Magneto with Impulse Starter**

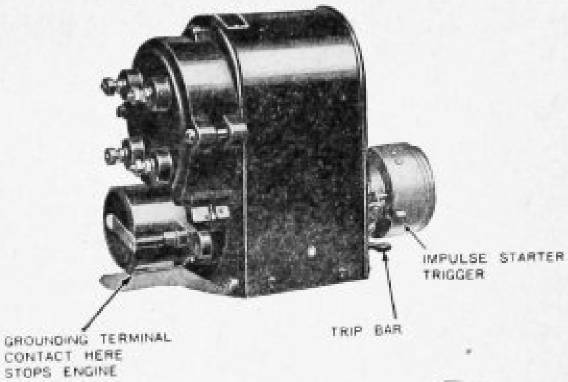
shaft. Where impulse starters are used the dental connection must not fit too tight or the free action of the starter will be interfered with. If gears are used they must not fit too tight or they may spring the armature shaft and thus ruin the magneto.

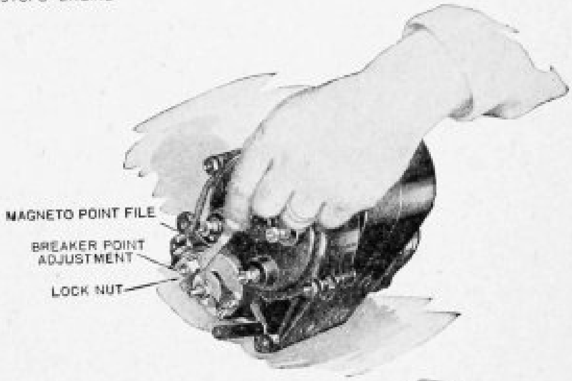
The instructions here given are such that if carefully followed, will keep the magneto in first-class condition and insure the best possible service at all times.

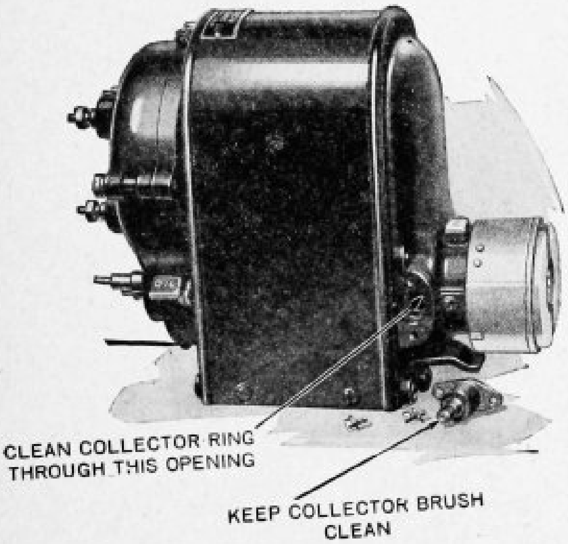
The very best advice we can give is to leave the magneto alone until you have made sure that the trouble is in the magneto. Fully 95 per cent of so-called magneto complaints that have been investigated have been found to be in no way chargeable to the magneto itself, in fact in many instances not even to any part of the whole ignition system.

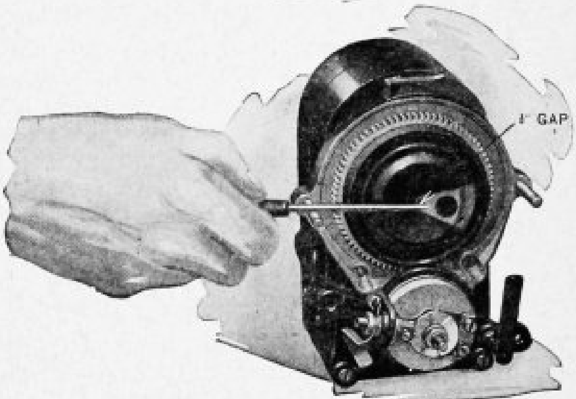
211. How to Time the Magneto to Motor. Place No. 1 cylinder on dead-center. Retard spark by shifting breaker arm to the farthest position. Then rotate the armature of magneto in the proper rotation until the cam is just starting to open platinum points. See











TESTING FOR SPARK

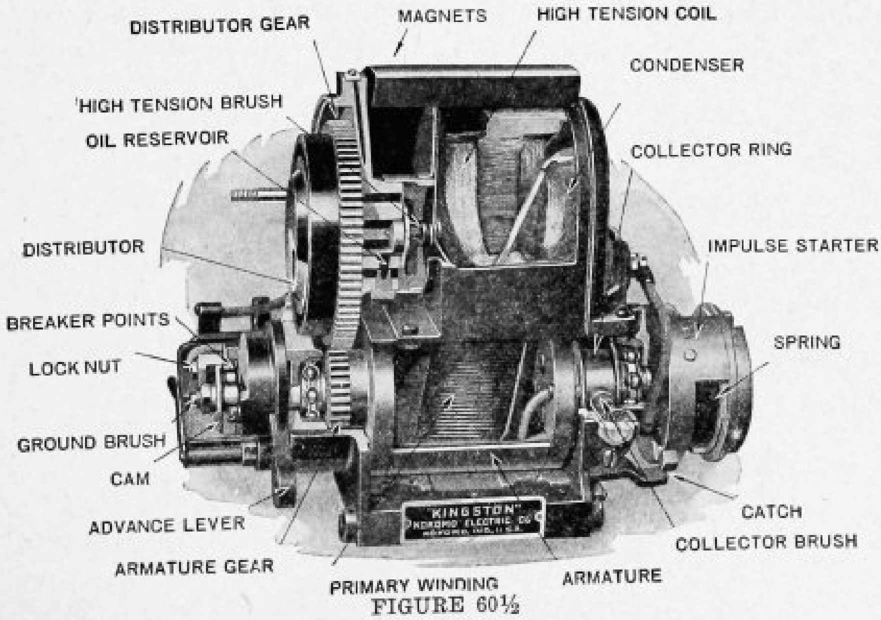


FIGURE 60½

that brass plate on distributor disc is directly underneath the terminal on distributor head, which you will use for cylinder No. 1. See that wires are placed on terminals in the firing order of your motor. Be sure that you place wires on distributor head in opposite direction to rotation of armature.

Arrow indicates the rotation of armature. Magneto must be run as arrow indicates. Under no circumstances should an attempt be made to reverse or change the magneto in any way.

Always advance spark lever about half way when starting motor, as when spark lever or breaker box is in full retard position, connection is made which acts as a switch and magneto delivers no spark. Always drive motor with spark lever advanced as far as motor efficiency permits. To stop motor, fully retard spark lever. OILING—Use three-in-one or light hand separator oil in the three oilers; three or four drops per week when running the motor daily.

Caution. If your spark plugs are clean and in good condition with points not over 1-32 inch apart, and you have a spark at plug points, do not blame your magneto if you can not start your motor.

Find out if your gasoline is of proper quality and flows freely through the supply lines and carburetor. Poor quality of gasoline is responsible for more starting troubles than all other causes. Also investigate your motor conditions such as compression valves and valve springs, lubrication, carbon in cylinders, etc. To find out if spark is being delivered through the plugs, remove the spark plug and clean thoroughly, attach wire cable and lay the plug on the motor. If any one of the plugs miss or do not deliver spark, examine plug for broken porcelain, loose connection, or broken or worn cable insulation. If the motor misses continually in one or more particular cylinders, the trouble is not due to the magneto, but probably to defective wiring of spark plugs.

Do not adjust the platinum points until they stop breaking. Then smooth off the surface with a fine file, and adjust so that the entire surface meets even and they break from 1-64 inch to 1-32 inch. The points must be kept clean.

If the magneto does not deliver a strong spark the brush-making contact on the collector ring may have accumulated dirt, thereby not making good contact. The brush should be removed and cleaned. The collector ring may be cleaned by placing a piece of emery cloth against same and revolving the armature. The construction of the Kingston magneto is such that a test of the pull of the magnets by revolving the armature is of no value whatever in determining the strength of magnets on Kingston magnetos.

212. Impulse Starter. Important—See that your impulse starter is releasing all right. A quick, sharp snap indicates starter is working o. k. Should dirt accumulate in the starter in such a manner as to interfere with the trigger dropping out freely, an injection of gasoline or kerosene will usually remedy such defect.

213. Repair Parts and Number for Model "O" Magneto.

Cat. No.	NAME	Price
33	Gauze Brush (Ground)	$...
53	Collector Brush and Spring	...
83	Carbon Brush and Spring (Spool to Coil)	...
323	Insulated Spool	...
374		
373		
	Distributor Disc and Contact Plate	...
434	Cam, Clockwise, 4-Cylinder	...
435		
436		
	Spring and Stud, Breaker Case Cover	...
437	Cam Counter Clock, 4-Cylinder	...
484	Terminal Nuts, Distributor Cover 10-32 Hex.	...
596	Platinum Screw Lock Nut Wrench and Spacer	...
657	Armature Gear	...
X652	Ball Bearings, Drive End (Large) N. D. 16	...
X653	Ball Bearings, Distributor End N. D. 03	...
657		
658		
	Distributor Gear (Brass) and Steel Shaft	...
659	Distributor Gear complete, parts No. 373-374-657-658	...
679	Oiler Wick Holder	...
683	Cam Washer	...
690	Bushing (Bronze) Distributor Shaft No. 658	...
695	Magnet (Single)	...
X710	Key for Cam 3-8-in.x3-32-in.	...
X711	Nut for Cam 5-16x28	...
783	Contact Screw Platinum Point and Nut	...
803A	Brush Assembled Complete Collector Ring	...
818	Armature Complete with Ball Bearings	...
826	Oiler Wick	...
832	Drive End Bearing Plate	...
833	Distributor End Bearing Plate	...
848	Plate Brush Holder	...
849	Oiler Cover, Spring and Screw	...
852	Cover Magneto	...
860	Breaker Case Casting (only)	...
860A	Breaker Case Complete with Platinum Points	...
862A	Base Complete, Base (1) Pole Pieces (2)	...
886	Support for Contact Platinum Point and Screw	...
887	Insulation for Contact Platinum Point and Screw Support	...
888	Insulation Collector Lead	...
889	Collector Lead	...

891 Washer (Fiber) used with parts No. 886-889 . . . .
893 Bushing (Rubber) used with parts No. 886-889 . . . .
964 Distributor Cover Complete. . . . .
965 Screws, Distributor Cover 10x32 1 1-8 in. Fil. Head . . . .
969A Breaker Case Cover Complete. . . . .
974 Grounding Terminal Counterclock. . . . .
975 Grounding Terminal Clockwise. . . . .
X976 Lock Washers 1-16x1-32-in. Parts No. 974-975 . . . .
979 Screws to Anchor Coil to Condensor. . . . . . .
982A Primary Lead, with Terminals, Condensor to Interrupter. . . . .
994 Contact Spring and Platinum Point Complete . . . .
1015 Condensor Complete (only). . . . .
1016 Coil Complete (only). . . . .
1020 Condensor and Coil Complete. . . . .
1021 Screws Magnet No. 14, 5-8x20 Flat Head . . .
1031 Cam Clockwise (2-Cyl.). . . . .
1032 Cam Counterclock (2-Cyl.). . . . .

214. The K-W High Tension Magneto. A High Tension Magneto, however, is a complete ignition system all in itself, requiring no spark coil, no timer, and no batteries. It is geared or timed to the motor, and can be used on any make of motor that has a provision for a magneto; or on motors that have no provision for a magneto, it can be driven by gears or sprocket and chain.

The speed is exactly crank shaft speed for all one, two, and four-cylinder motors, and one and one-half crank shaft speed for three and six-cylinder motors.

The first K-W High Tension Magneto was made a little over four and one-half years ago; since then constant experiment and relentless and exhaustive tests have combined to develop a high tension magneto, the equal of which the world has never yet seen.

The Model HK Magneto is Model H with the addition of the K-W Impulse Starting Device and 1 inch longer magnets.

The Impulse Starting Device holds back the rotor of the magneto until the firing point of the motor is reached, when it is tripped and by means of a spring is driven forward at a high rate of speed, producing a hot starting spark in the cylinder. It operates only when the trigger is set. Normally the shaft is driven straight through the coupling or connection to the motor and the trigger need only be set for starting. When the motor comes up to speed, the Starting Device is automatically thrown out of action and simply revolves with the shaft.

This magneto is furnished for either coupling or gear drive. Gear drive is illustrated above. When for coupling drive, male half of the coupling is furnished, as shown on Model HKT.

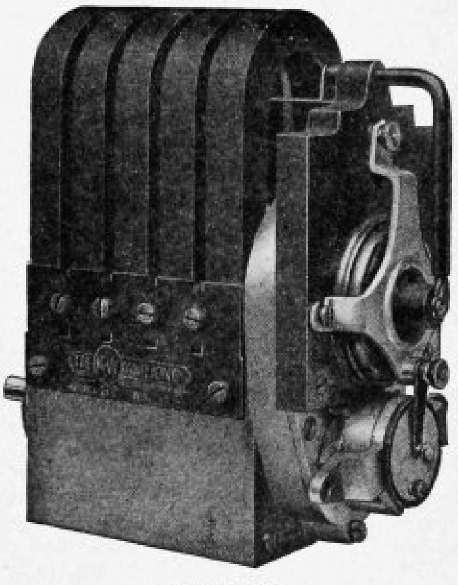
215. The Fundamental Parts of the K-W High Tension Magneto. There are two things in a high tension magneto that must be absolutely right, if the magneto is to be dependable. First, the condenser must be absolutely puncture-proof; and second, the high tension winding must be thoroughly and well insulated. In other words, the insulation of both must be many times in excess of that required to do the work; for absolute reliability can be obtained only by having a very large factor of safety.

216. The Only Revolving Part in the K-W Magneto is shown by illustration This part is the rotor, which is constructed of fine laminations of the softest Norway sheet iron. These laminations are riveted together, are accurately bored out to fit the rotor shaft, and accurately machined as to width and diameter, being mounted on this shaft at exactly right angles to each other.

217. The Winding, which is concentric with the armature shaft, is mounted in between the two halves of the rotor and stands absolutely still. These rotors collect the magnetism from one pole piece and conduct it through the center of the winding to the opposite pole piece, thus giving a powerful wave of current from a quarter revolution of the magneto.

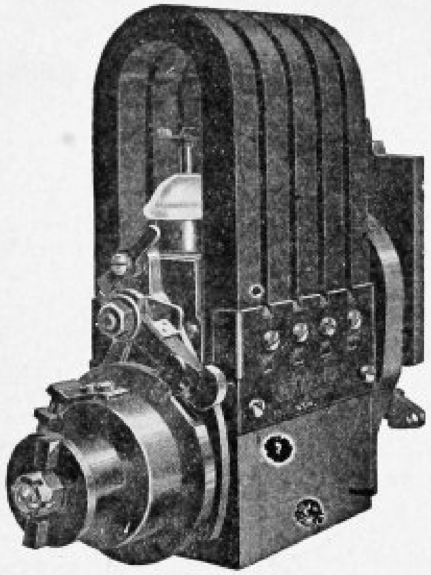
The winding as shown in the center of the illustration B is a double winding; that is, it has a primary or low tension winding, which is surrounded by a secondary or high tension winding. This primary winding goes through the circuit breaker of the magneto and has its current interrupted by the circuit breaker.

At the moment of this interruption of current in the primary, a powerful surge of current is generated in the secondary winding. The current from this secondary winding goes straight up through the hard rubber terminal to the bus bar, 186 and 100 in diagram A, page 206, to the center of the distributor brush;



Model HT

FIGURE 61



Model HK
FIGURE 62

and from there is distributed to the various cylinders of the motor.

By this method of winding construction, we are given ample room for an adequate insulation to hold the high tension current. It is surrounded by one-eighth inch of silk and varnish insulation, and passes through twenty-seven distinct operations in insulation, each operation consuming a day's time in the baking oven. The windings are first impregnated under the vacuum impregnating process, which removes all of the moisture from the paper insulation between layers and the silk insulation on the wire; and then a molten, solid insulating compound is forced into the interstices between the windings and into the pores of the paper at a pressure of 125 pounds to the square inch.

218. The Condenser. No. 126, Fig. 64, is bridged across the circuit breaker points. Its function is to absorb the low tension spark at the circuit breaker points, caused by the breaking of the primary circuit. This condenser is made of a large number of sheets of tin foil and mica. Each sheet of mica has been tested separately under 5,000 volts potential, so as to insure our condensers absolutely against breaking down in service. The strain that each separate part is subjected to before being assembled is many times in excess of any possible strain that could be put on them in service.

219. The Safety Gap. No. 118, Figure 64, is a necessary part of any high tension magneto. Its object is to form a path for the high tension current to jump through in case a secondary cable that leads to the spark plugs should be off when the motor is running. This safety gap, as its name implies, prevents the magneto from burning out; for as long as there is a path for the high tension current to pass through, it will never puncture the insulation of the secondary winding.

It will be noted, by referring to diagram A, that the distributor shaft is carried on two ball bearings, as is also the rotor shaft. The distributor block, 96, is moulded from a special composition of hard rubber, and is accurately machined all over. The brass segments that connect with the various plug holes on top of the distributor are moulded in with the hard rubber. A carbon brush is mounted in the distributor arm, which presses slightly against the distributor segments. The interior of the distributor is practically dust and moisture-proof, being protected by a hard

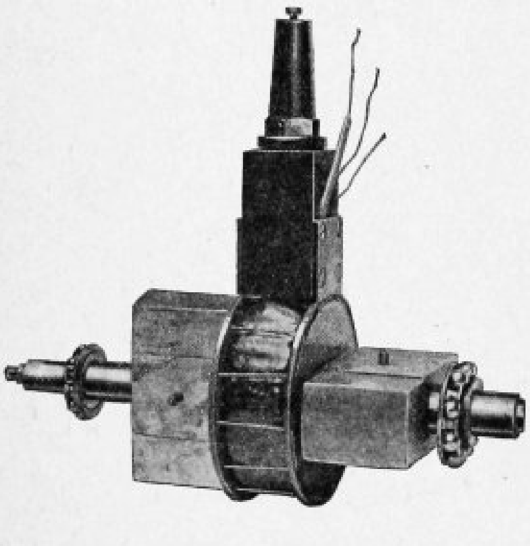


FIGURE 63

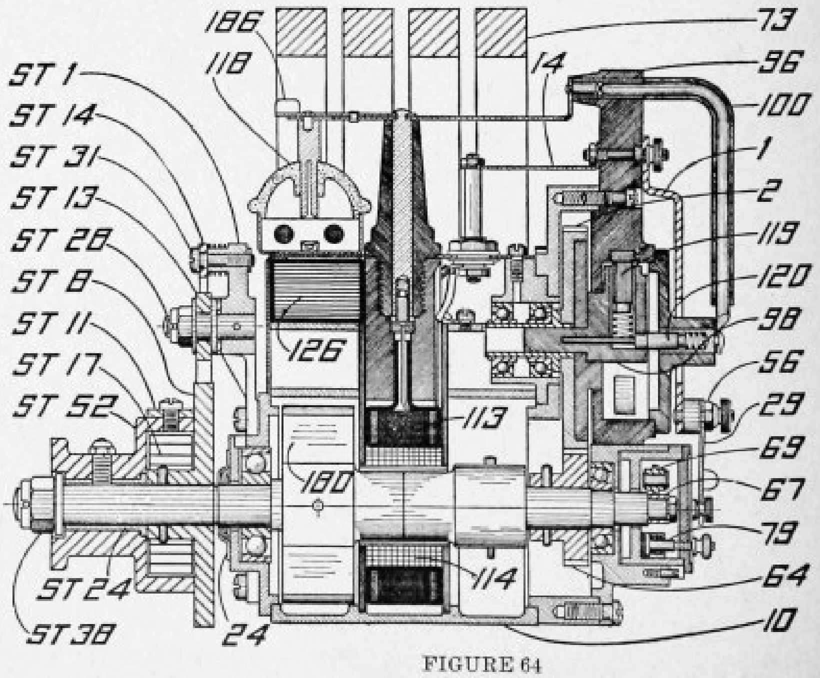


FIGURE 64

rubber cover, which is held in place by a three-legged spider or bridge, No. 1. The primary circuit is carried to the circuit breaker through this bridge or spider. The binding post, No. 56, is the point from which the switch wire is run to the switch for stopping the motor.

220. The Magnets. The foundation of any magneto lies in its permanent magnets. If these are weak or too short and squatty, they will not retain their magnetism, nor will they furnish sufficient magnetism to enable one to start the engine directly on the magneto. In this particular point the K-W Magneto differs from any other magneto made. Its magnets are long and strong. Their length enables them to draw all the lines of force from the permanent magnets through the windings, thus generating from three to ten times as much current and proportionately a hotter spark than do other magnetos.

221. Cross-Section Type H and HT Magnetos. Figure 64 shows a longitudinal sectional elevation of type H and HT Magnetos. By referring to the numbers in the following instructions, some idea can be obtained of the function of the variuos parts. This diagram will also assist in ordering repair parts as the numbers correspond with those in repair part list.

222. The K-W Circuit Breaker. The entire circuit breaker is removable. Release spring No. 189 by pushing it aside with knob on end. Pull out complete breaker box and remove cover nut No. 79. This allows removal of circuit breaker cap and gives access to breaker parts. The same type of circuit breaker is used on all K-W High Tension Magnetos, and is shown by diagram D. It is arranged to have 30 degrees of advance or retard.

When the points P, diagram B, fail to separate, or when the distance is too far apart, adjust part 194 with small screw driver inserted through hole for that purpose in housing. The proper distance apart is one sixty-fourth of an inch. A gauge is sent with every magneto.

While there is no guarantee on the platinum iridium points, they should, with proper care, last about 5,000 miles or more on auto motors and give equal service on large stationary or tractor motors.

Don't fill the circuit breaker box with oil or grease. Once a month oil the wick in roller 68 on upper contact arm. See that no oil gets on contact points, as oil destroys the contact and makes hard starting. See full directions under "A Few Don'ts" and "Care of Magneto."

The firing point of the magneto is just when the points are beginning to open or break circuit, not when they touch.

223. To Open the Distributor. Remove the high tension lead 100 by turning it to right, and unfastening it at bottom. Unscrew nut 55 and remove the bridge or spider I, thus releasing cap on distributor block and giving view of distributor and brush B, No. 119.

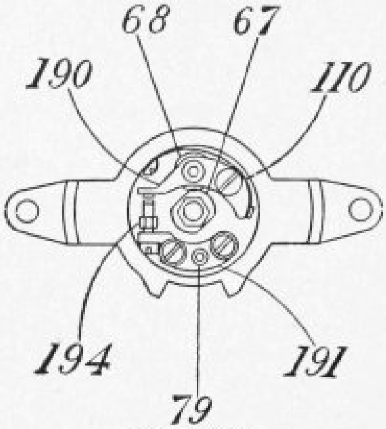


FIGURE 65

224. The Direction of Rotation. Be sure the magneto when installed is running in direction as stamped by arrow on the dust cap around the driving end of shaft. This is "Clockwise" or right-hand, or "Anti-clockwise" or left-hand. Magnetos will not operate in opposite direction to that for which they are intended.

To Change Direction of Rotation. Take off cam 67 and turn it around end for end. Take off Hard Rubber Distributor Block exposing moulding (part 94, plate No. 1), fastened by three screws to large distributor gear (No. 2, plate 1). Shift to other set of holes for the screws and put back together.

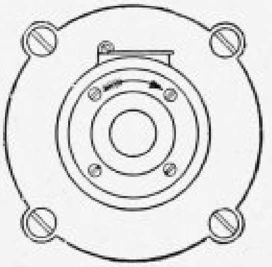


FIGURE 66

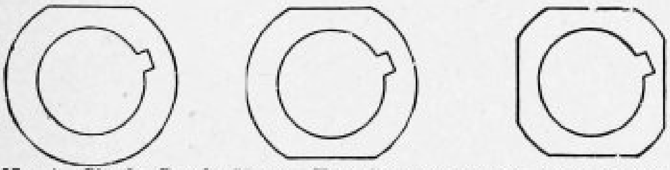
225. Mounting the Magneto. Mount the Magneto on an iron bracket, if desired, as it is not necessary to use a brass or aluminum bracket for the Models H and HT K-W Magnetos, because they have a brass base with magnets some distance from the bottom. If a strap is desired to go over the magnets to hold magneto down, this must be of brass, as any part touching the magnets must be brass. Can it be mounted at an angle, if desired, in order to avoid obstructions, as it is not necessary to have magneto upright. Be sure the bolts for attaching magneto to the bracket are not too long so as to break through the magneto base and strike the rotor. Three-eighths inch is all they should go in to magneto.

226. The Speed of K-W High Tension Magnetos. The speed is exactly crank shaft speed for all 1, 2, and 4-cylinder motors and one and five-eighths times crank shaft speed for 6-cylinder motors.

227. Table of Cams Used. The K-W High Tension Magneto can be arranged to give either one, two, or four breaks, or sparks, per revolution of the Magneto, because it gives four waves of current per revolution.

Below we show different cams used, and give table of the speed at which the rotor or driving shaft, of the magneto should run in comparison with the speed of the crank shaft.

The cams on the Model J do not interchange with the cams on Models H and HT, the difference being a slight change in the keyway.



No. 1—Single Spark No. 2—Two Sparks No. 3—Four Sparks
FIGURE 67

Four-Cycle Motors			Two-Cycle Motors		
Cylinder	Speed	Cam No.	Cylinder	Speed	Cam No.
1	1	1	1	1	1
*2	1	1	2	1	2
3	1½	1	3	1½	2
4	1	2	4	1	4
6	1½	2	6	1½	4
8	1	4	8	2	4

*On two-cylinder four-cycle motors, where the cylinders are together and crank throws 180 degrees apart (or opposite); that is, where the cylinders do not shoot equi-distance apart, but both on the same revolution; use a four-cylinder magneto and connect distributor segment 1 and 2 to spark plugs in the cylinder, and segments 3 and 4 to outside spark gap on magneto.

228. K-W Model T Magneto. This is constructed upon the inductor principle, same as our Model H and HT, assuring an exceedingly hot spark at as low a speed as the engine can be run.

It has a rapid circuit breaker, making the operation of a 12-cylinder motor possible at over 3,000 r. p. m., without missing.

This construction allows four sparks per revolution, allowing Magneto to be driven at engine speed for 8-cylinder motors and one-half times motor speed for 12-cylinder motors.

It is enclosed as protection against dirt, water and oil.

For motors which are hard to crank, use Model T, equipped with Impulse Starter, designated as Model TK. See Fig. 68.

The Impulse Starter Attachment, illustrated on end of driving shaft above, allows the motor to be started regardles of cranking speed, as the rotor is held stationary while the coupling is moving 80

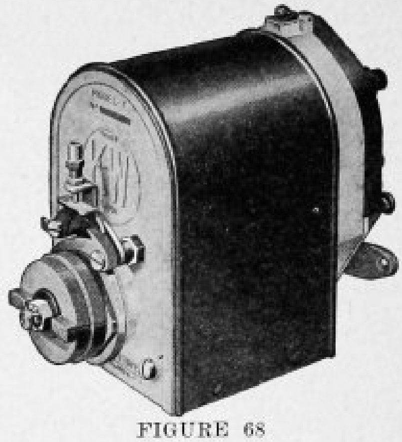


FIGURE 68

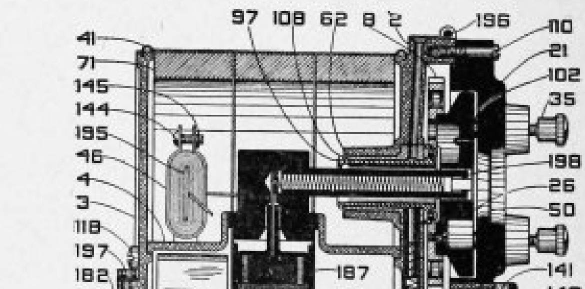
degrees, then is tripped and thrown ahead at the rate of 500 r. p. m., assuring a very hot spark for starting.

After a predetermined motor speed has been reached, the starter coupling is automatically thrown out of engagement and the Magneto is driven direct.

It also eliminates any chance of a back fire, as the relation of the piston position to the firing point of Magneto is controlled by the Starter until it has thrown out of engagement, when it is controlled by the circuit breaker.

229. Magneto Design. Model T and TK Magnetos are of the inductor type construction, having stationary winding and revolving rotor. This does away with all moving wires, collector rings, special contacts, etc; and is the simplest form of construction.

230. To Change Direction of Rotation. Take off cam and turn it around end for end. Then remove distributor block, which will expose the distributor moulding and segment. Remove the screws and set over to the other set of holes and draw screws up tight.



Cross Section Model T Magneto
FIGURE 69

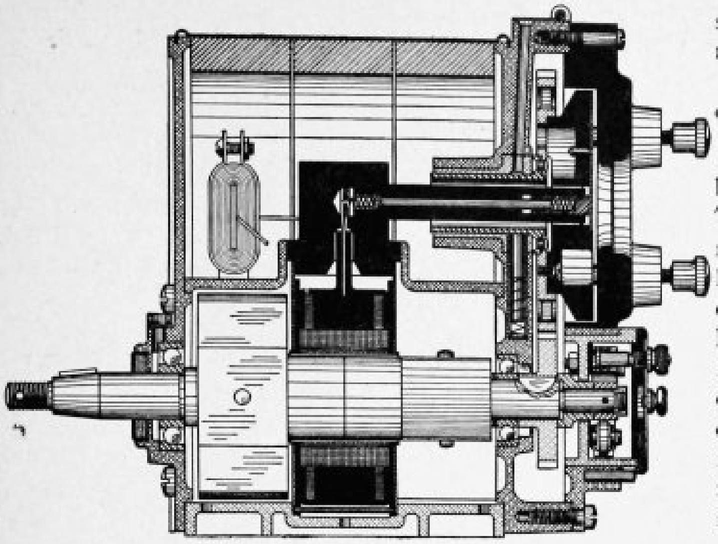


FIGURE 69½

231. Magneto Mounting and Drive. Model T Magnetos must be mounted on a brass or aluminum base or separated from an iron base by at least half an inch of non-magnetic material. If mounted on an iron base, use a brass or fibre separator with brass bolts. If Magneto is to be held down by a strap, it should be made of brass.

When bolts are used, be sure they are not too long, as they should go into Magneto only five-sixteenths of an inch; otherwise they will break through the base and strike the rotor.

The most satisfactory method of driving is by gear or Oldham coupling; but if neither of these drives is applicable, sprocket and chain may be used. This method is not recommended if over nine-inch centers are used, on account of the slack due to the stretching of the chain and so many wearing points to throw the Magneto out of time.

The Magneto must be positively driven at motor speed for 1, 2, 4 and 8-cylinder, 4 stroke cycle motor, and 1, 2 and 4-cylinder, 2-cycle motors. For 3, 6 and 12-cylinder 4-cycle motors the Magneto must be driven one and one-half times motor speed.

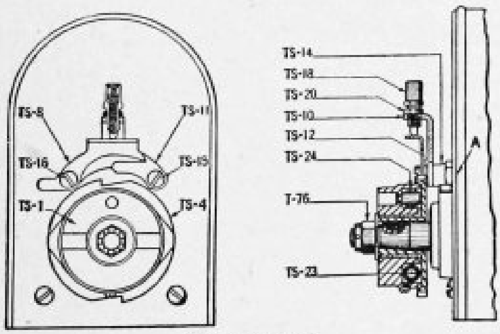


FIGURE 70

232. Impulse Starter. To Time Model TK Magneto to Engine. Put piston in No. 1 cylinder on D.C. Trip starter dog into engagement. Turn impulse starter until cam on starter case T.S 1 is starting to move dog T.S. 11 out of engagement.

This is the proper place to couple magneto to drive shaft.

To Operate Starter. By pressing down on back end of ratchet catch lock T.S. 8, ratchet catch T.S. 11 will be released and allowed to engage with notch on ratchet T.S. 4, this is keyed to the rotor, holding it stationary while case T.S. 2 is moving 80 degrees and compressing spring T.S. 23. When the lug on case T.S. 2 moves around to release catch T.S. 11, the rotor is thrown ahead with a rush, causing an exceedingly hot spark to be delivered. This will continue until a pre-determined motor speed has been reached when the starter is thrown out of engagement, and the magneto is driven direct through the starter coupling.

233. Instructions for Applying Impulse Starter to Model T.

Remove the two screws shown at A and insert two studs T.S. 14. Bracket T.S. 10 is mounted against the face of these studs followed by washers T.S 12, and ratchet catch T.S. 11 on right side and ratchet catch lock T.S. 8 on left side. These parts are held in position by screw T.S. 15 on right side, and screw T.S. 16 on left side for clockwise rotation T.S. 9, 11, 15, 16 are reversed for anti-clockwise rotation. The starter case completely assembled is slipped on taper shaft and held in position by nut T. 76 and cotter pin.

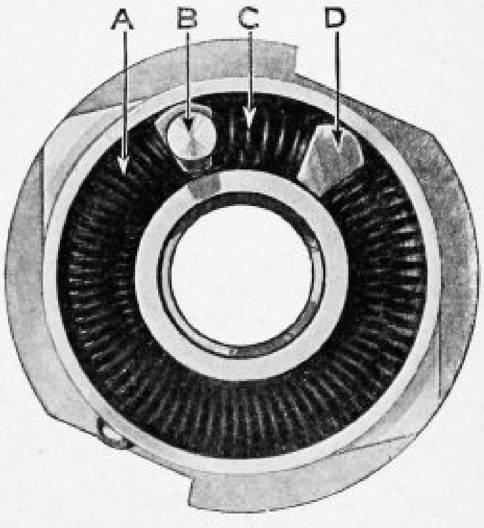


FIGURE 70½

234. To Replace Spring. Remove nut T. 76 and withdraw case T.S. 2 which will expose spring T.S. 23 and spring T.S. 24, which can then be taken out and replaced easily. On the inside of case T. S. 2 a lug will be found which must be inserted between the two springs when replacing case. This can be accomplished very easily by leaving spring T.S. 23 stick out about half way. Then by setting the lug against spring and turning the case, it wil slide into position. To adjust the speed at which the starter throws out, loosen lock nut T.S. 20, and turn adjusting screw T.S 18 up or down until properly set, and then lock with nut.

THE DIXIE MAGNETO AND SUMTER IMPULSE STARTER

235. The Dixie Magneto. The Dixie Magneto is of the true high tension or jump spark type, producing within itself and independent of outside units, an electric current of high voltage and comparatively high amperage suitable for utilization in a jump sparkplug.

The Dixie is constructed on the Mason principle, invented and patented by Chas. T. Mason of Sumter, S. C. This principle utilizes quite new and novel features to produce a magneto with several peculiar and valuable characteristics.

236. How the Dixie Makes a Spark. The Dixie magneto consists principally of a pair of magnets, a rotor, a field structure, a winding, an interrupter (breaker), and a condenser.

The rotor (Fig. 71) consists of two iron wings separated by a piece of brass (B). The ends of the wings are always in contact with the legs of the magnets, these having north and south poles.

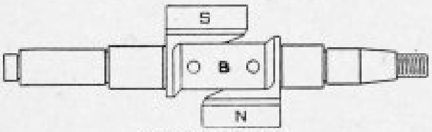


FIGURE 71

Wing N is north; wing S. is south—always. By rotating in the field structure, as shown in Figures 72 and 73, these wings direct the magnetism of the magnets through the coil core (C) first in one direction and then the other. Each change in magnetism through this iron coil core generates, in the insulated wire which is wound round it, a current of electricity varying in intensity. The greatest strength of this primary current is when the rotor is in the position shown by Fig. 74 when the gap **X** is .015 to .035 inches wide. The maximum strength varies, but is probably about 6 volts only when running at normal motor speed. This is about as strong as the current from four dry cells.

The current which is generated in the primary winding of the coil is led through the "primary lead,"

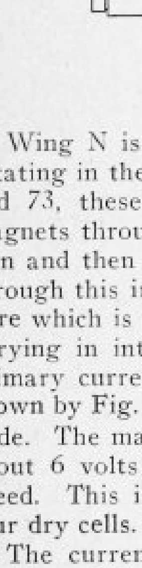


FIGURE 72

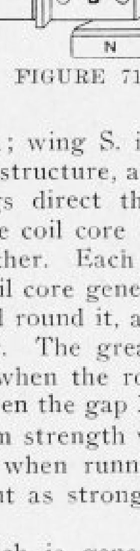


FIGURE 73

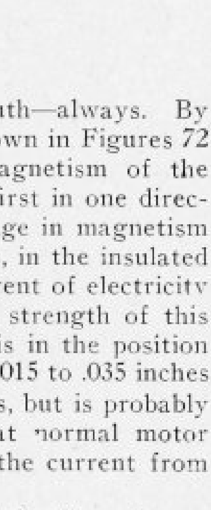


FIGURE 74

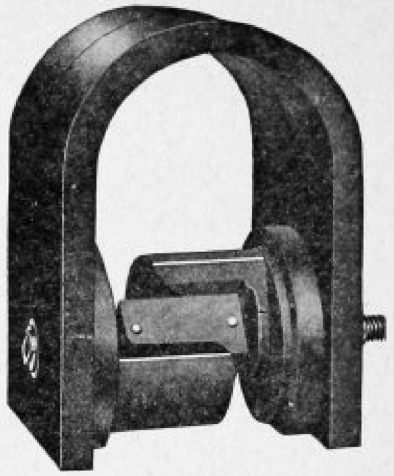


FIGURE 74½

a short insulated wire, to the breaker mechanism—the "interrupter". Here the current flows through the platinum points which are together and back through the frame of the magneto to the other end of the coil, thus completing the circuit. At the instant the current is at its greatest value, the platinum contact points are separated quickly by the cam. This suddenly breaks the flow of the primary current.

When the points separate, the current has a tendency to flow between the points as they open, forming an electric arc or spark. Such action will quickly burn away the points—and prevents the very sudden breaking of the current flow. So a condencer is wired in across the points. The condenser has the peculiar ability of absorbing the current which tries to produce this spark; and if it is correctly balanced with the coil, as it is in the Dixie, the spark is all absorbed. The condenser in the Dixie is mounted right on top of the coil where it can easily be replaced should anything happen to it.

This construction gives the Dixie magneto the valuable characteristics.

1. The spark has the same intensity whether the magneto is in advance or retard position, because the pole and coil structure with the breaker mechanism rotate around the shaft through the angle that the magneto is advanced (or retarded). The value of the primary and secondary currents, therefore, remains constant as the **relation** between the magnetic change and the electrical break remains the **same.**

2. As large angular advance and retard as is desired for any engine. If necessary, the Dixie could be made to advance a full 180° without impairing the spark value, because of this feature. The Dixie 46 has 40° advance which is as much as most engines made today require.

3. A stationary breaker mechanism which can be inspected and, if necessary, adjusted, while the magneto is running.

4. A magneto on which the magnets do not lose the customary 10% to 30% due to the reaction of a

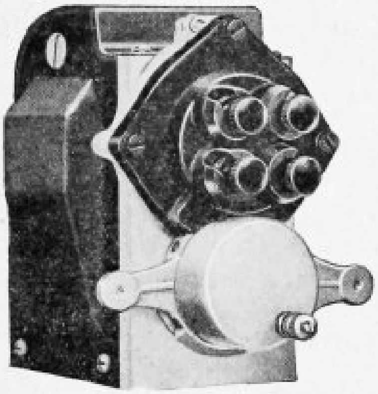
rotating armature. Many careful tests prove that Dixie magnets are not subject to this reaction and therefore retain all their original magnetism.

5. Close-fitting covers which protect against water, dust and oil.

6. Unsurpassed simplicity and accessibility. By removing the covers and turning down the magnets, one on either side without removing them, the condenser and coil and connections are available for examination and, if necessary, replacement.

237. Adaptability of the Dixie. While the Dixie is adaptable to practically any internal combustion engine, and is manufactured for many different types—it is necessary to consider here only those models which are used on farm tractors. Space will not permit the description of all the models for farm engines, both low and high tension, for airplane engines, and for special service.

The most widely used tractor model is Dixie 46



Model 46
FIGURE 75

(Fig. 75) which is suitable for use on engines as follows:

1. Four cylinder, four cycle, of the conventional type with the cylinders in line on one side of the crank shaft. Engine speed.

2. Four cylinder, four cycle, opposed—two cylinders on each side of the crank shaft. Engine speed.

3. Four cylinder, two cycle, cylinders in line on one side of the crank shaft, crank pins 90° apart. Should be driven at twice engine speed.

4. Four cylinder, two cycle, "V" type, with two cylinders on each side of the "V" which must be 90°. Twice engine speed.

5. Two cylinder, two cycle, cylinders side by side, cranks 190° apart. Two opposite points on the distributor inter-connected. Engine speed.

This magneto makes two sparks per revolution and is therefore applied to a four cylinder engine so as to run at engine speed.

Dixie model 462 is the same machine, slightly modified, so that it produced but one spark per revolution and has but two terminals on the distributor. This magneto is used on:

1. Two cylinder, four cycle, cylinders side by side, connecting rods working on the same crank pin, or on pins which are on the same side of the crank shaft. Engine speed.

2. Two cylinders, four cycle, cylinders opposed on opposite sides of the crank shaft, cranks 180° apart. Engine speed.

Dixie model 246 is, again, a slight modification of the model 46. While it produces two sparks per revolution, but two out of four sparks produced are used by the engine, the other two being led to the ground across a special gap moulded into the distributor block. This type of magneto is necessary for those two cylinder engines which do not fire at even intervals. On this type one cylinder fires, the engine then rotates 180° and then the other cylinder fires, then the engine turns 540° or 1½ revolutions before cylinder number one fires again.

A standard 4-cylinder magneto may be used on this type of engine but two terminals must be grounded and this does not make so efficient or nice appearing outfit. Dixie model 246 is built for:

1. Two cylinder, four cycle, cylinders side by side, cranks opposite (180° apart). Engine speed.

2. Two cylinder, four cycle, cylinders on opposite sides of the crank shaft, connecting rods working on the same crank pin or pins, which are on the same side of the crank shaft. Engine speed.

238. The Sumter Impulse Starter. The Sumter Impulse Starter has been designed to make the starting of even the largest engines directly from the magneto, safe, sure and easy. It is a purely mechanical device matching in simplicity and sturdiness the Dixie magneto itself, for which it was designed. It requires no attention except periodic lubrication and eliminates the necessity of dual and auxiliary battery systems. There are nearly 100,000 in successful service.

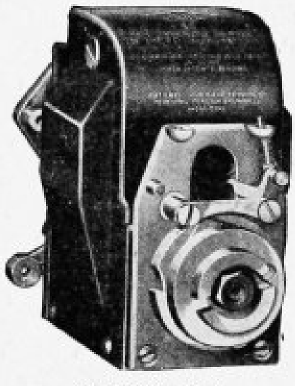


FIGURE 75½

General—

The Sumter Impulse Starter is composed of two units—a Stationary and a Rotating.

The Rotating Unit is composed mainly of two members—the magneto member and the cam member. The former is keyed to the rotor shaft of the magneto. The other telescopes into the first and is retained by the shaft nut and washer. Each member has a lug securely riveted into it and projecting into the annular space between the two members. Compressed between the two lugs are two springs—one long actuating spring SC-10, and one short cushion spring SC-11. The magneto member has one or two notches cut in its periphery—one notch for magnetos making one spark per revolution, two notches for those making two sparks per revolution. The pawl engages the notches of this member.

The Stationary Unit consists mainly of a flat plate attached securely to the drive end of the magneto by two screws. Above the Rotating Unit, this plate carries two pins connected by a link. If the coupling is for right hand rotation, the pawl is on the right hand pin; if for left hand rotation, on the left hand pin. The pawl held in either engaging or disengaging position as the case may be, by a small plunger passing through a bronze compression spring.

239. Operation. When the engine is to be started, throw the pawl into operating position,—toward the left if right hand rotation; toward the right, if left hand rotation.

When the engine is turned forward, the Rotating Unit rotates. The pawl engages the magneto member in one of the notches and arrests the movement of that member, this also stopping the movement of the magneto rotor. But the cam member of the rotating unit, being driven by the shaft and flexible joint, continues to revolve. The long actuating spring between the two members is compressed. The drive member continues to rotate until the cam which is integral with it reaches the pawl. This cam forces the pawl out of the notch. The compressed spring expands and throws the magneto member and the magteto rotor forward at a several-hundred-revolutions-per-minute rate until the two members reach their former relative positions. The short cushion spring absorbs the shock and brings the rapidly moving magneto member to a stop gently. During this rapid forward movement of the magneto rotor, the breaker points of the magneto separate and a hot intense spark is produced in that cylinder whose piston is then in the firing position. This spark has the same intensity as that procured when the magneto is running at full engine speed and consequently starts the engine even under conditions not the most favorable to good combustion.

The shape of the pawl and of the notch is such that when the engine starts and comes up to a speed of about 200 to 250 r. p. m., the pawl is thrown outward with such force that it is caught and held in the inoperative position. The driven member then drives the magneto member positively and at the same speed as the engine. The coupling then has no effect whatever on the spark but acts as a common magneto drive coupling.

It is unnecessary to give the Impulse Starter further attention until it is again desired to start the engine. Then, simply press the pawl into engagement again.

240. Mounting the Sumter Impulse Starter on the Magneto.

Rotating Unit—

The small wire holding the two members of the Rotating Unit together should be removed, care being taken that the members are not allowed to come apart. Slip the magneto member onto the magneto shaft with the Woodruff key in position. Put on the special washer, and the shaft nut. Try turning the driven member with the pawl engaged in the magneto member to see that the two parts work together freely.

Stationary Unit—

The Stationary Unit can be quickly and securely attached to the magneto by removing the two screws from the lower side of the drive end of the magneto —putting the plate in position—and driving in the screws again. The plate should fit snugly against the end plate of the magneto and be solid when the screws are tightened up.

241. Mounting the Magneto equipped with the Sumter Impulse Starter. The Dixie magneto has standard S. A. E. mounting dimensions. The Sumter Impulse Starter, when accompanied by the adjustable drive coupling assembly which can be furnished with it, agrees with the standard S. A. E. magneto drive coupling dimensions.

After the Starter has been attached to the magneto, it remains only to mount the magneto on the bracket in line with the drive shaft—to securely attach it to the bracket—and to provide the necessary drive coupling members to connect the drive shaft to the Starter.

242. Automatic Spark Retard and Safety Features. The action of the Sumter Impulse Starter automatically retards the spark for starting. The impulse spark is several degrees later than the normal retard position of the magneto. It makes no difference in the time of the spark produced with the coupling in operation, whether the timing lever of the magneto is in advance or retard but as soon as the pawl is snapped out of operation, the time of the spark is determined by the position of the timing lever.

This automatic retard feature makes it possible, if desired, to use a fixed spark magneto timed far enough in advance to give the most power. The Starter retards the spark for starting, making it impossible for the operator to receive a back-kick, and causing the magneto to produce a hot and intence spark.

243. Timing the Magneto. The Sumter Impulse Starter is keyed to the rotor in the proper position and in order to time the magneto to the engine, the pawl is simply snapped back into inoperative position and the magneto timed in the usual way.

244. Assembling. Note from Figure 77 that the parts which constitute the rotating element carry two compression springs, the long actuating spring SC-10 and the short cushion spring SC-11. The cushion spring snaps securely in place and does not need to be removed when the Starter is dissembled. This spring has a certain position relative to the stop lug, depending upon whether the Starter is Right Hand or Left Hand, being located in a clockwise direction from stop lug on Right Hand Starter, (as shown in Fig. 76) and in a counter-clockwise position from stop lug on Left Hand Starter, as shown in Fig. 76. When couplings are assembled, the stop lug on cam member SC-9 are assembled, the stop lug on cam member SC-9, is positioned between the springs. To put the actuating spring in place, a pin or nail should be inserted in the lateral hole as shown in Fig. 77 Ends of the spring are pressed into spring chamber first, and by pressing on the middle portion, it can be readily assembled. This will leave a suitable

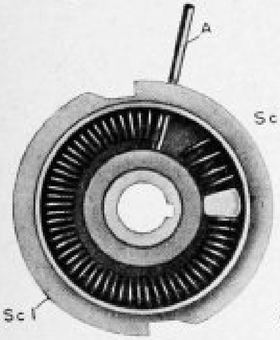


FIGURE 76

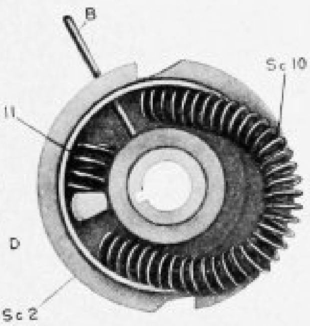


FIGURE 77

opening between the small cushion spring and the pin "A" Assemble cam member with its stop lug in this space, after which the pin or nail is removed. By turning the two members on each other, a simple test can be made which will determine as to the correct action of the spring.

245. Care of the Sumter Impulse Starter.

Oiling—

The Starter is packed with grease at the factory. The grease used does not harden in cold weather and consequently leaves the members free at all temperatures. This is the preferred method of oiling but necessitates the dissembly of the Starter for renewal of the grease. A liberal supply of machine oil should be applied through the hole indicated in Fig. 77 at intervals of a week or so. Should the engine not be used for several months, it may be found desirable to take the Starter apart, clean it and repack with grease.

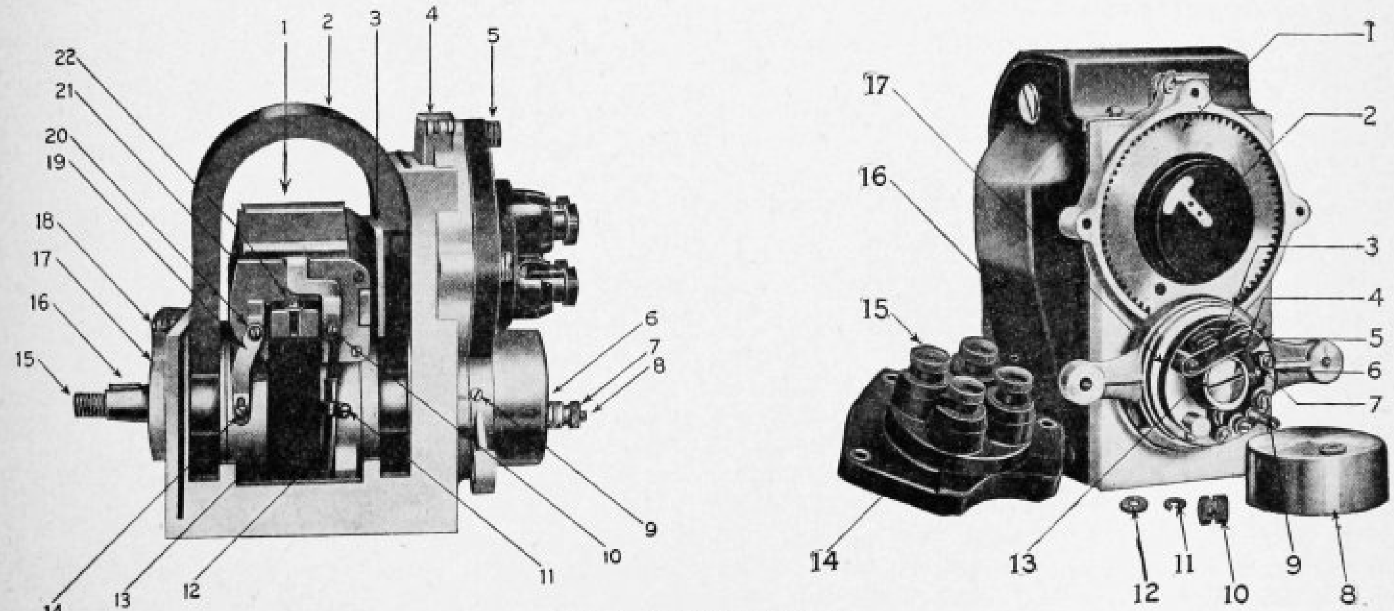
Oil the pawl pin and see that the pawl works freely on the pin. Oil the plunger and its spring and pin and keep these parts free from accumulations of dirt and grease.

General—

246. Keep the Starter Clean. Should the engine stand exposed to the weather, cover the Coupling with a coating of grease or oil to protect it from rust.

Never attempt to force the pawl into engagement at high speeds. Never permit the pawl to remain in operation while the engine is running. If the pawl does not engage at slow speeds or when starting, do not by any means attempt to weight it or otherwise hold it into engagement. Determine the cause for the improper action and remove it.

If the pawl does not automatically throw out of engagement at about 200 to 250 r. p. m., be sure that it is working freely on its pin and that the plunger and spring are free to act. If the pawl throws out at too low speeds, stiffen the plunger spring by stretching it slightly or put on a new spring. It is important that you do not stiffen the spring if the pawl is disengaging at a speed of 250 r. p. m., or over.



The K. W. Impulse Starter

FIGURE 77½

247. Care of the Dixie Magneto. Lubrication— The rotor of the Dixie is light and carried on big substantial ball bearings. Very little oil is required, but that little is quite necessary.

It is important that if the tractor is new, or if it has been idle for two or three months, that before starting you fill the oil cups "A" and "B" (Fig. 78) with

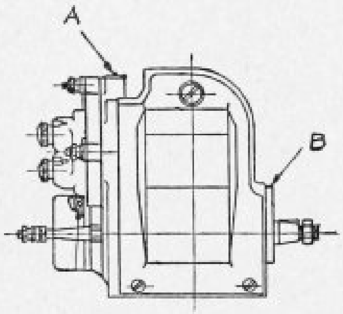


FIGURE 78

a good light oil such as "3-in-1" or sewing machine oil twice.

Oil the back cup "B" (Fig. 78) every twenty hours of actual operation with two drops of good oil. The oil goes to the ball bearing on the drive shaft end of the magneto.

Oil the front cup "A" (Fig. 78) with four drops of the same oil every twenty hours of actual operation. Part of this oil goes to the breaker end ball bearing, while part goes through another hole to the bronze distributor bearing well.

Every two hundred hours of operation get a drop of oil on a toothpick and place it on the breaker bar hub oil hole as shown in Fig. 79. This oil goes down into the center of the hollow pin which forms a bearing or stud for the breaker bar to work on and is fed to the rubbing surfaces as required.

Always be careful not to over-oil the magneto. While some provision has been made for disposing of an excess amount of oil automatically, and while the

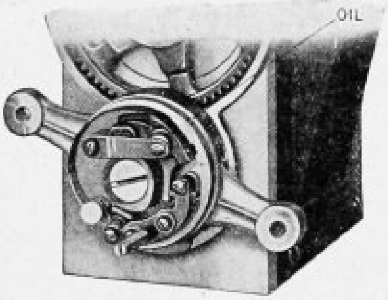


FIGURE 79

high-up stationary windings in Dixie are not easily reached by oil, still too much oil fouls the platinum contact points, causing sparking at the points, burning of the contacts, misfiring of the engine, hard starting, and means that eventually the contact points will have to be replaced. Keep the magneto as a whole and the breaker mechanism in particular, free from excess oil.

And never use a heavy engine or cylinder oil in the magneto. Better not oil it at all for a few days until you can procure the right kind of oil.

Oil the magneto regularly. Keep it clean.

248. Contact Points. The contact points in the Dixie are made of an alloy of platinum and iridium, the best material so far found for this purpose. While reasonably good substitutes are available, the quality of the Dixie magneto has never been cheapened by their use, although a considerable saving in cost could be made.

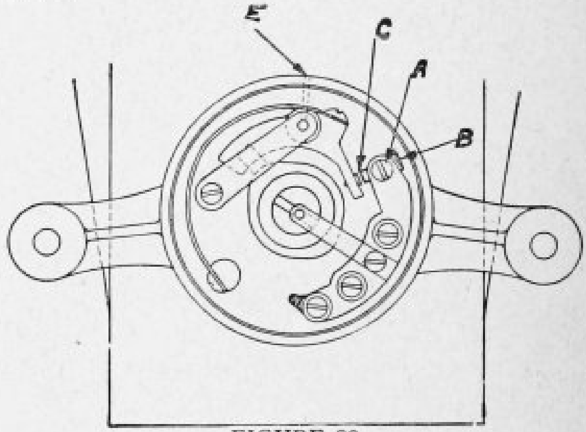


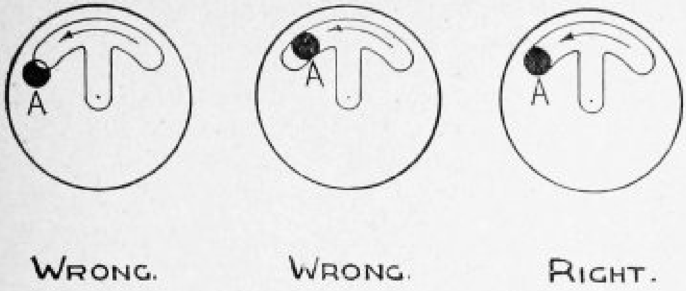
FIGURE 80

The contact points "C" should have a maximum separation of .020 inches which is 1-50 inches. The Dixie screw driver which accompanies each magneto has riveted to the handle a small brass gauge of this thickness which should just slip in between the points when they are widest apart.

Should you need to adjust the points, first loosen the lock screw "A", then turn the platinum pointed screw "B" one way or the other as necessary to get the required gap. Then be sure to tighten the lock screw again. And if a new platinum screw is put in or if the old one is taken out for any reason, be sure that the screw is cleaned and the hole into which it goes is clean, so that good electrical contact will be made.

When oil gets onto the contact points it acts as an insulator and hinders the primary current from flowing across readily. It flashes and burns, and eventually helps to destroy the platinum. A good way to remove oil is to insert a small piece of hard paper or cardboard between the points. Then turn the engine until the points clamp together. Then pull out the card and it will wipe off and absorb the oil. Do not use a soft paper, as it will leave shreds on the points, preventing them from making good contact.

After a season's use the points may become rough. With a coil file or a finger nail file, smooth them squarely and carefully so that they will touch over the whole surface. Platinum is expensive, so file very carefully.



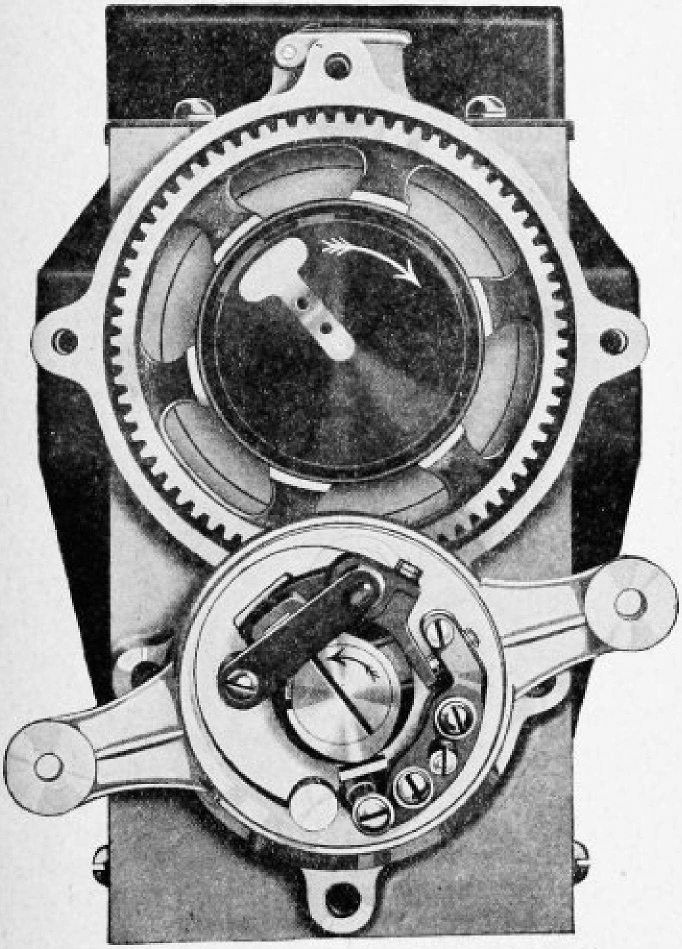


FIGURE 81

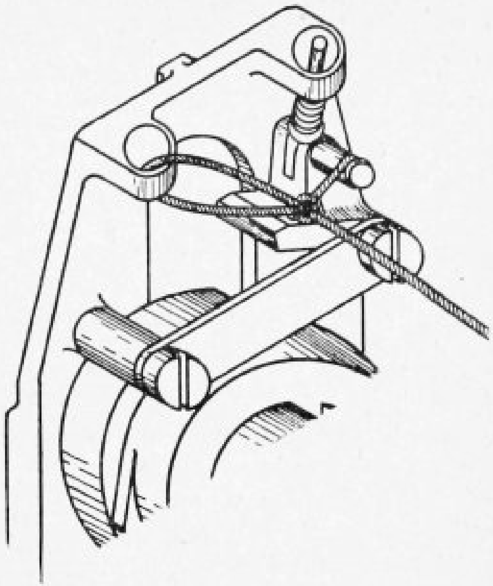


FIGURE 82

249. Timing a Magneto Without Impulse Starter to a Four Cylinder Motor.

FIRST: place the mark on the fly-wheel, D.C., 1 and 4 under the pointer. Examine the tappets on cylinder No. 1. If both tappets can be rattled, No. 1 is on D.C.0 degrees in its cycle. If the intake can be rattled and not the exhaust, then No. 1 is on in-center 360 degrees in its cycle. It will be necessary to revolve the motor one revolution until the same mark D.C. 1 and 4 comes under the pointer; now examine the tappets. When cylinder is on D.C. both tappets can be rattled. Remember that the cylinder on either end of the motor can be called No. 1 without changing the firing order, or effecting the working of the motor in any way.

Second. Remove the cover from the breaker box and distributor, rotate the armature in direction of rotation until the distributor brush is straight down. Retard the braker box as far as it will go by turning it with rotation of the armature. Turn the armature in direction of rotation until the cam in the braker box allows the contact points to come together, and just start to separate. The distributor brush is now on segment No. 1. Hold armature firmly so that it cannot rotate.

Third. Place the magneto on the pad on the motor base. Then bolt up the universal joint. Also bolt magneto to pad. Being careful not to rotate the armature shaft, remove drive gear if necessary in order to line up the universal joint on the magneto drive shaft. In a clock-wise magneto, the segment in the lower left hand corner is No. 1. In a counter clock-wise magneto the segment in the lower right hand corner is No. 1.

FOURTH. Now having the magneto timed to the motor, so that the contact points with a retarded breaker box separate on D. C. and the distributor brush on segment No. 1 lead a high tension cable from segment No. 1 on distributor to the insulated binding post of the spark plug on cylinder No. 1, lead a high tension cable from segment No. 2 to the spark plug on the cylinder next to fire, lead a high tension cable from segment No. 3 to the spark plug on cylinder No. 4, lead a high tension cable from segment No. 4 to the spark plug on the next cylinder to fire. Always wire up in the order of ignition. See Fig. 83, which illustrates the firing order and wiring of a clock-wise magneto to a four cylinder motor, with a firing order 1-3-4-2. See Fig. 84, which is a clock-wise magneto properly timed and wired to a four cylinder motor, with a firing order 1-2-4-3. See Fig. 85, which is a clock-wise magneto properly timed and wired to a six cylinder motor, with a firing order of 1-4-2-6-3-5.

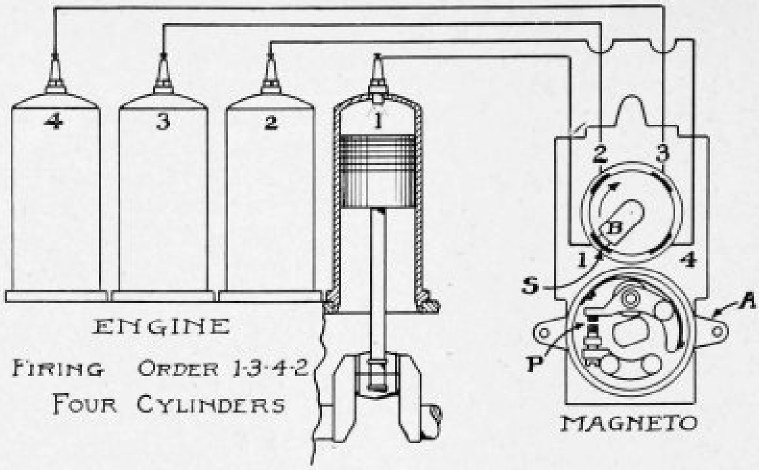


FIGURE 83

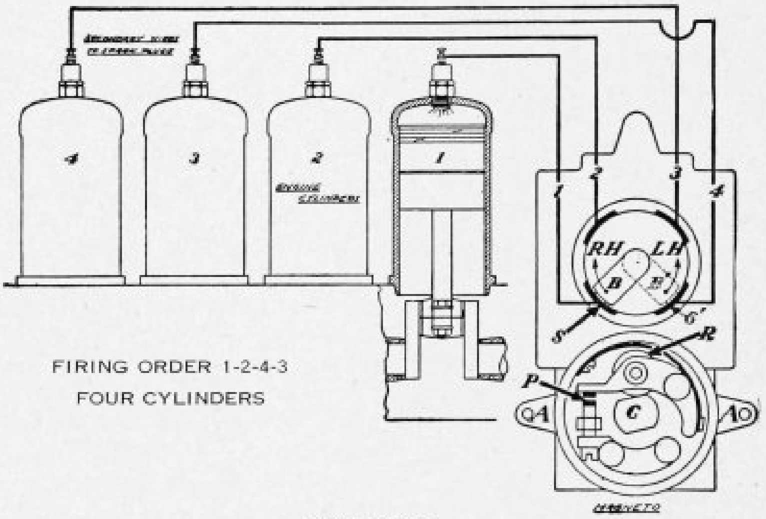


FIGURE 84

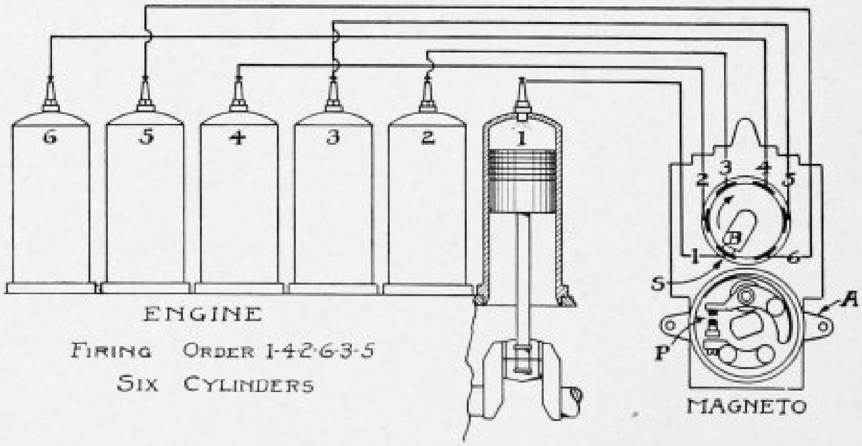


FIGURE 85

The Direction of Rotation. The direction of rotation is determined by the direction the drive end of the armature shaft revolves, or by the direction the distributor brush revolves. If a motor or shaft revolves in the same direction as the hands of a clock it is said to revolve clock-wise. Against the hands is counter clock-wise.

250. Timing a Magneto Equipped With an Impulse Starter to the Motor. First place cylinder No. 1 on D. C. Then remove the distributor cap, and rotate the armature in the direction of rotation until the distributor brush is straight down. Then trip the impulse starter, and rotate it to a point where it is just ready to unhook. Then place the magneto on the pad which is on the motor base, and replace distributor cap and wire to the motor as formerly described.

251. Caution. When timing an ignition system to a motor, always disconnect the wires from the plugs until you are positive the spark occurs on D. C. Never hold the wire to the plug when testing, but to the cylinder, Where an ignition system is equipped with an impluse starter. Always time it with the trip on the starter and not by the contact points, as the position of the two vary; and as long as we cannot get a spark until the starter trips, see that it trips on D. C.

252. Care of Ignition Systems. It is necessary that all parts of an ignition system be kept free from oil and dirt; and that all low tension connections are clean, square, and tight, as the current has not pressure enough to force its way through a loose, dirty connection. Carefully watch all nuts and screws in the low tension system.

253. Care of the Breaker Box. It must be understood that an electric current, flowing from one electrode to the other, carries metal from the positive and deposits it upon the negative. When a direct current is used, it tears down the positive and builds up the negative. Consequently the points grow rough rapidly, by using an alternating current which reverses the polarity of the contact points, and has a tendency to keep the same metal in transit, greatly increasing the life of the points. If the points become rough they produce a throttling action on the primary current, and greatly reduce the magnetic field around the secondary winding with a corresponding drop in voltage in the secondary current. This cause the motor to skip when starting, or when working at exceedingly high compression on heavy loads. These contact points MUST be filed frequently with a coil file, keeping them perfectly square and in line, so that full surface of contact is made. By filing these points frequently less metal is wasted, and more easily started and better running motor is maintained. When filing do not remove more metal than necessary to get a perfect contact, as the metal is very expensive.

254. Gap at Contact Points. When the contact points have been filed, or the breaker box taken down and re-assembled, inspection should be made to see that the gap between the points is correct. When it becomes necessary to readjust the gap, both lock nuts on the adjusting screw should be loosened, and the platinum tipped screw turned in or out until they are set so that the cam will separate them 1/64 inch. When the proper adjustment has been secured, lock nuts should be screwed up tight. The tendency of the contcat points is to grow farther and farther apart. The first symptoms, will be noticed when skipping takes place at high speed, or when the back wheels of the tractor coast into a dead furrow or the plows just lift out of the ground, or when coasting down a grade, when threshing if all pitchers should suddenly stop work. The cause of a motor skipping at high speed when the contact points are too far apart, the cam does not allow them to remain together long enough to induce a magnetic field sufficient to excite the secondary coil.

255. Contact Points Too Close Together. When the contact points are too close together the condenser will not absorb the current causing them to arc keeping the primary current in circuit and the magnetic field around the secondary winding still established. Consequently no high tension current is generated, only as the arc is occasionally broken.

256. Care of the Distributor. The distributor as applied to an ignition system, is a mechanical device, for distributing the high tension current from one segment to the other, in the order of ignition. These segments are connected to the corresponding plug by the use of high tension cables. These cables must be highly insulated and protected so as not to injure the insulation which would cause the current to jump to ground and not jump the gap at the plug. As the current travels through the distributor brush to the segment, it carries metal with it; therefore it is constantly tearing down the brush, which is usually constructed of carbon. This fine carbon is distributed from one segment to another forming an easy path over which the high tension current can travel. When the path caused by these particles of carbon offer less resistence than the gap at the spark plug, the current will pass over them to the segment, corresponding with the cylinder, following the one to fire. This cylinder is about at 540 degrees in the cycle on the intake event, and offers little resistence at the gap in the spark plug, causing this cylinder to ignite and pop back at the carburetor. If the motor is heavy loaded it is apt to cause the motor to stop. The distributor housing must be cleaned often, and it is some times necessary to polish the path over which the brush travels with No. 00 sand paper, as the fine particles of carbon and brass are imbedded in the distributor housing. It is important to keep the path of the brush smooth and clean, also keep the outside of the distritor housing free from oil and dirt, since oil is a nonconductor of electricity. While oil and dirt is a conductor of electricity, if allowed to accumulate will cause the current to pass from one high tension terminal to the other and jump the gap in the cylinder that is on the intake event rather than the one on compression.

257. Advance and Retard the Spark. Although we have broken up the fuel into fine molecules and compressed them very close together, and have compressed the mixture to as high a pressure as practicable, and to a temperature just below the ignition point of the fuel used, in order that the rate of flame propagation be as rapid as possible, and although the flame propagation is practically instantaneous, the fly wheel will travel about 30 degrees when the motor is traveling 800 piston feet per minute, while this charge is burning. Threfore the breaker box must be equipped so that it can be advanced and retarded, according to the speed of the motor. The breaker box should be fully retarded when starting, and running at very low speed and should be advanced about 15 degrees at one half speed, and 30 to 35 degrees at full speed, so that the charge is ignited early enough in the cycle, that maximum pressure is reached at 720 degrees in the cycle. If ignition is late maximum pressure will not be reached, resulting in an over heated motor and a loss of power. When the breaker box is fully advanced at high speed, and the motor slows down, the breaker box must be retarded accordingly. If not, preignition will occur, and a consequent loss of power.

258. Summary. In the preceding lessons I have tried to explain the fundamental principles of the internal combustion motor, the carburetor, and the ignition of the charge and various devices commonly employed to attain the highest thermo and mechanical efficiency. The operator must bear in mind the importance of having a perfect cumbustion, and a tight cylinder so that no leakage occurs to create hot spots or to lower compression.

1st. The fuels must be broken up into the finest molecules possible and impregnated with the true proportions of air to give a true mixture at all volumes, velosities, and reasonable angularities, at the coolest initial temperature.

2nd. The charge must be compressed to the highest pressure possible which is limited only by the ignition point of the fuel used, and the cleaness with which the fuel burns. The higher the charge is compressed, the closer the molecules are together, and the hotter they become, the faster the flame wave travels across the combustion chamber and the higher the initial pressure on the power strike.

3rd. The hotter the spark the quicker the charge ignites causing increase in flame propagation. Consequently there is a less advance of spark necessary to obtain complete burning by the time the crank reaches 720 degrees D. C. This means increased efficiency.

From the above it will be understood that the quality of the ignition system has a great deal to do towards gaining higher efficiency of the motor. It must also be remembered that an ignition system for a gas tractor is more difficult than in the automobile and the truck. Statistics show the automobile is called upon to carry the highest compression and deliver its maximum power only 3 per cent of the time. A truck delivers its full power only 25 per cent of the time, while the gas tractor 75 per cent of the time. Therefore the gas tractor requires a better ignition system.

Owing to the fact that a better ignition system is required for the gas tractor, the high tension magneto has been practically universally adopted. The reason for this can probably be no better explained than by reproducing a paper read by J. A. Williams, President and Chief Electrical Engineer the K-W Ignition Company before Minneapolis Section S. A. E., entitled "Magnetos vs. Battery Ignition for Tractors."

In referring to the title of this paper, "Magneto vs. Battery Ignition," this subject several years ago would not have developed any particular amount of interest.

The natural evolution of ignition in internal combustion motors, from hot tube to battery systems, then to the low tension magneto, and finally to the independent high tension type of magneto, was accomplished through innumerable series of tests during the days of automobile motor development. These tests had brought out the fact that the high tension magneto gave best results under any and all conditions causing the high tension magneto to be universally recognized as the standard.

Efficiency in power production, fuel economy and reliability were the things sought after by the engineers of the automobile industry at that time, exactly as the tractor industry and the stationary gas engine industry are being developed today.

Following the development of the automobile motor, the next demands on automobile engineers were for some means of starting and lighting automobiles. Mechanical starters and air pressure starters were tried out and proved unsatisfactory; then the electric starter and lighting systems entered into the field and have become universally adopted, adding, however, not only considerable first cost to the car, but entailing a considerable charge for upkeep.

It was quite natural therefore for the car manufacturer to seek means to lower the cost of his car in other directions to offset in a measure the added cost of electric starting and lighting equipment. With a storage battery as a source of current, one would naturally argue, why not a battery ignition system? The result, especially among the popular priced cars, was that most of them adopted battery ignition systems. The higher priced cars, however, mostly continue to use the independent high tension magneto. We find the status as to battery ignition among pleasure cars this year to be that fifty-eight models are using high tension magneto ignition and 137 models are using battery ignition. Automobile trucks, however, almost universally are equipped with high tension magnetos.

It is a regrettable fact that this change from magneto to battery ignition has given the general public the idea that perhaps battery ignition was just as good as high tension magneto ignition, whereas a casual analysis of the situation shows the change was made for commercial reasons only.

In our engineering work we have always had in mind the great difference between conditions of automobile operation and conditions of tractor operation. The tractor only resembles the automobile to the extent that a gasoline engine is used for motive power in both cases, and a transmission and differential is used in both cases, but right here the comparison stops.

Automobiles are built as lightly as possible, run on pneumatic tires on good hard roads, carry comparatively light loads and are equipped with motors of such size that they are probably operated 95 per cent of the time at a very low throttle opening. They are rarely ever called upon to develop their maximum output of power and even then but for a few minutes at a time, and inasmuch as it is a pleasure vehicle very little thought or care is given to its fuel economy.

Tractors, however, work nearly all the time under full loads, operate steadily for hours at a time in dust and mud, and run over plowed fields under all weather conditions. They are exposed to the rain and sunshine, heat and cold, when not in use, and their operation is exclusively for profit and not for pleasure. This means that fuel economy and cost of upkeep are extremely vital points. Reliability of operation is not merely hoped for, it is demanded.

For these reasons the designing of a high tension magneto for tractor work cannot be based entirely upon the experience gained on magneto ignition in the automobile field. This applies not only to the magneto ignition system, but practically to every other accessory and part used on a tractor.

In accordance with the title of this paper, I have endeavored to treat both systems of ignition fairly and absolutely impartially from a scientific and technical standpoint. We begin with the principles of battery ignition system, then in the light of these diagrams and explanations, we follow with a description of high tension magneto ignition. We then give a comparison between the two types of ignition, concluding the paper by illustrating diagrammatically how and why a hot spark causes the engine to produce more power and economize greatly on fuel consumption.

Before proceeding with the subject, it might be well to explain to you how a coil of wire is made to generate electricity.

The only known way to generate electricity with a coil of wire is to create lines of magnetic force within its axis, or to remove magnetic lines of force from its axis by decreasing the amount of lines of force, or better still, by reversing their polarity or direction of flow.

The greater the amount or number of lines of force your coil of wire surrounds, and the faster you can effect a rate of change in the quantity of them, the more voltage you will generate within your coil of wire.

It does not make any difference whether your coil of wire should be a spark soil, a dynamo, a magneto, or any other piece of electrical apparatus; this method of fluctuating the amount or reversing the direction of lines of force is the only known method of creating voltage or electrical pressure by means of the use of coils of wire.

The volt is the unit of measurement of electrical pressure, just as is the pound the unit of measure of steam or water pressure.

The ampere of current is the unit of measure of volume, just as is the gallon or cubic foot a unit of measure for fluids.

The ohm is the unit of resistance which opposes the flow of electricity.

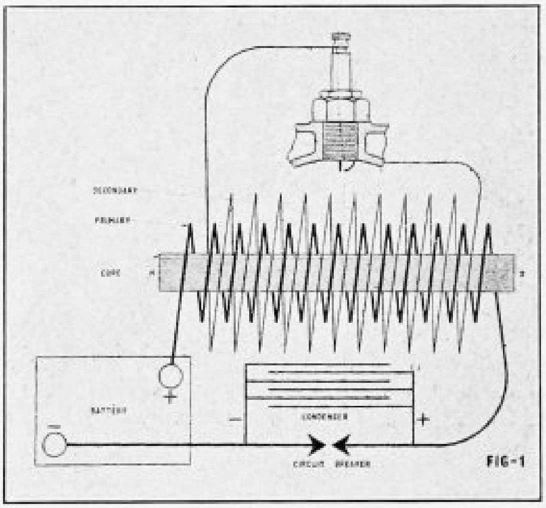


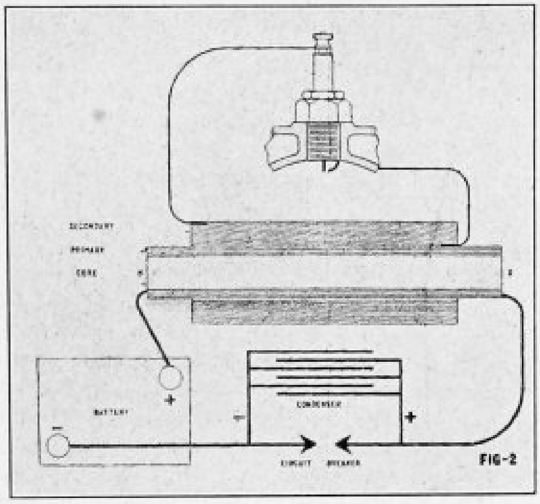
FIG-1

We will now call your attention to Fig. 1, an outline view, and Fig. 2, a sectional view of a battery ignition system.

These views illustrate and show all of the functional parts not only of one battery ignition system, but of all of them, irrespective of their different arrangement of parts for outward appearance.

In the spark coil there as a central core of soft iron wire. This iron wire core is surrounded by or wound with from 150 to 300 turns of insulated copper wire of comparatively large size and low resistance, and is called the primary winding.

Outside of and surrounding this primary winding there is another winding which consists of a large number of turns of very fine copper wire, usually from 20,000 to 30,000 turns, called the secondary winding, one end of which is connected either directly



or indirectly to the frame work of the motor and the other end of which is connected to the terminal of the spark plug.

Referring again to this primary winding it, of course, has a switch in circuit located at some convenient place not shown in the diagram, for turning the ignition on and off by opening or closing the primary circuit.

It also has a circuit breaker or interrupter as designated by the arrow heads in the diagram. This circuit breaker or interrupter is magnetically operated on the ordinary vibrating coil and is mechanically operated on other types of battery ignition systems.

Connected to each terminal of this circuit breaker there is a condenser which is composed of several sheets of tinfoil.

The even numbered sheets are connected to one terminal of the condenser and the odd numbered sheets to the other terminal. These sheets of tinfoil are separated and insulated from each other, either by means of mica sheets or specially prepared paper.

There are in every ignition system two kinds of condensers, a good condenser and a bad condenser. The good condenser does the thing we want it to do and is connected across the terminals of the circuit breaker or interrupter. The bad condenser does the thing we do not want it to do and locates itself within the secondary winding of the coil, and is technically called static capacity of the secondary winding.

Inefficient ignition systems have a very large bad condenser or a great deal of static capacity in the secondary winding.

Good ignition systems have a very small bad condenser and consequently very much less static capacity in the secondary winding.

Having shown the various parts of a battery ignition system, we will discuss the function of the separate parts.

The storage battery simply acts as a source of current.

The iron wire core serves to concentrate and direct the magnetic lines of force that the current circulating through the primary winding creates.

The function of the primary winding is to form a path for the electric current so that it can circulate many times around the iron wire core and thus produce the magnetic lines of force in the core.

The function of the secondary winding is to generate a very high voltage, anywhere from 20,000 to 30,000 volts, so that we will have sufficient voltage or pressure to jump the gap in the spark plug and carry whatever amperage of current the coil delivers.

The function of the circuit breaker or interrupter is to break the circuit and interrupt the flow of current when the current circulating around the core has reached its predetermined or ultimate value.

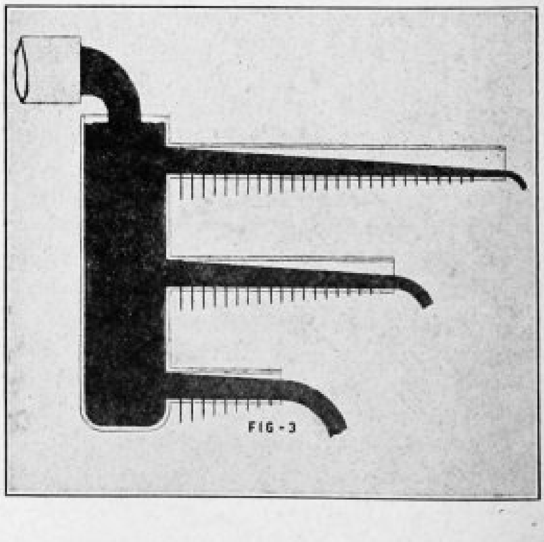
We now come to the function of the good condenser. Its purpose is to absorb the current that forms an arc across the gap between the circuit breaker points when they separate. It is surprising what a large amount of current in amperes or volume a small condenser will absorb.

The capacity of all condensers depends upon two things: First, the area of metallic surfaces opposed to each other; second, the nearness together of those surfaces. In other words, the larger the surfaces involved and the closer together they are, the greater the capacity of the condenser to absorb current.

It is very important in any ignition system to have a condenser of just the right capacity to absorb the current and stop the sparking at the points of the circuit breaker. The points, however, must be allowed to spark a little, just enough to keep themselves burnt clean.

The function of a spark plug is simply to create a gap in the cylinder of the motor for the spark to occur in, which gap should be of the proper width to absorb the maximum energy that the ignition system will produce.

It might be well at this time to explain the function of what we call the bad condenser, the condenser that we do not want, but which insists on being pres-



ent to a greater or less extent in every ignition system no matter how unwelcome it is. When designing an ignition system we must cut down this bad condenser to its smallest possible capacity to do harm.

This bad condenser is located along every inch of wire that the secondary winding has in it. The longer the wire in the secondary winding and the more turns it has, the greater the capacity of this bad condenser.

The har mthat this bad condenser does is to absorb the amperes of current, thus robbing the spark plug and preventing the spark from being as hot as we would like to see it.

To further illustrate the action of this bad condenser or the static capacity of the secondary winding, we will refer you to Fig. 3. We show here three different lengths of water pipe connected together at one end to a larger pipe which is kept full of water.

These pipes all have the same size holes drilled in them and the same number of holes per inch length of pipe, thus creating leaks whereby the water gets away instead of running through the pipe.

You will note that very little water comes out of the end of the longest pipe. Nearly all of it leaks away through the small holes drilled along the length of the pipe.

You will also see that a greater quantity of water flows out of the next longest pipe.

You will also note that the shortest length of pipe has the greatest quantity of water flowing out of the end of it.

Now just imagine that these pipes are the secondary windings of different types of ignition systems, and that the end of the pipe is the spark plug gap, and that the amount of water flowing out of the end of the pipe is the amount of amperes of current flowing across the spark plug gap generating the heat of the spark.

Now let us suppose that the water that is leaking out of the small holes drilled in the pipe represent the amperes of current that are being absorbed or wasted by the bad condenser, or static capacity of the secondary winding.

You will then realize how the secondary winding of an ignition system forms itself into a condenser and wastes the current which we ought to have and would like to get at the spark plug gap for ignition purposes. You will further see that the shorter we can have this secondary winding and still generate the required voltage to jump the spark plug gap, the more current we will have left to create heat in the spark.

You may compare with truth and accuracy these different lengths of water pipe shown in Fig. 3 with three different types of ignition systems as follows: The longest pipe to a battery ignition system; the next longest pipe to the old style or H armature type of high tension magneto; the shortest pipe to the most efficient design of high tension magneto.

In briefly following up the operation of a spark coil, when the circuit breaker closes current flows around the turns of the primary winding, creating and building up lines of magnetic force in the iron wire core. The next step is to have the circuit breaker points open, causing the current which built up and supports the lines of force to cease flowing. The lines of force in the core of the coil no longer being maintained by the flow of current, fall or disappear. They fall, however, in a much smaller period of time than it takes to create them. As previously explained, by disappearing they create electrical pressure or voltage in the turns of the secondary winding. This cycle of operation is repeated every time the circuit breaker points close and open.

The action of a battery ignition system is just like lifting up a hammer and letting it fall on a nail. The only force which you have to apply to the nail is the power that the hammer exerts through its weight in falling. This is rather an inefficient way to drive a nail, is it not?

We have no means in a battery ignition system to handle the lines of magnetic force any more energetically than just to let them fall as the hammer falls on the nail.

The height which you raise the hammer can be compared to the volume or number of lines of magnetic force which you have built up or created in the iron wire core, and their need of disappearance compared to the force of gravitation which brings the hammer down.

We have already shown the manner in which electricity is created by means of a coil of wire, either by increasing or decreasing the amount of magnetic lines of force that the coil or wire surrounds.

Now the amount of electrical energy produced depends upon two things: First, upon the number or volume of lines of magnetic force that you are dealing with; second, upon the rapidity or speed of change that you can effect in their amount or direction of flow.

You will note that half of the magnetic circuit of a spark coil is the air. The lines of force produced in the core of the coil have to travel from one end of the core to the other through the air.

Now as air offers something like 280 times the resistance to the flow of magnetism as does iron, you see that a battery ignition coil has a very inefficient magnetic circuit requiring a very strong current of electricity circulating around the iron wire core in order to produce a very few lines of magnetic force.

The question might be raised as to why it would not be good construction to lengthen the iron wire core and join its two ends together, making a ring of it so that it would have a path of very high magnetic conductivity so that a very small amount of electrical energy could thus produce a very large amount of magnetic lines of force.

The reply to this question would be that it would then take a very long time for the electric current to rise to its full value, owing to the largely increased induction in the coil. Furthermore, after having raised the magnetism to the highest obtainable point, on breaking the circuit it would collapse or disappear very slowly, for as lines of force are generated in the core of the coil, by their very generation they create an opposing voltage which tends to oppose the voltage of the battery current and prevent its rapid rise to its maximum.

Spark coils for battery ignition systems have to be made with straight iron wire cores in order to secure sufficient rapidity of action, consequently they must of necessity have a very inefficient magnetic circuit.

Now if by any means we could double the rapidity with which we vary the amount of these lines of force, or if we could by any means double the quantity of lines of force, we would then be able to get along with half as many turns of wire on the secondary winding.

The effect of this shortening up of the length of the wire in the secondary winding would mean the cutting in half of the static capacity or absorption of current by the secondary winding, and consequently double the amount of amperes delivered at the spark plug points without decreasing the voltage.

You see the more volts that we can make one turn of secondary winding produce, the less surface we expose to absorption of the current produced and the larger the output of energy we get at the spark plug points.

In a battery ignition system we are compelled on account of the limitations imposed by the speed of operation to use an inefficient magnetic circuit which generates a comparatively low voltage per turn of secondary winding, necessitating the use of a very large number of turns and the exposure of a large surface to the absorption of current through static capacity, resulting in the production of the skeleton of a spark at the spark plug points and the leaving of the meat of the spark or amperes absorbed in the secondary winding.

In summing up the principles involved in battery ignition systems, we find inherent faults as follows: First, they do not and cannot create enough lines of magnetic force; second, they do not and cannot handle the few lines of magnetic force they do create with sufficient energy or speed.

In consequence of these two faults they cannot generate sufficient voltage per turn of secondary winding.

Inasmuch as a low tension magneto simply acts as a source of current and a circuit breaker and has to use the same kind of a spark coil as a battery ignition system, it does not produce a much better spark except that it is a much more reliable source of current.

Now if we can design an ignition system which will have nearly all of its magnetic circuit composed of soft iron or steel, this will give us a very efficient magnetic circuit, thus permitting us to generate and handle a very large number of lines of magnetic force. We must, however, have means for causing the rapid disappearance or reversal of these lines of force.

Let us now look into the principles employed in the high tension magneto and we will see whether or not that device remedies any of the defects existing in the spark coil of a battery ignition system.

Fig. 4 is an illustration of the working principle of a modern high tension magneto largely in use in the tractor and stationary gas engine fields.

We have a soft iron core, a primary winding surrounding it, a secondary winding outside of the primary winding, a circuit breaker and a condenser. We have every functional part of a battery ignition spark coil.

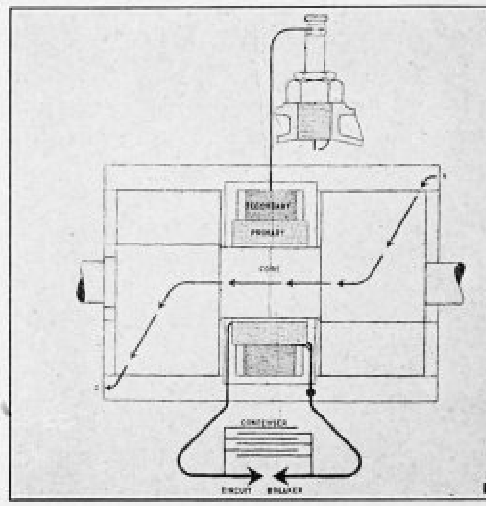


FIG-4

Instead, however, of a storage battery we have permanent magnets. The permanent magnets in this view are not shown, as we are looking up from the bottom of the magneto so as to get a better view of the windings and core.

You will note that the coil of the armature, which is the core of the winding, is 1ound and short and stubby. It has two extensions on each end so as to conduct the magnetism or lines of force from the pole pieces of the permanent magnets to the core of the winding through the core of the winding and out at the opposite pole.

This core of the winding is located in the direct path of flow of the greatest number of lines of force from the permanent magnets, and being made of the softest iron, it forms a good conductor, thus concentrating all the lines of force of the permanent magnets and conducting them to the center or axis of the winding.

You will further note that the secondary winding is very short for a large number of turns, and a great length of wire is not necessary in this design.

The pole pieces on this magneto, instead of being set directly opposite each other, have their centers spaced 90 degrees apart. The extensions of the armature core or rotor are also set 90 degrees apart, so as to conform to the location of the pole pieces of the permanent magnet, thus giving the shortest possible path for the magnetic lines of force to go from pole piece to pole piece, and at the same time making all of them pass through the center or axis of the winding.

By referring to Figure 5, which is an end view of the same magneto, you will note that the air gap in circuit is just as small or short as will permit of a safe running clearance of the rotor or care extensions.

In comparing Fig. 4 and 5 to the construction of the spark coil of battery ignition system, you will see that we have enormously shortened the core of the coil, and in addition thereto have almost entirely eliminated the long high resistance air path of the battery spark coil, thus providing an easy path for a very large number of magnetic lines of force to flow through.

Now let us see how we can compel the rapid disappearance of this large body or number of lines of force, by reversal of polarity, thus not only handling a very greatly increased number of lines of force, but also handling them at least twice as energetically as could be done with the battery ignition coil.

Position A of diagram 5 shows the rotor or core at rest. The magnetic lines of force are coming down through the wing of the rotor nearest to us, are passing centrally through the round core and round winding and are going up the core extension on the other side of the winding to the opposite pole of the permanent magnet.

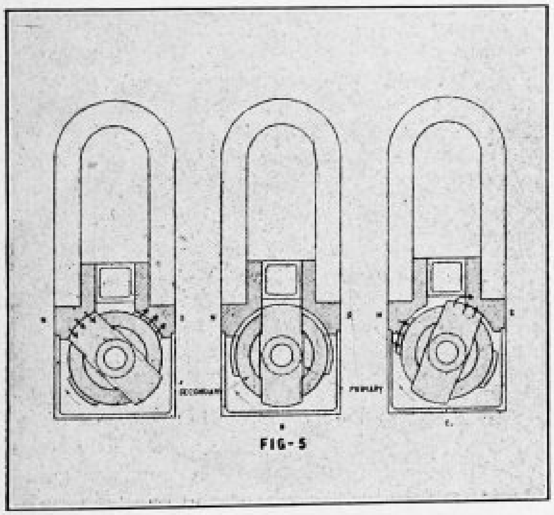


FIG-5

In position B, diagram 5, the armature is shown in a different position as it is being rotated to the position C. Position C shows the rotor in position that it occupies during the time that a spark is being delivered to the spark plug. We will now see that the arrows are going into the core on the opposite or further side of the winding and are going through the core and passing out on this side of the winding, showing that we have a complete reversal of polarity through the winding.

Now in summing the whole matter up in a few words, we find that a modern high tension magneto corrects all of the inherent defects in a battery ignition system. It handles a very much larger number of lines of force accelerating their rate of change by reversal of polarity, thus handling them far more energetically.

This is doing just the thing which we have previously noted will cause the generation of a higher voltage per turn in the secondary winding, thus permitting the use of a secondary winding of very much shorter length, consequently exposing much less surface wire to the action of absorption of current by static capacity, cutting down the opportunity of the so-called bad condenser to rob the spark plug gap of the current necessary to give it the greatest heat of spark.

Referring to this hammer and nail illustration with this high tension magneto, we can now raise the hammer to a very much greater height and we can slam it down with a great deal more force, thus driving our nail efficiently and quickly.

Now, having shown why a battery ignition system produces a weak spark, and a high tension magneto system produces a hot spark, it remains to be shown how and why a hot spark will cause an engine to produce more power with less fuel consumption than a weak spark.

There has always been a great deal of difference of opinion among engineers as to whether a hot spark is any better than a weak spark. Some of them seem to think that a spark is a spark, and so long as it does not make a missed explosion you are getting all out of it that is possible.

Nothing is further from the truth than that assumption. In practice we find that the weaker the spark is the slower the propagation of flame in the mixture, necessitating a much greater advance to the spark.

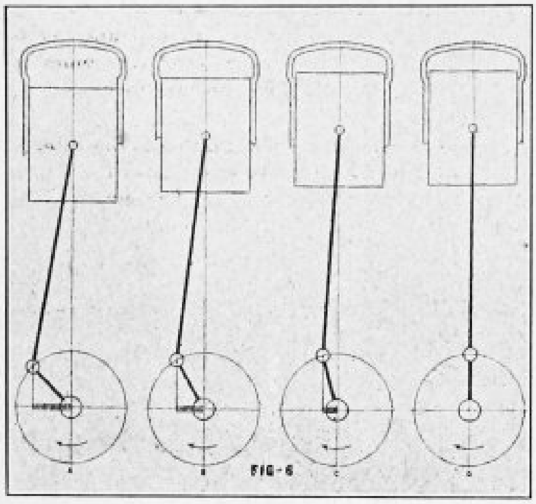
Practice further shows that the hotter we can have our spark the less early we have to make it occur in advance of dead center, for there is a direct relation between the heat of the spark and the speed of flame propagation in the mixture.

Fig. 6 is a diagrammatic view of an engine cylinder, piston, connecting rod and crank throw, showing four different positions.

The sparking is supposed to be occurring in these different positions. Position A shows the spark advanced further than in any other diagram. This position represents the engine firing with a weak or battery ignition spark.

Note the shaded area projected down from the center of the crank shaft. This represents minus torque, or that power which is using up fuel in an effort to run the engine backwards.

Position B represents the engine firing with a still hotter spark, and consequently with less spark advance needed. You will note that the minus torque arm is now shorter, showing less fuel burned and less power expended in the minus direction.



Position C shows the engine in operation with a hot, powerful high tension magneto spark, which is occurring still nearer dead center, wasting less fuel, generating more power in the forward or plus direction, and burning less fuel and exerting less power in the minus direction.

Position D represents the ideal condition, which we have not yet attained, but will attain just as soon as we can create ignition sparks as hot as they should be. If we can get an ignition spark hot enough and large enough, we can make the propagation of flame through the mixture so fast that we will not have to begin to ignite the mixture a long way ahead of dead center as we do now with the weakest sparks.

Do you imagine that a steam engineer for one minute would think of admitting his steam pressure to his cylinder as far ahead of dead center as a gas engine has to admit its pressure by starting ignition?

Of course you all know that steam is admitted to a steam engine slightly after it passes the dead center position. So will gas engines admit the spark which ignites the mixture slightly after the crank passes dead center position, just as soon as they are provided with ignition sparks that are hot enough to give the proper rate and speed to the propagation of flame through the mixture.

One might say to this: "Why, of course we have to advance the spark in order to get the greatest power out of our engine; if we operate the engine with too late a spark our engine will run hot and will not develop its full capacity of power."

That of course with the present ignition sparks is absolutely true, for when lighting a mixture with a weak spark its flame propagation is so slow that unless ignited a long way ahead of dead center, it will still be burning when the exhaust valve opens, and a great deal of fuel will be thrown out of the exhaust valve unburned.

I cannot see how anyone for a moment could doubt the greater value of a hot spark over a weak one. Suppose you were going to kindle a fire in the stove or grate and wanted to have that fire burning briskly within the shortest possible space of time, would it not greatly facilitate matters if you used plenty of good kindling and lit that kindling with a hot blow torch flame all over at once? Of course it would.

Well, in the clynider of your gas engine you are kindling a fire, and in a high speed motor you have to kindle that fire and burn up all the fuel in an inconceivably short space of time.

This might be an appropriate time to let you know that we are constantly doing a great amount of research work in our laboratory, and we believe that this ideal spark is not only a possibility but a probability. At any rate, we have absolute faith in the accomplishment of it, as the results obtained from our experimental data and research work lead us to believe that we are working in the right direction.

In conclusion, since we have seen that the modern high tension magneto not only gives now, but promises for the future so much better results than any type of battery ignition, is it not the part of wisdom for builders of engines to cleave to and encourage the development of that system of ignition which promises ultimately to solve properly their ignition problems?

CHAPTER VI

THE SPARK PLUG

259. The Spark Plug. The spark plug is a simple devise which consists of two terminal electrodes carried in a suitable shell member, which is screwed into the cylinder. An extending into the combustion chamber with the high-tension system of ignition, the spark is produced by a current of high voltage jumping between two points which break the complete circuit.

The spark plug is the device which makes final use of the ignition current. It must have, to be successful and efficient, many characteristics which have been more or less difficult to obtain.

The primary plug function is to convey all the spark current to the gap between the electrodes. This means that its insulation must withstand the enormous voltages generated by modern ignition magnetos. Under all conditions of heat, cold, moisture, and pressure, the insulation must permit no leak.

The inner end of the plug is hot. The temperature in the combustion chamber of a tractor engine reaches 3000 degrees Fahrenheit. Its outer end is cold, fanned by cool air, or even rained or snowed upon when in operation.

The pressure of the exploding gases reach, sometimes, 400 or 500 lbs. per square inch. The plug must stand that without leakage.

The spark, which is an electric arc, jumping the gap, has a corrosive effect on the metal in the points. The products of combustion also tend to corrode these points. The metal in these must withstand this corrosion.

Frequently, in replacing a plug, the wrench slips and hits it. If the insulator has not good mechanical strength, it breaks and must be replaced.

Carbon is deposited in the combustion space of all tractor engines. Carbon collects on the exterior surface of the parts exposed to the explosion. Some engines are much worse in this respect than others. This carbon, when it collects in sufficient quantities, forms a leakage path for the high tension current to travel over the surface of the insulator from the central electrode to the shell without jumping the gap. The carbon must be cleaned off occasionally and this requires that the plug be made in pieces so that it can readily be taken apart and re-assembled.

Typical spark plugs are shown in section Fig. I.

A, is known as the conical plug.

B, is known as the petticoat plug.

C, the open type plug.

In operating the motor on gasoline either one of these types will give satisfactory service, but when

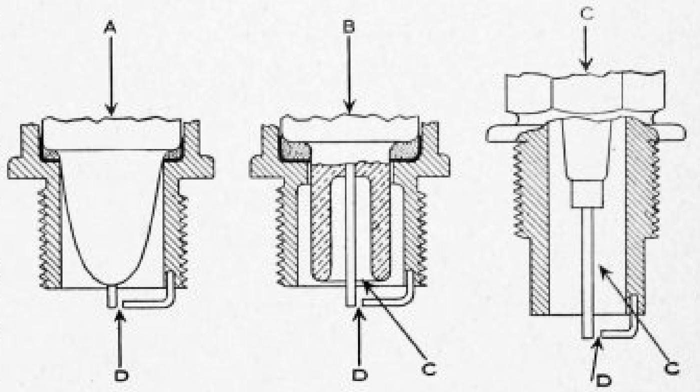


FIG. 1.

operating on kerosene plugs B. and C. have been found to give the best service.

It will be noted at C, Fig. I, there is a large gap between the center electrodes and the procelain which prevents carbon deposits shortening the circuit. The gap at D. Fig. I. should be about 1-32 of an inch.

In replacing spark plugs care should be taken to have the end of the plug extend through the cylinder wall and flush with the inner surface of the combustion chamber. See Fig. 2.

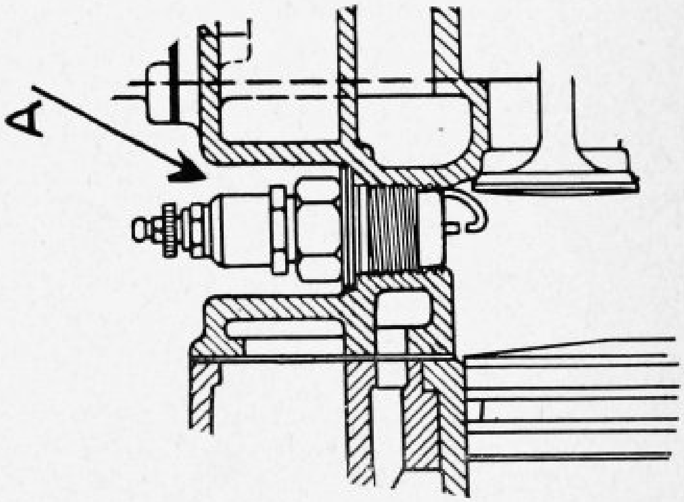


FIG. 2.

260. The Splitdorf Green Jacket Spark Plug. This plug is different in that the insulator is constructed of rolled Ruby India mica. The mica, in strips, is rolled onto a tapered steel stem. This, with the mica, is then pressed into a steel sleeve having the same degree of taper. The mica layers are then pressed tightly together and are leak proof. This mica constitutes the sole insulating member, but to protect it on the outside and to give the plugs a neat appearance, a green jacket is slipped over it and held on by a nut and washers. The central electrode which is steel, carries on its inner end, securely attached, a stem of nickel which extends out the end and forms one of the electrodes. The other electrode, also of nickel, is securely riveted into the shell, and bent over to form the gap between itself and the central electrode.

This construction makes an ideal plug for heavy duty because—

The mica is not affected by heat.

There is no porcelain to crack and chip under high temperatures and pressures.

The plug is leak proof.

Mechanical blows do not break it.

Moisture does not affect it.

And it can easily be taken apart for cleaning.

While this plug costs more than other plugs, it is fully worth it, as it is practically indestructible, and will last, under proper care and conditions, as long as the engine. See Fig. 3.

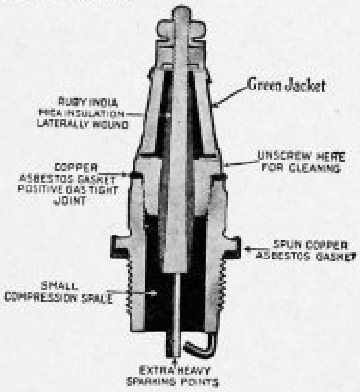
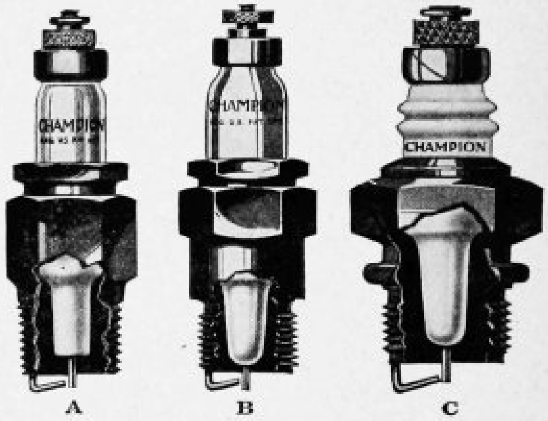


FIG. 3.

261. Care of the Spark Plugs. It is better to examine the plugs occasionally than to wait until trouble compels you to. Take them out, take them apart and clean them thoroughly all over. An old tooth brush and gasoline are good agents to use in cleaning the carbon from the inside of the shell. Use a brush very carefully indeed on the mica insulator. Better, use a cloth and gasoline to wipe off the carbon that has collected on the mica. Do not scrape the mica with a knife or tool, as this will scale it off and make it rough.

Reassemble the plugs, being sure to get them good and tight to prevent leakage. A plug that leaks not only makes the engine inefficient by lowering the compression, but it gets very hot and full of carbon and oil.

Before putting either a new or a cleaned plug into an engine, be sure the gap is right. The standard plug gap is .025 inches (which is 1-40 inch) to 1-32 inch in width. Use the contact point feeler on the handle of the Dixie screw driver and set the plug gap about 20 per cent wider. This gap setting is very important, and should always bave attention.



A—Two-piece plug — illustrating the Petticoat or open type insulator.

B—Two-piece plug — illustrating the Conical or closed type insulator.

C—One-piece plug—Conical type insulator.

FIG. 4.

CHAPTER VII

STARTING AND LIGHTING

262. Review of Electrical Units. We have already taken up the three most common units in our discussion on elementary electricity; but we shall refer to them here again, and illustrate their relation to each other by example. It will be remembered that the unit of electrical pressure or potential is the **volt.** The unit of current is the **ampere,** and the unit of resistance is the **ohm.**

All electrical conductors offer more or less resistance to the flow of an electric current. The resistance varies greatly with similar conductors of different materials; and with conductors of same materials it varies with the length, cross section and temperature. That is, if the length of a wire of a given diameter is doubled, its resistance is also doubled; and if the cross section of a wire of a given length is doubled, the resistance is only one-half of what it was before. The resistance of most conductors increases as they heat up, but with a few the opposite is true.

The relation between the units is expressed in ohm's law stated before, and is indicated by the formula (1) $I \; \frac{E}{R}$ where I = amperes, E = volts, and R = ohms. This formula can be written in terms of either of these units so that if any two are known, the other can be found by solving the formula. That is, (2) $R = \frac{E}{I}$ and (3) E = I R. For example, we have a 6-volt storage battery; and we want to know what current will flow through a conductor whose resistance is 3 ohms, when it is connected between the terminals of the battery. We would then apply formula (I) $I = \frac{E}{R}$ or $I = \frac{6}{3} = 2$, showing that two amperes will flow through the conductor. In like manner, if we know that a conductor is passing 2 amperes at 6 volts, and we want to find the resistance of the conductor, we would apply formula (2) and $R = \frac{E}{I} = \frac{6}{2} = 3$, showing that 3 ohms is the resistance of the conductor.

We wish to consider also the **watt** or unit of power. This is obtained by multiplying the amperes by the volts. One **watt** is equal to one ampere flowing at a pressure of one volt. Thus the formula can also be or watts is Watt — E I. This formula can also be written in terms of either E or I, so that if any two of these units are known the other can be obtained.

For example, a tungsten headlight takes one and one-quarter watts per candle power. That is, if we have a 15 candle power headlight, the number of watts that it will use will be equal to 15x1¼ or 18.75 watts. If it is a 6 volt lamp it will use 3.125 amperes, this result being obtained by dividing the watts by the volt, or $I = \frac{Watt}{E} = \frac{18.75}{6} = 3.125$ amperes.

It takes 746 watts to make one horsepower; so that if we know the watts developed in a circuit, we can get the horsepower by dividing the number of watts by 746. For example, if a 12 volt storage battery is discharging 100 amperes through a circuit, it is developing 12x100 = 1200 watts, or $\frac{1200}{746}$ 1.6 horse power.

263. Electrical Conductors. All substances conduct electricity in some degree; but substances like glass, rubber, fibre, porcelain, mica, etc., offer a very high resistance to the flow of electricity, and can for ordinary purposes be considered as non-conductors or insulators. Metallic substances such as copper, silver, iron, nickel, brass, carbon and lead, offer very little resistance to the flow of an electric current, and are commonly called electrical conductors. Of these copper is most used, this being the best conductor next to silver.

264. Positive and Negative Terminals. The terms positive and negative poles or terminals are often used in connection with electrical circuits, and their meaning should be clearly kept in mind. Every direct current generator has two main terminals. The electric current flows from one of these terminals through the external circuit and back to the other terminal. The terminal from which the current flows is called the **positive terminal,** and the one to which it flows back the **negative terminal.** In a battery the same holds true. The positive and negative terminals are indicated by the signs + and — respectively.

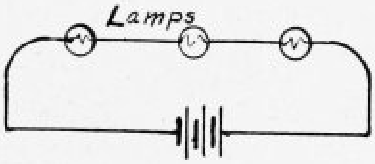


FIG. 1.

265. Different Methods of Connection—Series Connection. Fig. 1 shows three lamps connected in series. It will be seen that in this type of connection the current flows through one lamp after another and then back to the battery. If one lamp burns out the circuit is broken and all lamps will go out. In this case, if they are all six-volt lamps it would take three times six, or 18 volts pressure in the circuit to make the lamps burn bright, since the resistance in the circuit is three times that of one lamp.

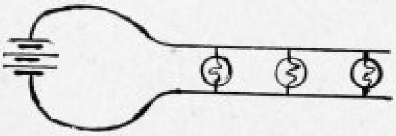


FIG. 2.

Fig. 2 shows three lamps connected in parallel. In this case the current flowing from the battery divides up and flows in equal amount through each of the three lamps and unites again on its way back to the battery. If the lamps are 6 volt lamps as before, it will be seen that the voltage of the circuit will need to be only six volts; but the current drawn from the battery will be three times as great.

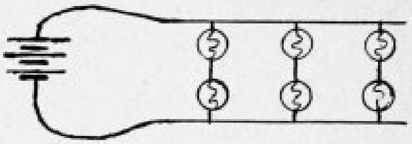


FIG. 3.

The multiple series connection is a combination of the two and is shown in Fig. 3.

266. Short Circuits and Grounds. A short circuit means that the current has found a shorter path back to the battery or generator, than that over which it is supposed to flow. For example, consider a headlight

SIGNS SYMBOLS AND ABREVIATIONS

+	Positive.
—	Negative
→	Arrow indicating direction.
or C.W.	Crockwise revolution.
or C.C.W.	Counter-clockwise revolution.
	Coil of insulated wire. (coarse).
	Coil of insulated wire. (fine)
Ⓐ	Ammeter.
Ⓥ	Voltmeter
	Shunt wound machine.
	Series wound machine.
G	Generator.
Ⓜ	Motor.
	Wires joined together.
	Wires crossing.
	Rheostat or variable resistance.
	Incandescent lamp
+ –	Dry cells or storage battery. cells in series
V	Volt.
A	Ampere.
DC	Direct current
AC	Alternating current.
KW	Kilowatt. (1000 watts).
HP	Horse Power. (746 watts).

FIG. 4.

circuit from the battery through the headlights and back to the battery again. A short in this circuit means that the wires or conductors have come together, forming a shorter circuit back to the battery than the original circuit through the headlights.

In the case of a one-wire system where the ground or frame is used for a return conductor to the battery, a short circuit is called a ground.

267. Signs and Symbols Used in Drawings. The signs most commonly used are shown in Fig. 4.

268. Generators. The electric generator acts as a pump in raising the pressure of electricity so that it can be made to flow through an external circuit and used for doing work.

269. Elementary Generator. The simplest form of generator would consist of a single loop of wire, A, B, C, D, arranged to rotate in a magnetic field, as shown

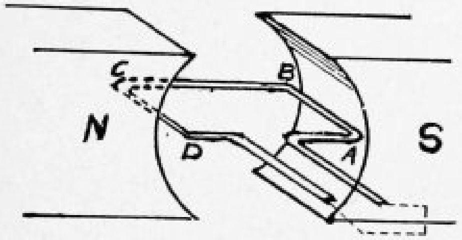


FIG. 5.

in Fig. 5. As the loop is rotated, the sides A B and C D will cut lines of force as they pass under the poles of the magnet. Beginning with the loop of wire in the position shown in the figure, and rotating it in a direction indicated by the arrow, an electro motive force or E. M. F. is induced in the coil. The E. M. F. will depend upon the rate at which the lines of force are cut; and as the loop approaches a vertical position, the E. M. F. decreases until the loop reaches the vertical position when it is zero, since no lines of force are cut. As it starts down on the other side an E. M. F. is again induced, but in the opposite direction. This will be a maximum when the coil reaches a horizontal position, and will again be zero when it reaches a vertical position. If the ends of the loop are connected together by an external conductor, a current will flow through this circuit; but this current will be alternating, since the E. M. F. generated is first in one direction and then in another. An alternating current cannot be used to charge a storage battery, and hence this type of generator is not used in connection with starting and lighting of automobiles. To change the alternating current into direct or continuous current, a commutator is used. Fig. 6 illustrates a commutator in its simplest form. It may be imagined as consisting of a small brass tube which has been sawed in two longitudinally, the halves being mounted on a wooden rod. The wood and the two cuts in the tube insulate the halves from each other. Each one of these halves is connected to one terminal of the loop as shown in the illustration, Fig. 6. If the brushes are set so that

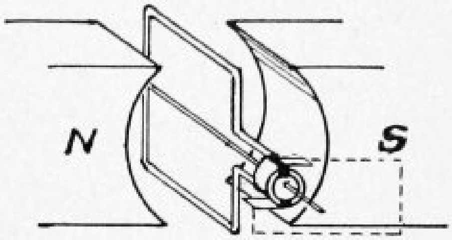


FIG. 6.

each half of the split tube moves out of contact with one brush, and into contact with the other at the same time that the loop passes the vertical position as shown in Fig. 6, a direct current will be delivered to the outside circuit. This current, however, will be pulsating; that is, it will rise to a maximum, then fall to zero and rise to a maximum again. To eliminate this in the practical generator we add more coils, the current from each overlapping that of the others, forming a steady flow of current.

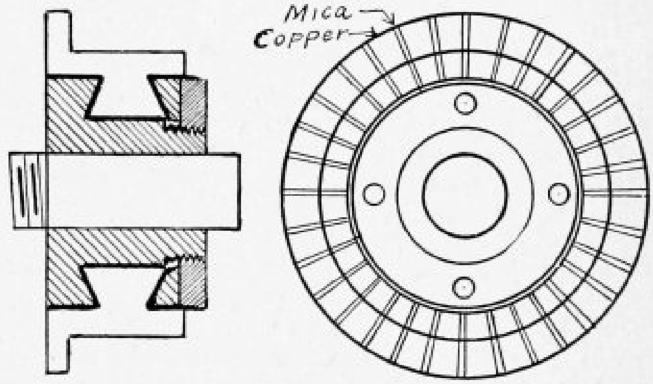


FIG. 7

270. Construction of Commutator. Fig. 7 shows a commutator as used on a practical machine. It consists of copper segments insulated from each other by mica. The ends of the coils in the armature winding are connected to the bars of this commutator.

271. Armature Winding. The armature windings used for automobile generator and motors are of the drum type. The core, which is built up of soft iron discs, is in the form of a cylinder, with slots on its surface into which the wire coils are wound. The principle upon which it works, however, is the same as in the simple generator which we have already discussed.

272. Armature Cores. Iron is the material universally used for armature cores, because it forms an easy path for the magnetic lines of force. The purpose of the core is to carry the magnetic flux from pole to pole of the field magnets and at the same time form a foundation for the armature coils.

To reduce the heating of the armature due to local currents generated in a solid piece of inron, the core is built up of iron discs dippd in insulating compound, and assembled on the shaft which runs through their center.

273. Field Magnets. The simplest form of field magnet is the permanent magnet used on a magneto. This type of magnet is also used on some small generators; but owing to the large size needed to produce a strong magnetic field, they are not used on larger machines.

Another reason is that their strength cannot be varied.

274. Self Excited Fields. The field magnets generally used on electric generators for automobiles are electro magnets. They are called self excited because the current passed through their coils to produce a magnetic field is supplied by the generator itself. By the use of this form of magnet, the output of the generator can be increased or decreased by varying the strength of the field magnets. This is done by increasing or decreasing the amount of current flowing through the field coils.

275. Types of Field Windings. There are three different types of field windings and electric machines. Both generators and motors are classified as follows, depending upon the type of field winding used:

(a) Series wound.
(b) Shunt wound.
(c) Compound wound.

In the series wound machine, the field coils are made of heavy copper wire and so connected that all the current flowing through the external circuit flows through the field coils also, before it completes its circuit. This type of machine is clearly shown in Fig. 8.

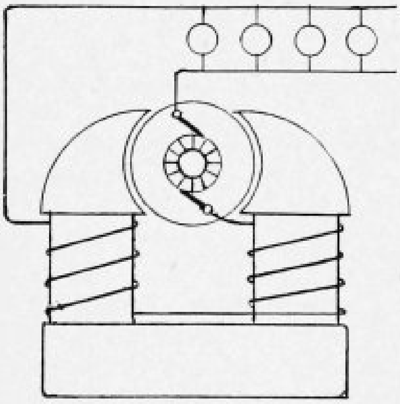


FIG. 8

The shunt wound machine is shown in Fig. 9. In this type the field coils are made of a great number of turns of fine copper wire, and are connected directly

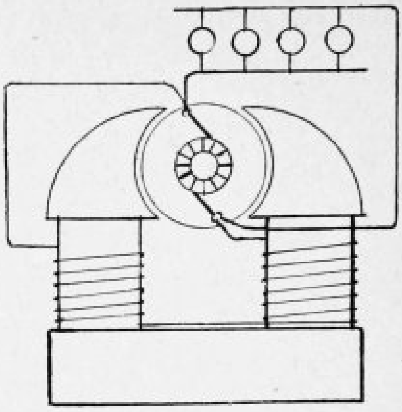


FIG. 9

across the brushes of the machine. Thus the field is supplied directly from the brushes of the machine and are entirely independent of the external circuit. The field coils receive only a small part of the current generated, the greater part of it flowing through the external circuit and serving for lighting lamps, etc.

The compound machine is a combination of the

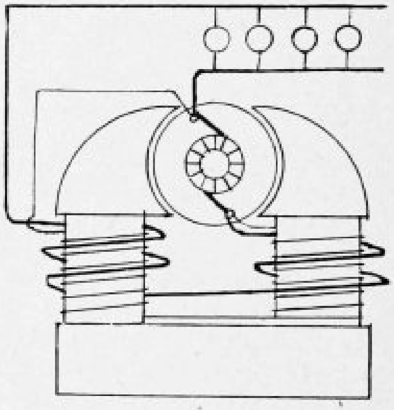


FIG. 10.

series and shunt machines, and is shown in Fig. 10. The shunt and series field coils are wound one over the other. The magnetic field produced by the shunt coil is known as the shunt field; and that produced by the series coil, the series field. In some cases these two fields work together to produce a strong magnetic field; but more frequently in automobile use, the series coil is wound in a reverse direction so that its field opposes or "bucks" the shunt field. It is then known as a "bucking field" or "bucking coil." This bucking action is one method of controlling the output of automobile generators, and will be taken up again later.

276. Brushes. In order to make electrical contact between the windings of the armature which rotates, and the stationary terminals and field winding, it is necessary to use rubbing contacts. For this purpose brushes are used. The first type of brushes used were made of copper strips rubbing on the commutator; but owing to the constant sparking and wear on the commutator, they were soon replaced by copper gauze brushes of rectangular or cylindrical cross section made to slide in brush holders fastened on the frame and held to the commutator by springs pressing on the brushes. The gauze brushes were an improvement over the copper strip brushes, but were not satisfactory.

Carbon or composition brushes have now come into universal use and are much more satisfactory in every way. When these brushes are of a smooth even composition, they work quietly and smoothly over the commutator, forming a glazed surface and making good electrical contact. If gritty or hard spots are present in the brushes, they are often a source of trouble in that they wear the commutator unevenly and cause chattering, resulting in excess sparking and poor electrical contact. When this trouble is encountered the commutator should be cleaned and the brush in question fitted to the commutator by a strip of sand paper. Never use emery paper for this purpose.

The brushes used for starting motors are more metallic than those used for generators, because they must have a greater current carrying capacity. Some starting brushes are made of copper gauze surrounded with carbon.

Brushes are either fastened to one end of a swinging arm or brush holder, and brought to bear on the commutator with the proper pressure by a spring mounted in the arm; or they are made to slide freely in suitable brush holders and held to the commutator by coil or flat springs acting on the top of the brush.

277. Control of Generators—Necessity for Control. Owing to the variable speeds at which automobile motors, and consequently the electric generators connected to them, are run, it is necessary to provide some means of controlling the output of the electric generator at high speeds. The average driver generally drives his car mostly at a speed of 15 to 20 miles per hour; and it is desirable to have the generator produce the maximum charging rate at about 15 miles per hour in order to keep the battery fully charged. If a generator is built to give the desired output of 10 to 14 amperes at a speed corresponding to 15 miles per hour of the car, its output at 25 or 30 miles per hour would be abnormally high if there were no means of controlling the output; and the battery and windings of the generator might be seriously injured. There are several ways in which generators can be controlled, as follows:

278. Ways of Controlling Generators.

1. By friction governor.
2. By bucking coil or reverse series field.
3. By vibrating relay.
4. By third brush system.

1st Class. Generators coming under class one are called constant speed generators. A centrifugal governor and a friction clutch are employed. The driving spindle and the armature are connected through this friction clutch which is held in contact by spring tension. At slow speed there is practically no slip in the clutch; but as the speed increases the centrifugal governor releases the spring tension and the clutch slips in proportion to the speed; this keeps the armature from turning faster than the speed for which the governor is set. The early Gray & Davis systems employed this method of control, but it is little used now.

2nd Class. In the second class we have generators which employ the compound field winding already referred to. The shunt field, which consists of a great number of turns of fine wire, forms a circuit by itself; and draws a small current of about two amperes directly from the brushes of the generator. The series field is made up of a few turns of heavy wire, wound in the opposite direction to that of the shunt field; and is connected in series with the armature, thus carrying all the current flowing through the outside circuit. Fig. 10 shows the way in which the fields are connected up; but the series field is usually wound in the opposite direction to that shown in the figure.

The two fields are so proportioned that if the speed of the generator is increased still more after a normal output of 10 to 14 amperes is reached, the bucking action of the series field becomes so great that the shunt field coil is unable to build up its field any further; and the charging rate will not increase any more even if the generator speed is increased. This method of control is very reliable and has been used extensively by the Auto-Lite Company, and also on some types of Westinghouse generators, and others.

3rd Class. The third class includes generators controlled by throwing a resistance into the shunt field circuit, when the output exceeds a certain predetermined value. The resistance is cut into and out of the shunt field circuit by a vibrating relay, called a regulating relay, or regulator. It consists mainly of an electro-magnet connected in series with the external circuit, and provided with a bar or an armature pivoted about its center so that when one end is attracted by the electromagnet the other end separates two contcat points, which forms part of the shunt field circuit.

A resistance is connected across these points so that when they are open the shunt field current must flow through this resistance. This cuts down the current flowing through the shunt field so that its strength soon drops, and consequently the output of the machine also decreases. As the current in the external circuit decreases, the electromagnet of the regulator becomes weaker; and the armature is brought back to its original position by means of a spring thus closing the contact points. This allows the shunt field to build up until the output again becomes too high, when the process is repeated. When the generator is run above the speed necessary to produce the desired output, the regulator continues to vibrate, keeping the output constant. Fig. 11 shows the internal wiring of a Ward-Leonard Dynamo Con-

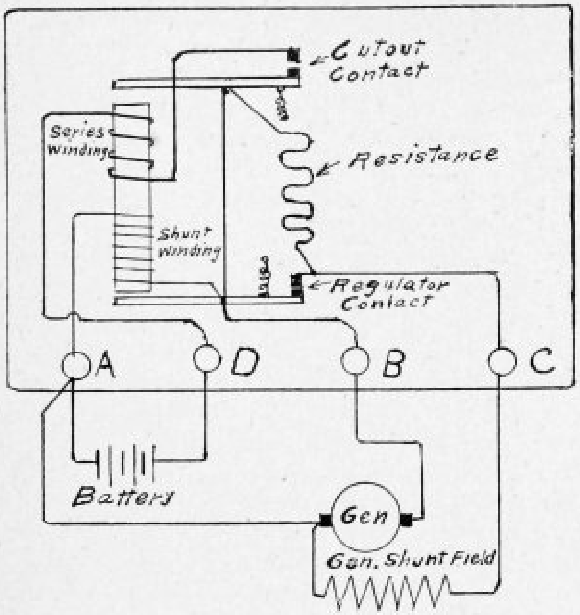


FIG. 11.

troller. This type combines both the controlling relay and cut-out relay in one which is common practice when a regulator is used.

The cut-out relay will be discussed in detail later.

4th Class. This class takes in all generators controlled by what is known as the third brush method. This method has become more and more popular during the last few years, and is now used on nearly all of the principal makes of generators. The shunt field coils, instead of being connected across the main brushes, have one end conencted to one of the main brushes and the other connected to the third brush which is located a short distance from the other main brush. Fig. 12 shows the relation of the brushes to each other.

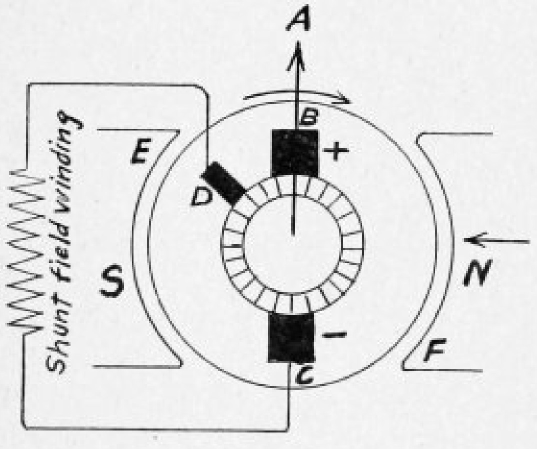


FIG. 12.

Since the output of a generator depends upon the number of lines of force cut by the conductors per unit of time, it is evident that if we can decrease the strength of the field as the speed increases, the total lines of force cut per unit of time can be kept a constant and our regulation is accomplished. To understand this system of control it is necessary to keep in mind that there is always a magnetic field produced about any conductor carrying an electric current. Referring to Fig. 12, the operation is as follows: If there was no disturbance of the magnetic field produced by the field windings, the lines of force would pass uniformly through the armature from the north to the south poles and the voltage between any two neighboring commutator bars would be the same. The maximum voltage of the generator is obtained from brush B to brush C; and this would be about 6½ volts, when the voltage from brush C to brush D is about 5 volts, which is the voltage applied to the shunt field winding.

But as a current is generated in the coils of the armature, a magnetic field is set up through the armature core with the lines of force passing in the direction of the arrow A. This magnetic field of the armature will distort that of the generator field so that instead of flowing uniformly between the north and south poles, the lines of force will concentrate themselves, or group together at the pole tips E and F, and cause the field to be strong at these points. The field through which the conductors pass in going from brushes C to D becomes weaker, and consequently the voltage between these brushes falls and less current will flow through the shunt field. As the speed increases the lines of force of the field are distored and crowded together still more at the pole tips E and F, and consequently there is a lower voltage applied to the shunt field. It is evident then that as the speed increases, the voltage across the shunt field, and therefore its strength, will decrease.

The charging rate can be adjusted by moving the third brush away from or towards the other main brush. When the brush is moved with the direction of rotation, the charging rate is increased; and when moved against the rotation, it is decreased.

Whenever the brush is moved it should be fitted to the commutator by a strip of sand paper.

279. Automatic Battery Cut-Outs. It will be remembered that an electric current will flow through a circuit whenever that circuit is complete and not broken at any point. Therefore it is evident that when the motor is stopped, or when its speed is so greatly decreased that the generator voltage is below that of the battery, the battery will discharge through the generator unless some means is provided to break the circuit. This can be done either by a hand switch or an automatic switch called automatic cut-out, or reverse current relay. The latter is most generally used, and consist of a pair of contact points and an electromagnet. One point is stationary and the other is mounted at one end of an arm which forms the armature for the electromagnet. When the motor is standing still, or running so slow that the voltage of the generator is below that of the battery, the points of the relay are open. As soon as the voltage of the generator is high enough to charge the battery, the elctromagnet of the relay pulls the points together, thus closing the circuit. There are two coils in the relay: one of fine wire and many turns, called the shunt coil, and the other of coarse wire and few turns, called the series coil.

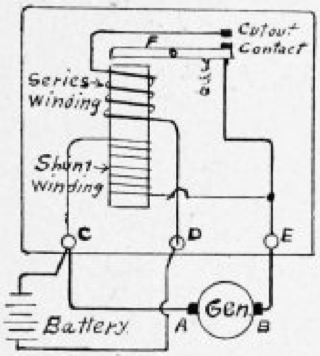


FIG. 13.

Referring to Fig. 13 the relay works as follows: When the generator is rotating fast enough to develop a voltage higher than that of the battery, enough current flows through the shunt coil of the relay to pull down the arm F and close the contact points. This completes the circuit; and the current from the generator will flow from brush B through the contact points, the series coil of relay, and through the battery back to brush A of generator. The purpose of the series coil is twofold. It holds the contact points firmly together after the cut-out is closed and the charging goes on. As soon as the speed of the generator decreases and its voltage falls below that of the battery, the current will begin to flow from the battery back through the generator. As soon as the current is reversed in the series coil its polarity is changed, the soft iron core loses its magnetism and its influence on the arm F, and the spring tension on the arm opens the contact points, and prevents the battery from discharging.

280. Starting Motors. The purpose of the starting motor is to start the motor from rest and turn it over fast enough so that it can pick up under its own power.

It must be so designed that it will give a strong torque or turning force without too much current from the battery, or occupying too much space on the car. To decrease their size and weight, motors are generally built to run at high speed; and are connected to the motor through a train of reduction gears or sprockets and chain.

281. Operating Principle of Motors. It was learned when studying magnetism that like magnetic poles repel each other, and unlike magnetic poles attract each other. This is the principle upon which the electric starting motor works. When current flows from the battery through the starting motor, it first enters the series field and builds a strong magnetic field about the armature. Then it flows through the coils on the armature and magnetizes the armature core, but the polarity of the armtaure core is very nearly at right angles to that of the magnets. The north pole of the armature core is repelled by the north pole, and attracted by the south pole of the field magnet; while with the south pole of the armature core, the opposite is true. As the armature turns, the brushes so distribute the current through the coils that its north and south poles are always in the same place, and a continuous turning force is exerted upon

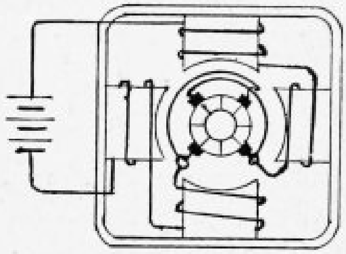


FIG. 14.

the armature. Fig. 14 snows the common arrangement of a four pole starting motor.

Most starting motors are now built to work from a 6-volt storage battery, and at this low voltage a very large current is needed to give the required starting torque. Both the field and armature windings are therefore made of heavy copper wire or copper strips. Each pole piece of the field often has as low as three turns, and a coil in the armature may have but one turn. The field coils are always in series with the external circuit.

Starting and lighting systems may be either of the single unit or two unit types. In the single unit system both the starting motor and generator are combined in one unit. The field coils usually have both a motor and a generator winding; while the armature often has only one winding, using the same one for both generating and starting. Other single unit systems have two separate windings on the armature with a separate commutator for each set of windings. The two windings are insulated from each other, and one is used for starting and the other for generating.

Two unit systems, as the name implies, consist of a separate generator and a separate motor, each independent of the other. This system is by far the more popular and is also more easily installed and taken care of.

282. Single and Two Wire Systems. The two wire system was first employed on all cars. The whole electrical system is entirely insulated from the frame of the car, two wires being used for all lamps and other electrical appliances. The cost of installing such a system was high on account of the large amount of

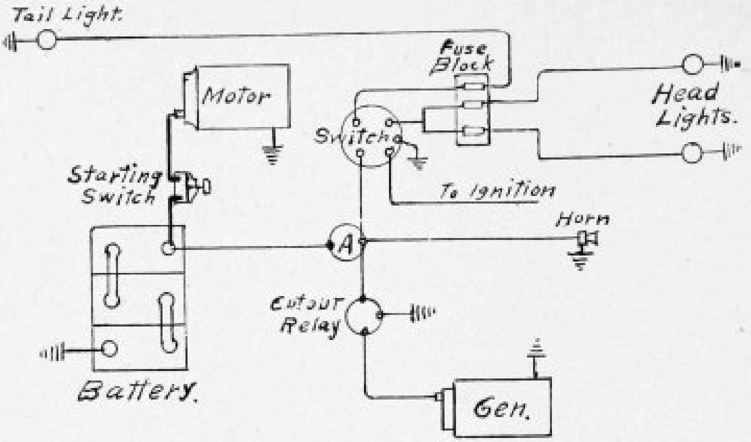


FIG. 15.

wire needed; and it has now been replaced by the single wire system, which has now come into nearly universal use. In this system the ground or frame of the machine is used in place of one wire. Fig. 15 shows a wiring diagram of a single wire system.

283. Care of Generators and Starting Motors. Dismantling. The first and most important care with any piece of machinery, and particularly with electric generators and motors, is to keep them perfectly clean. Any and all apparatus that has been in service and returned for inspection and repair, should be thoroughly cleaned before and during examination. Use great care in cleaning and handling all apparatus whether mechanical or electrical. Do not attempt to dismantle any piece of apparatus without first of all examining it carefully to see how it is put together

284. Re-assembling. When re-assembling electrical apparatus, make sure that all insulated parts have the proper insulation in place. This insulation should not be cracked or damaged in any way. All screws and nuts should be either secured with lock washers and cotter pins, or lock nuts.

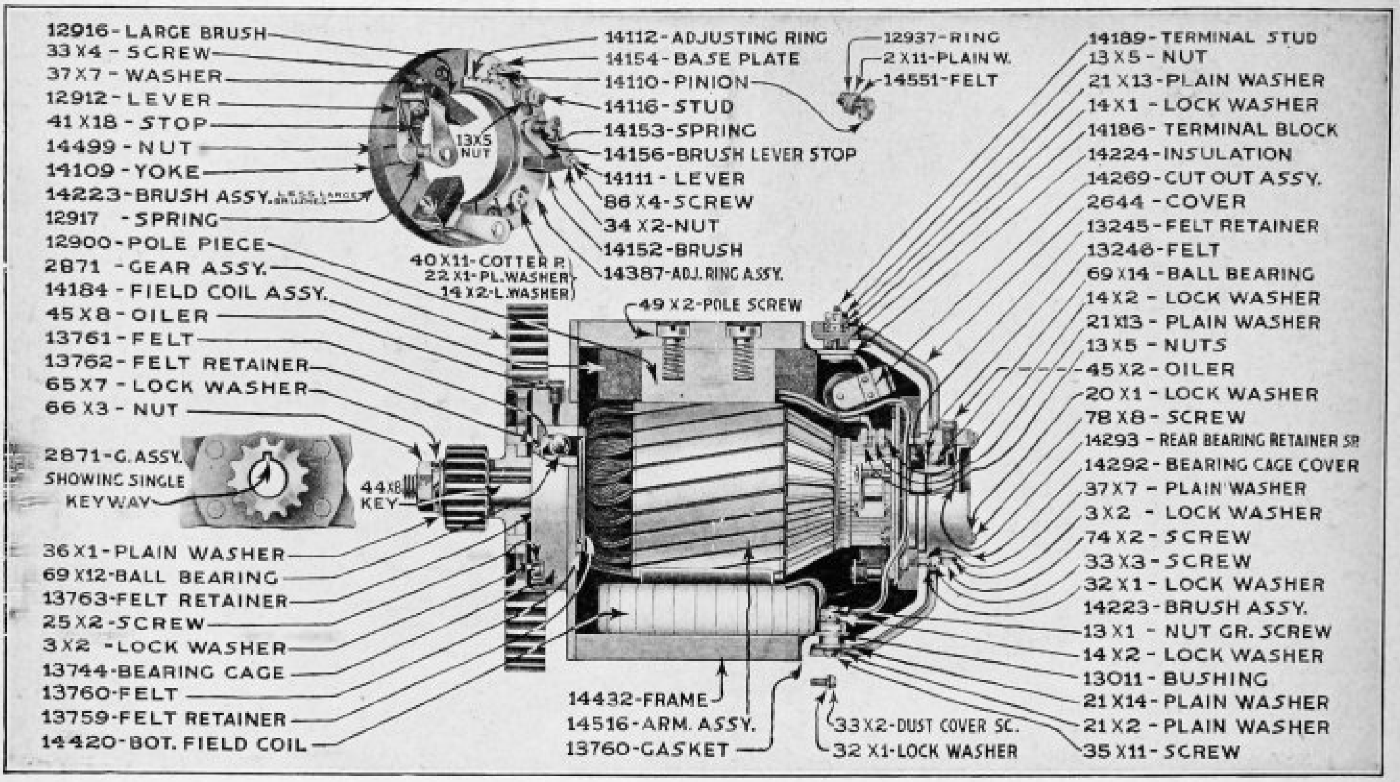
285. The Commutator. The most important parts of the generator and motor are perhaps the commutator, brushes and connections. Great care therefore should be taken in dissembling the end frame upon which the brushes are mounted. Also when re-assembling the end frame, note the following: (1) See that all the leads are correctly in place, (2) that the brushes fit properly on the commutator, (3) that the brush arms are free to work smoothly on their pivots, (4) that they have the necessary spring tension to hold the brushes against the commutator, and that the mica separators do not extend above the copper segments; (5) care must be taken to see that the brush holder is not bent during installation. In a grounded system this would particularly affect the brushes that are not grounded because it might cause them to be grounded, thus grounding the generator. In a grounded system using a four pole generator, two of the brushes are insulated from the end housing, the other two being grounded to it.

286. Bearings. Care should be taken in removing ball bearings to see that they are not injured in any way and that they are replaced in the same position. The use of ball bearings makes it possible to run the generator with a very small air gap. The air gap is the distance between the outer circumference of the armature and the inner face of the pole pieces. By making a generator or motor with a very small air gap, the efficiency of the machine is greatly increased.

287. Removing the Armature. When removing the armature, care must be taken to see that the leads and commutator are not damaged in any way. The commutator is made of copper, which is easily marked if it comes in contact with any hard substance. The leads should be examined to see that the insulation is not cut or worn so as to expose the copper. Single leads, if exposed in this way, should be carefully taped with friction tape, then covered with rubber tape and finally shellaced.

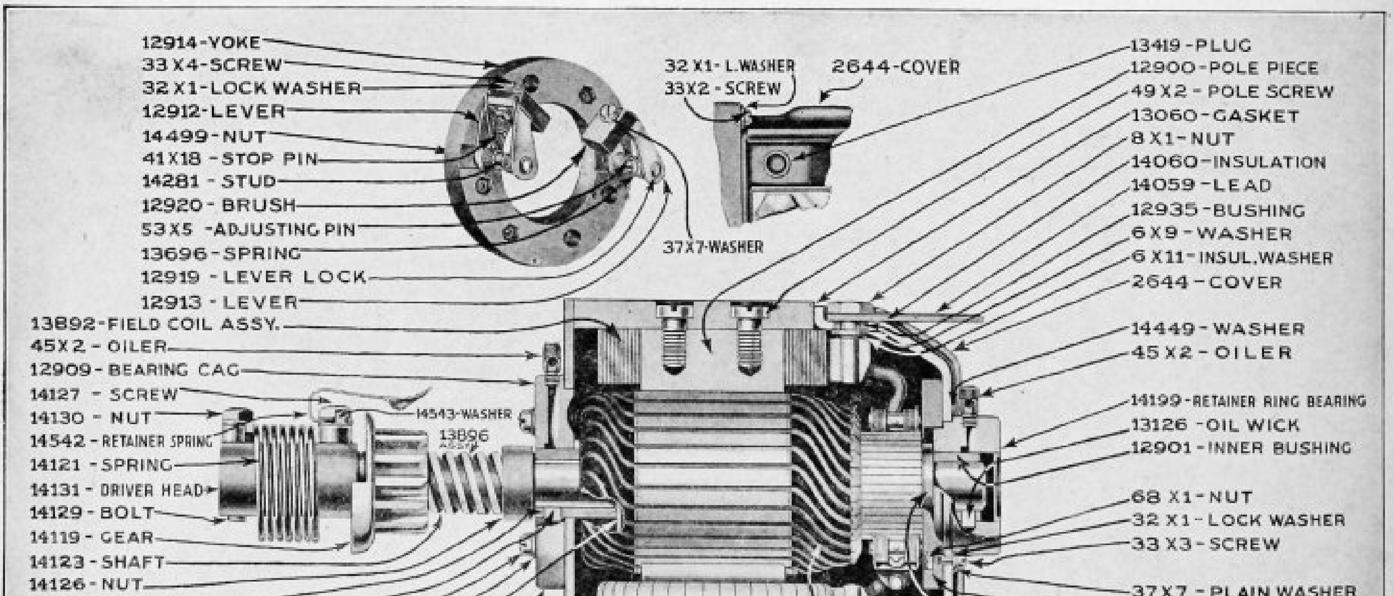
288. Removing the Field Coils. It will not usually be necessary to remove the field coils from the generator frame; but if it should become necessary, the screws holding the pole pieces in place must be removed. The four field coils are assembled together as one unit before being placed in the frame. When replacing the pole pieces, note carefully their prick-punch identification marks. Also see that the screws are drawn up tight, making a snug fit between the ends of the pole pieces and the inside of the generator frame. The reason for this is that the magnetic lines of force pass from the pole pieces to the frame, or vice versa; and if the contact is not good the magnetic strength will be decreased. This will weaken the generator or motor field, and consequently the efficiency of the generator and motor will be lowered.

289. Reassembling the Field Coils. When reassembling field coils on the pole pieces, care must be taken to see that the correct polarity is established on each pole piece. The poles that are opposite each other should be of the same polarity, and this can easily be checked with an ordinary pocket compass. Another method is to trace the winding beginning on one end of the field and following it around each pole piece in turn. The direction of the winding should change each time it goes through another field coil. See that the bearings are properly lubricated with the right kind of oil. Remember that too much oil is just as injurious as too little. For example, if too much oil is used, it is liable to get over on to the commutator, which will cause excessive wear of the brushes and commutator and will also tend to cause arcing on the brushes. The commutator and brushes must be kept clean and dry at all times. Do not use any grease or lubricant on the commutator. See that the brushes fit the curvature of the commutator properly. The commutator must be made as smooth as possible using a strip of fine sandpaper. If the commutator is kept clean and dry, the brushes will seat down smoothly and will last indefinitely.



GRAY & DAVIS GENERATOR

FIG. 16.



GRAY & DAVIS STARTING MOTOR

FIG. 17.

CHAPTER VIII

MOTOR GOVERNORS

290. The Governor. The governor as applied to tractor motors is a mechanical device to regulate the speed of the motor, generally by utilizing one of nature's natural forces, called centrifugal force.

The function of a governor is to regulate motor speed between predetermined limits, and to hold the speed to those limits during all the cycles of operation under all conditions, ranging from no load to full load. The history of governors is related very closely to that of the steam engine, and our present day devices are largely adaptations or improvements of the steam engine type.

Governors can be divided into two classes:

(1) Hit-or-miss.

(2) Throttling.

With the use of the tractor engine which employs both the external and internal combustion motors, the uneven loads encountered make hand regulation impracticable. Therefore the mechanical governor has been adopted.

It was recognized, however, that any device of a mechanical nature must be reciprocative or rather compensative in action. The mere limiting of the speed, without consuming the full power of which the motor is capable, would necessarily decrease the value of the advantage gained from a mechanical standpoint, and make necessary a much larger powerplant than would be actually required if the maximum power of a smaller unit were available at the safety speed. The same problem had been encountered in steam practice, and the means of solving it was a device consisting of two or three fly-balls or weights revolving around a common axis. The force generated by this centrifugal action actuated a rod or lever usually connected directly to a valve, the opening or closing of which governed the amount of working fluid available for the operation of the powerplant. The fact that the functions of such a device must indeed be of a versatile nature to regulate the speed properly, while keeping the maximum power available as the occasion demanded, was responsible for the name "governor" being applied to it, and, considering its functions and their importance together with the consistency necessary for the effective maintenance of satisfactory powerplant operation, perhaps no better word could have been chosen or one which would so adequately cover the range of its capabilities.

The benefit to be derived from an efficient governor cannot be over-estimated. It is nature's law that no work of man is permanent or indestructible. This incontrovertible fact is responsible for all human endeavor and a large amount of human grief, and it is only logical therefore to attach no little importance to the temporary preservation, at least, of the work of our hands. Even with the knowledge gained by years of endeavor, science and costly experience, the maintenance of past standards of quality and workmanship has been a long expensive battle.

A motor, to meet the demands of the day must insure a maximum of service with a minimum of mechanical trouble, and no factor plays such an important part as an agent of destruction as excessive speed; the toll is paid in expensive repairs, equipment wrecked or worn out before its allotted time, to say nothing of the loss of time. We recognize the fact that there are limits to the weight necessary or allowable in the design of motors. And these limits must be maintained at least at the point where we can be assured of the correct relationship between the various parts which go to make up the complete assembly. It may be possible to design and construct a motor which from the standpoint of non-breakage would last as long as the owner might think reasonable. This is the underlying reason for the universal demand for and use of governors.

Various estimates have been made from time to time as to the life of a motor and there are a number of opinions on the subject. It is my judgment that the average motor is capable of about 4 or 5 years of maximum service, governed largely by the quality of manufacture and the care expended in its upkeep. In making this statement, the stand is taken that the life of a motor for purposes of statistics is considered at an end when the upkeep with regard to service and general maintenance as distinguished from expense incidental to accident, etc., is equal to approximately 50 per cent of the value of the motor, this value taking into account all factors of depreciation. Individual motors have outlived this period of longevity, but it will be evidenced that the average motors are able to reach this period of service only by the use of such safety devices and standards of disciplinary care as will insure the maximum service with a minimum of expense. It is not to be doubted that from a standpoint of economy a governor is an absolute essential, whether considered in relation to fuel, or general efficiency.

291. Governor Construction. There are a number of variable factors entering into the design of a governor: The work the engine is required to perform, the allowable variation between no load and full load, size and type of intake control valve, flywheel inertia, speed, the manufacturing facilities and inspection, and, unfortunately, the compromise sometimes necessary due to lack of space. If an engine is to do such work as threshing and plowing, where there is a sharp rise in the power curve, the weights, springs, rise of governor collar, etc., shall be greater than on light work. The weights should be balanced and the springs calibrated so that there will be no binding or unequal pressure of moving parts. All moving parts should be enclosed in oil-tight dust-proof case and run in an oil bath or vapor Ball bearings should be used on the principal parts and especially on thrust bearings. Some manufacturers even mount the throttle-valve on ball bearings.

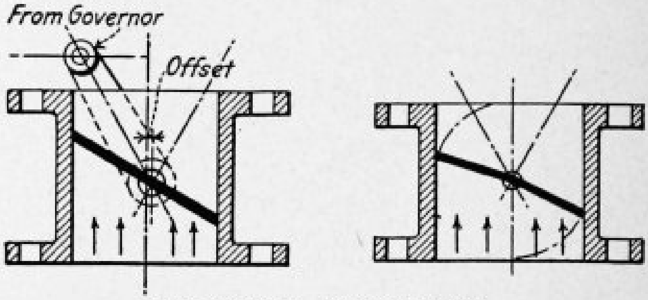
292. Hunting. The main fault of governors, aside from not being able to see the approaching hill or the extra bundles thrown into the separator, is hunting. This is due to the fact that where there is a change in load, the governor makes an effort to take care of it. As there is friction of parts, the energy required to start the parts moving is greater than that needed to keep them in motion; so the throttle over-runs its position. This speeds or retards the motor, and the reverse action is necessary to maintain an equilibrium. Larger weights with proper springs, proper fittings, balanced throttle-valve and anti-friction bearings will all help to overcome this defect.

The best way to mount a governor valve when separated from the governor proper is in a cage. This allows a proper correlation of parts without depending on the carburetor and also allows a change in the carburetor without disturbing the governor parts. The governor should be set to run the motor at maximum speed with the carburetor valve open. The retarding should be done with the carburetor control valve or governor speed controlling device.

The hit-or-miss type is now obsolete on the motor for modern tractor. In this type the governor acted on a pawl of "pick blade," which in turn held the exhaust-valve open or the fuel valve closed, allowing a charge of pure air to enter the cylinder instead of a charge of gas.

293. The Throttling Governor. The throttling governor controls the piston speed by a throttling action. By acting upon the entering gases it controls the velocity of the gas through the intake, raises and lowers compression within certain limits, and regulates the M. E. P. in proportion to the load, and at the same time maintains a constant piston speed. The throttle governor is now universally used, as modern design has improved the economy of this type to such an extent that the better regulation more than offsets the possible saving in fuel and does away with the trappy devices and irregular explosions of the hit-or-miss governor.

294. The Governor Valve. A study of governors is not complete without the study of the governor valve. The governor may be attached to the butterfly valve of the carburetor, but a separate valve-cage is much better. This allows governor action unhampered by the extra linkage of the hand control. The governor should be set with the motor operating at maximum speed when the carburetor butterfly is wide open. The hand control is attached to the carburetor butterfly and is used for slowing down the motor. (See Fig. 1.)



Two Types of Governor Valves
FIG. 1.

A widely used type of governor valve has the butterfly set at 60 degrees, but it may be set at 90 degrees with the axis. The working arc is greater with more chance for hunting as the valve has to travel farther from full-closed to any desired area of opening. If the butterfly stem is placed in the center of the valve, the pressure of incoming gases on the advancing side is greater than on the opposite side and imposes a greater load on the governor and linkage. This makes for uneven action, and the stem is often offset to equalize this pressure. This offset is governed by the size, angle and gas velocity.

In both the hit-or-miss and throttling types of mechanical governor we may have one of six classes or a combination of either.

(1) Centrifugal.
(2) Inertia
(3) Pendulum
(4) Hydraulic
(5) Velocity
(6) Electric.

The centrifugal governor and the electric governor are being used most extensively on gas tractor motors, therefore we will consider these governors only. The following are a description of a few of the standard makes.

295. A Velocity Governor. A velocity governor is represented in the monarch governor which controls the speed of the motor by the velocity of the gases in the intake manifold.

296. The Monarch Model "D." The Model "D" is a self-contained unit scientifically constructed, possessing a minimum of moving parts and a total absence of revolvink parts, having no connection to any moving part of the motor, its installation being between the carburetor and the intake pipe. The speed of the in-going gases is utilized as the motive power for operating the disc or control member, which floats in the path of the gas, subjecting it instantaneously to the changing speed of the gas, which speed is dependent on the motor speed. (See Fig. 2.)

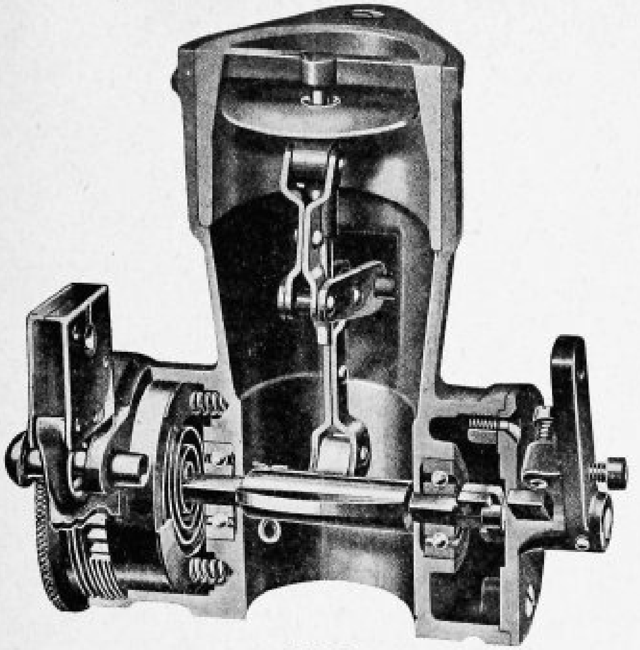


FIG. 2.

The operation of the disc at the same time harmoniously operates the throttle, being connected thereto. It will therefore be seen that any incrase or decrease in the speed of the gas occasioned by increasing or decreasing the motor load will result in the instantaneous action of the throttle and delivery of the proper charge to the engine at the psychological time and speed, thereby producing engine efficiency.

The position of the throttle is at all times in harmony with the speed of the motor, never snapping open and allowing conditions above it to approach atmospheric pressure, condensing the gases and causing them to precipitate on the walls of the manifold, a condition which obtains in a manually controlled throttle. The governor therefore enables the carburetor to deliver a homogeneous gas regardless of the motor load.

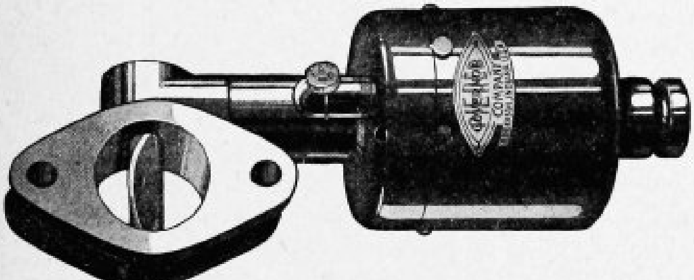


FIG. 3.

297. The Pierce Governor. The Pierce Governor employs the well known principle of centrifugal force, is entirely self-contained, and is enclosed in a housing small enough for any commercial purpose.

While every part must be accurate in construction and assembly, yet the operation of the governor is exceedingly simple. The only rotating part of the governor is the weight spider, and as this runs on ball bearings in an oil bath, it must be very evident that Pierce Governors are both wear-proof and trouble-proof.

But in addition to this, these governors possess many other features of superiority, that are responsible for their efficiency and popularity, viz.:

1. Only necessary to drop carburetor a distance equal to bore of manifold—less than half required by other governors.
2. Not necessary to remove butterfly from carburetor.
3. Flanges are S. A. E. unless otherwise ordered. No spacers or special adapters required.
4. Will work perfectly at any angle.
5. Is not affected by atmospheric changes.
6. Does not affect carburetion.
7. No obstruction in manifold to cause condensation of gasoline.
8. Butterfly valve used that can not stick.
9. Is not sluggish in cold weather.
10. Positive drive by means of enclosed solid steel shaft.

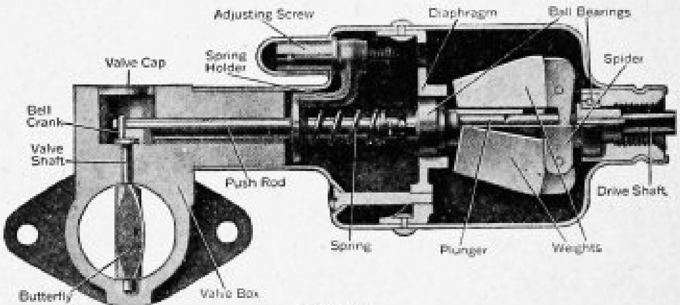


FIG. 4.

298. Construction and Operation. The governor proper is mounted between the carburetor and the intake manifold, and may be connected to the driving agent by means of either or solid or a flexible shaft.

In the governor valve box the butterfly valve is normally in a position that does not obstruct the flow of gas, but it is closed so as to reduce the valve port area, just as soon as the motor reaches the predetermined speed. The valve is actuated by what is known as the flyball principle. The two weights are mounted on a spider, which revolves on ball bearings, and are so pivoted that as their velocity increases they are swung outward, forcing a plunger forward, which in turn operates the butterfly valve. The plunger is forced against a spring calibrated to a standard pressure, so that as the velocity of the weights is lessened they return to normal position and the valve opens.

Naturally, the governor requires some oil, but this is easily supplied through oil cup in governor case. The two weights splash the oil to all moving parts.

The action of the governor is both positive and simple, adjustment is easily made, and as the housing is dust and water tight, there is no probability of wear if kept properly lubricated.

Every Pierce Governor is so constructed that the adjustment can be positively sealed by the owner, thus preventing any attempt on the part of the driver to change the speed.

299. The Governor Used on the J. I. Case 10-18. A fly-ball type governor is housed in the timing gear cover, and is lubricated by an oil lead from the oil pump. It is readily accessible for inspection or repairs by removing the plate on the front of housing. The governor is mounted on the end of the pump shaft and the balls are moved in and out by centrifugal force, according to the speed that this shaft runs. The movement of these balls operates the governor valve, which controls the amount of charge admitted to the cylinders. (See Fig. 5.)

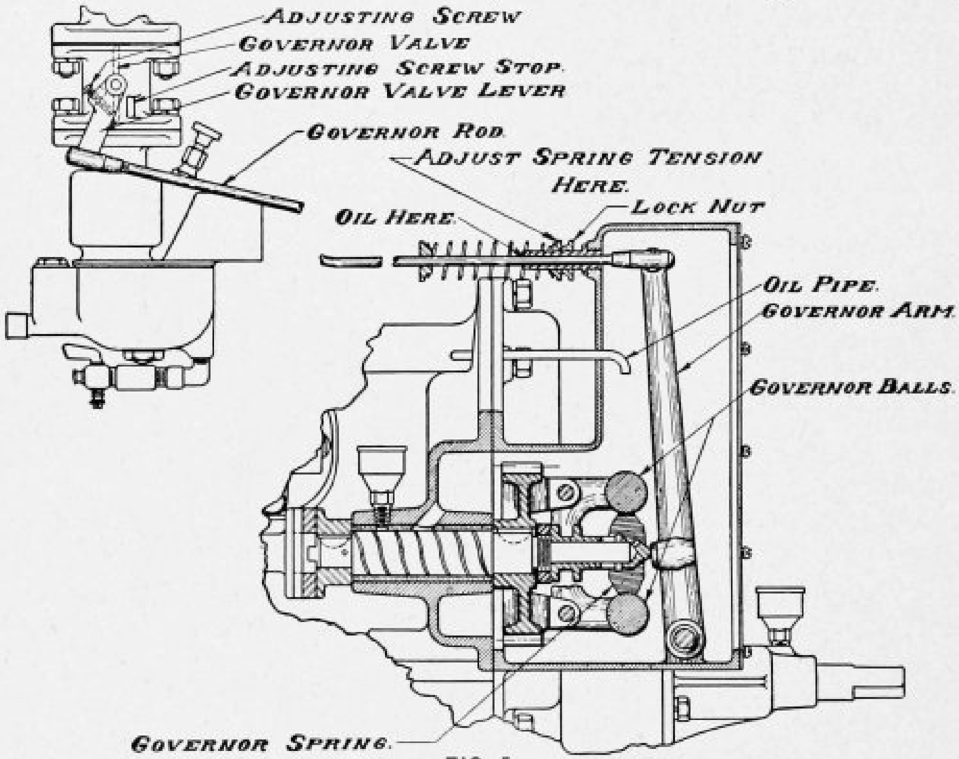


FIG. 5.

300. To Change Speed of Motor. The motor speed can be changed slightly by adjusting the spring tension on the governor rod, and this is accomplished by turning the knurled nut back of governor housing. Increasing the tension of this spring by turning this **adjustment** nut to the right increases the speed of motor.

301. Butterfly Valve. The governor valve is simply a butterfly valve located between the carburetor and the intake manifold, just above the carburetor, and is operated by a rod from the governor.

When the speed of the engine increases this valve closes and when the motor speed decreases the valve opens. When the engine is standing still this valve is in a perpendicular position or wide open.

302. Irregular Speed. When the governor action is erratic causing the motor to gain and lose in speed, it is said to be "hunting." This may be remedied by proper adjustment of the governor valve. The small lever that operates this valve is provided with an **adjusting screw** that works against a stop, which determines how near closed the valve can go. If this screw is set so that the valve will close entirely "hunting" will take place.

To adjust correctly loosen the lock nut and adjust this screw a little at a time until enough fuel will pass by the valve in its closed position to keep up the engine speed, and no more. If the motor runs away or races when the load is thrown off, the valve must be adjusted with less opening. When correct adjustment is obtained tighten lock nut, being careful in doing so that the screw is not turned out of adjustment.

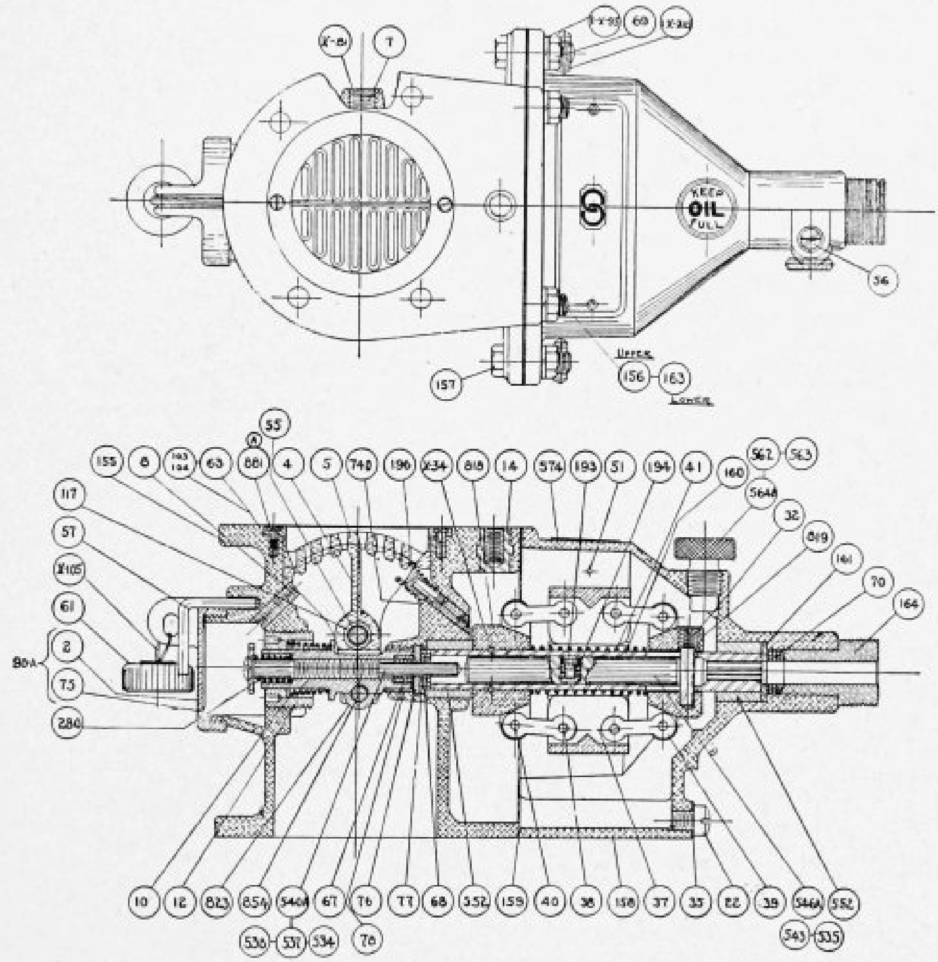
Sometimes irregular governor action is caused by the rod binding in the guide. This must work freely and should be oiled occasionally with light oil. See Illustration, above.

If governor trouble is suspected, remove inspection cover and see if fly balls work freely and that the springs are not broken or weak. The governor is set to operate the motor at its rated speed of 1050 R. P. M. when the tractor leaves the factory. To determine the speed of the engine use a reliable speed indicator.

303. The Simplex Tractor Governor. The gird valve which has been employed in the Duplex and Simplex models of governors for internal-combustion motors was designed with a view to increased efficiency over valves then in use for similar purpose. Experience with this valve, extending over a period of years and covering approximately 45,000 installations on trucks, marine motors, generator sets and tractors, has more than justified the claims originally made for the design. Tests of these governors have been made in the laboratories of almost all the large motor builders in the United States with a view to determining the characteristics of the valve action, and the efficency in general of the governor design. (See Fig. 6.)

is heavily charged with dust, fragments of straw, chaff, etc., and where air cleaners are not always used, this material might accumulate below the valve and thus interfere with its effective operation. Although this condition did not develop in truck, marine and generator service, a new design was undertaken to meet the special requirements of a govrnor valv for tractor service especially.

The design referred to and designed as a shutter valve, has been under consideration and in process of development since 1912, when the valve was first



SIMPLEX GOVERNOR MODEL M

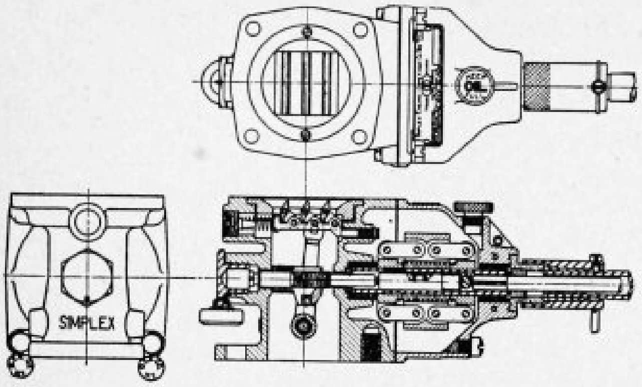
FIG. 6.

The amount of angular traverse required of the moving valve member in traveling from the extreme position of full-open to full-closed valve and vice versa, is short, varying in different governor sizes from approximately 1-16 to 1-7 in. From this design there results the possibility of approximately full-open valve to the governor may be set, and at which the valve should close, thus giving approximately full throttle up to almost the moment of cut-off.

Despite the high efficiency and general excellence of the construction described there seemed a possibility that for tractor service, where the atmosphere

used experimentally with a Duplex governor. This construction is shown and, as will be noted, consists of a series of three shutters, the angular traverse of which, from the full-open to the full-closed position, is approximately 60 degrees. This design, though not so efficient, incorporates many of the advantages of the grid valve with the elimination of the one possible objection to the use of that valve structure in tractor service. (See Fig. 7.)

The shutter valve is interchangeable with the grid valve on all Simplex models. The grid valve is recommended for every kind of governor service because



DETAILS OF A GOVERNOR FOR TRACTOR ENGINES IN WHICH THE MOTION OF THREE SHUTTERS THROUGH AN ANGLE OF 60 DEG. PROVIDES THE CONTROL OF THE THROTTLE-VALVE

FIG. 7

of its high efficiency. The other elements entering into the tractor governor construction are identical with those of the standard Simplex governor, and are interchangeable.

The motor then running under governor control with the valve approximately closed, the full load of the motor is thrown on with a drop in motor speed to the curve showing Maximum Drop, the motor then recovering speed to the curve of Full Load. The motor operates for a moment under full load, which is then thrown off with a rise in motor speed to the cruve of Maximum Overrun, and then a drop to the curve of No Load. The time interval of this cycle is also shown. Starting with zero time the full load is applied, the time interval as between the moment of applying the load and the maximum drop is shown as ½ sec., with recovery to full load in 1 sec. This load is carried for 2½ sec., the load being then released with a maximum overrun of 1-3 sec. and recovery to the no-load position in 2-3 sec.

The linkage and the valve members are of non-corrosive material and of substantial construction in every way. Production plans are under way for four governor sizes, the classification being based on a motor speed of 1,000 r. p. m.

Model	Piston displacement, cu in.
U	200
V	300
W	600
X	1200

The figures in the second column of the accompanying table are the maximum sizes of motor with which the governor can be used.

304. The Electric Governor. The electric governor is a mechanical device for controlling the speed of an internal combustion motor by a magnetic drag, caused by a magnetic field being set up around a revolving armature by electric magnetic induction.

The device consists of a four pole shunt wound direct current generator, an induction coil, a breaker box, distributor, and a control box. The housing which supports the field magnets is mounted on trunnion bearings, which allow the generator to turn through an arc of 30 degrees. The trunnion shaft is brought through the generator housing, and a lever is placed on the outer end. This lever is connected to the governor valve. A portion of the current generated passes through the field windings controlled by a hand wheel on the control box or field rheo-stat. This causes the iron cores to become strong electromagnets, thus creating a magnetic drag on the armature. The revolving armature imparts a rotating motion to the field frame. When the controller is placed in any given position the corresponding speed will be maintained. If the motor speeds up due to decrease in load, the magnetic drag of the field and the armature is increased, causing the field frame to turn in the direction of armature rotation and close the governor valve. If the load is increased the magnetic drag is decreased, allowing the field frame to be

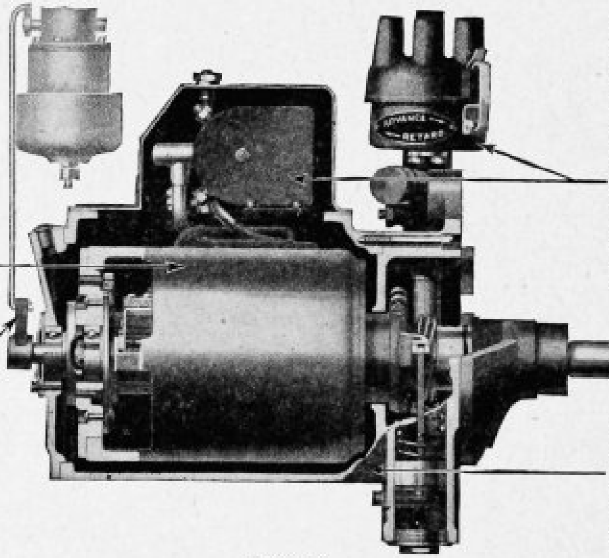


FIG. 8

turned against rotation of the armature by a spring, to which is also attached a piston operating in a dash pot to prevent too rapid movement of the arm controlling the governor-valve. The hand wheel on the control box indicates the speed at which the governor holds the motor. The speed range is from 400 to 1650 r. p. m., but the manufacturer will supply proper speed ratio to hold the motor to any required rate.

305. The Remy Governor enerator. The Remy tractor equipment consists of the Governor-Generator, Control Box, Ignition Distributor, Coil and the Starting Motor. (See Fig. 8.)

306. The Governor-Generator. The generator is of the well known four-pole, shunt wound type, which is the simplest, most reliable type of direct current generator.

308. Thrust Washer T. On the drive end of armature shaft a fiber thrust washer T (Fig. 9) is used between the drive gear and the drive end casting J (Fig. 9). This washer is about 1-16 inch thick, and should permit from .01 to .02 of an inch end play of armature with the gear in place. **It is very important that this washer be in place.**

There are five washers, No. 8356-7-8, No. 8258, and No. 8155, that can be used. They are of different thicknesses, to be used as needed.

309. The Field Frame. The field frame D (Fig. 9), which has four poles around which the four field coils are placed, is not mounted rigidly to the motor case, as is the usual custom, but is supported at the drive nd by a trunnion bearing on armature shaft in casting F. It is supported at the commutator end by the

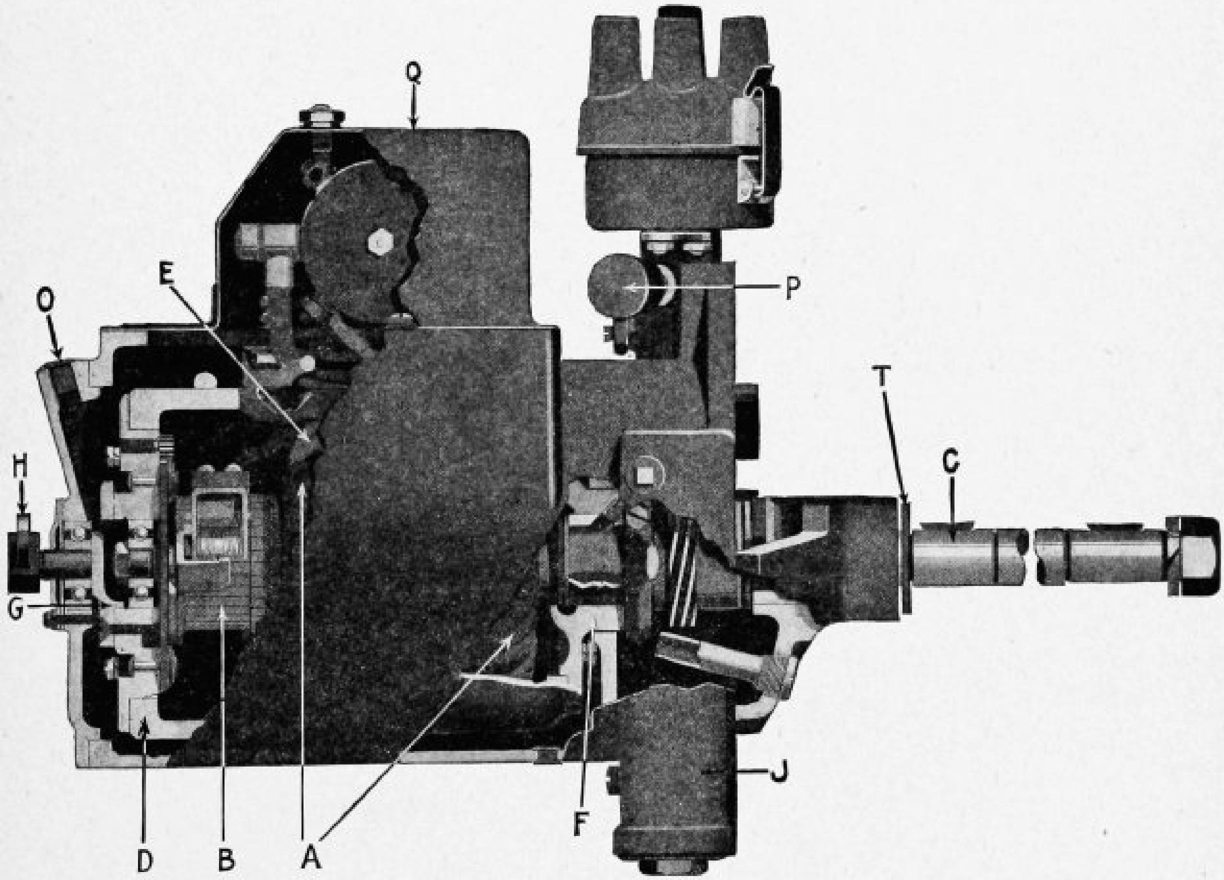


FIG. 9

307. The Armature. The armature A (Fig. 9) is assembled on a steel shaft on which the laminated core is built up, then the coils of insulated wire are wound on it, and their ends are soldered to the bars of the commutator B, which is of large proportions and rigid construction. A gear keyed to armature shaft C engages with the cam shaft gear, or suitable idler gear, in such ratio that the armature is driven 1½ revolutions for each revolution of the engine crankshaft on 4-cylinder engines, and 2 to 1 on 2-cylinder engines.

trunnion ball bearing supporting the fogging G. This permits the field frame to rock back and forth through an arc of 30 degrees. This rocking of the field frame is the Governor action. The control lever H is attached to shaft of G and is linked to the carburetor throttle. This throttle moves as the generator field frame D rocks.

310. Governor Springs. A spring I is provided to turn the field frame in a direction opposite to the armature rotation. This governor spring is located in the drive and head casting J of the generator housing. This end head serves the double purpose of enclosing the spring and the dash pot cylinder. The piston K, working up and down in oil in the dash pot, serves to prevent the too rapid movement of the field frame to which it is linked.

311. The Generator Housing. The generator housing serves the purpose of providing trunnion bearing supports for the generator proper so it will be free to turn through an arc of 30 degrees, also a very efficient dust and waterproof enclosure for the generator, ignition coil, ignition distributor gears, their connections of wires, the governor spring, and the dash pot.

312. The Control Box. The control box, in which are housed the combination lighting and ignition switch and the generator field rheostat, can be located anywhere in convenient reach of the tractor operator; but a good ground must be provided—see circuit Fig. 11.

be flowing from the battery to the ignition coil and to the generator. Therefore, the switch must not be turned on until you are ready to start the motor and if for any reason it does not start be sure to turn the switch off.

Turn Key to "Lights Run" Position for Night Running. When the key is in the "Lights Run" position, the ignition and lights are turned on, and the generator is connected to the battery, so that the discharge from the battery will be very great if the engine is not running. **Do not leave key in "Lights Run" or the "On" position when engine is not running.** When the engine is running a current will be supplied from the generator in sufficient quantity to carry the lights and ignition with a surplus which will go into the battery and keep it charged.

314. Turn Key to "Lights Stand" Position. When the key is in the "Lights Stand" position, the lights only are turned on, while the ignition and generator

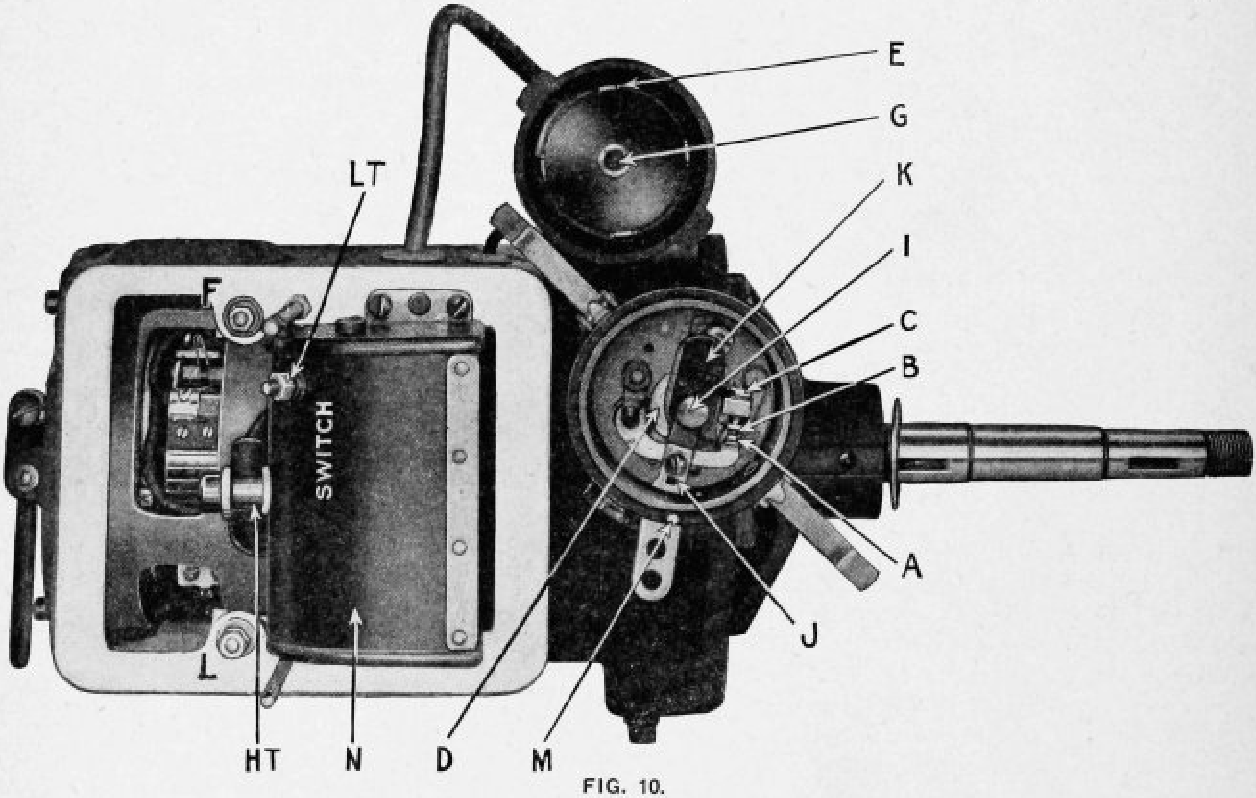


FIG. 10.

313. The Lighting and Ignition Switch. The lighting and ignition switch is combined in one. There are four positions marked "Off," "On," "Lights Run" and "Lights Stand," respectively.

Remove Key When Not in Use. When the key is in the "Off" position, all circuits are broken, and the key must be removed. **This is important.**

Turn Key to "On" Position for Daylight Running. When the key is in the "On position, the ignition is turned on and the generator is connected to the battery and if the motor is not running, the current will

are disconnected from the battery. This is the position in which the key should be placed when light is wanted but it is not desired that the engine should run.

315. The Field Rheostat. The field rheostat, as its name implies, is a resistance unit that is in the control box (Fig. 11). It is composed of a length of German silver wire with ten contacts so arranged that connection may be made to any contact by a movable contact arm. The contact arm is carried on a shaft

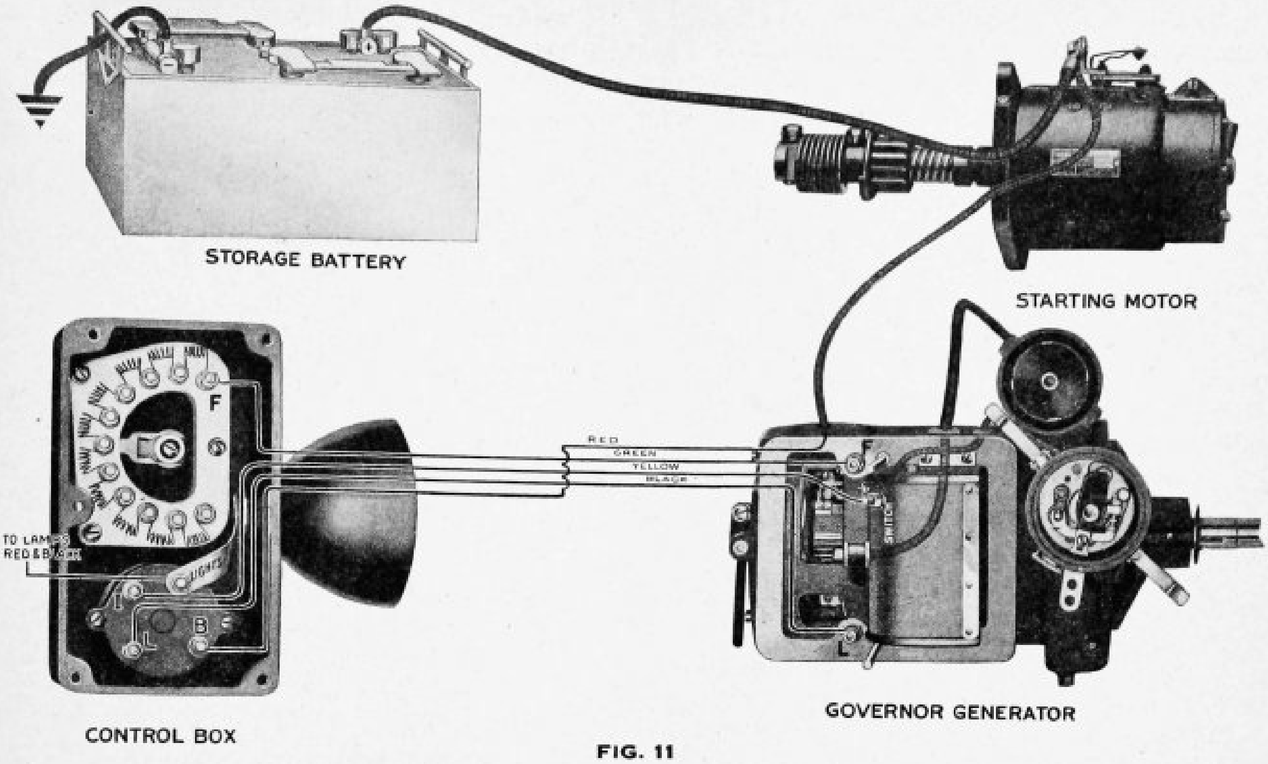


FIG. 11

which is extended through the face of the control box, and to which is attached the rheostat hand wheel. This affords a convenient method of adjusting the contact arm.

316. Engine Speeds. The ten positions of the hand wheel shown on the face of the control box indicate the ten steps of resistance in the rheostat.

Positions "1" gives a governed engine speed of approximately 400 engine R. P. M., and a generator output of 1 to 2 amperes. The governor is set on point fast to govern the engine at the maximum speed specified by the engine or tractor builder.

On point fast the generator output is approximately 7 amperes. The 9 intermediate speeds will be approximately equal steps from the minimum to the maximum speed.

The generator output will always be from 1 to 2 amperes more than the battery charging rate, as it is necessary for the generator to supply enough current for ignition before it can start charging the storage battery.

317. Operation of Governor-Generator. The generator field frame is mounted on trunnion bearings, and supported inside of the housing so it is free to rock back and forth to the extent of 30 degrees. The trunnion bearing shaft on the commutator end is brought out through the generator housing, and a lever is mounted thereon. To this lever is attached a link which transmits the rocking motion of the generator field frame to the carburetor valve.

When the armature is caused to rotate in the generator field frame, there is current generated. A part of this current passes around the field windings which are located in the generator frame. This current, in passing around the field windings, causes the iron cores around which these windings are placed, to become strong electro-magnets. On account of their magnetic attraction for the armature these magnets create a magnetic drag on the armature; and therefore the armature, in rotating in this magnetic field, imparts to the field a rotating motion.

There are two ways that the turning effort imparted to the field frame by the armature may be effected: First, by changing the resistance of the field circuit, which is done by turning the control box knob; and, second, by the changing of the speed of the armature rotation. This changing of the speed is caused by the variation of the load on the motor. In either case a change in the amount of current flowing through the field windings, and resultant change in the magnetic drag of the armature, is accomplished.

A change in the amount of current flowing through the field windings is accomplished by the adjustment of field resistance in the controller. If we place the controller on position "1" all of the resistance will be cut out of the field circuit, so that the current flowing into the field will be of maximum quantity, and the magnetic drag of the field magnets on the armature wil lbe very strong. At such times the magnetic drag will overcome the strength of the governor spring and close the throttle when running at a very low rate of speed, and the motor will be governed at a low rate of speed.

If we place the controller on position "Fast," all of the resistance will be cut into the field circuit; and the current flowing into the field will be comparatively small and the magnetic drag of the field on the rotating armature will be weak. Therefore, the motor and generator will need to run at a high rate of speed to create sufficient magnetic drag on the armature to compress the governor spring to the point required, according to the load on the motor, to maintain the maximum motor speed specified by the manufacturer.

When ordering parts or writing about your Electric equipment, be sure to state the Model number, including the letter or letters A-B-C-D-E-F-G, etc., as the letters denote a change in specifications and part numbers of some of the parts, and the proper parts cannot be supplied unless the Model number and letter are given. It will be will to give the Model number and letter on the control Box as well.

318. Action of Governor to Take Care of Load Variations. Any motor speed attained by placing the controller on a given position will be maintained because, if the motor speeds up due to a decrease in load, the magnetic drag of the field on the armature is increased, causing the field frame to turn in the direction of armature rotation and close the throttle. But if the motor slows down due to an increase in load, the magnetic drag of the field on armature is decreased, allowing the field frame to be turned by the spring in the direction opposite to armature rotation, thereby opening the throttle.

The action of the governor is very quick and it is sensitive to the smallest change in motor speed.

The old dash pot and piston prevents the spring from opening the throttle too quickly. The dash pot is exposed to the oil of the engine case and, therefore, needs no attention.

Whenever the throttle opens, some of the oil is forced by the piston from the dash pot through by-pass L (Fig. 12) back into the portion of the drive end head casting that encloses the distributor gears. This is possible because both the throttle lever and piston are connected to the generator field frame so that thy move up and down as the field frame rocks back and forth. The size of the by-pass is controlled by an adjustable screw M with lock nut. This has been adjusted at the factory and should need no attention unless oil other than that specified by the tractor manufacturer is being used.

319. Port S. When the piston travels up due to the magnetic drag, turning the field frame in the direction of the armature rotation, oil will run through port S (Fig. 12) and through or around the piston depending on the type, thereby refilling the dash pot.

320. Adjustment of By-Pass Valve. To adjust dash pot by-pass valve, loosen lock nut N, and turn screw M to left four turns. Place controller on position 8, then change quickly to position 1. If governor

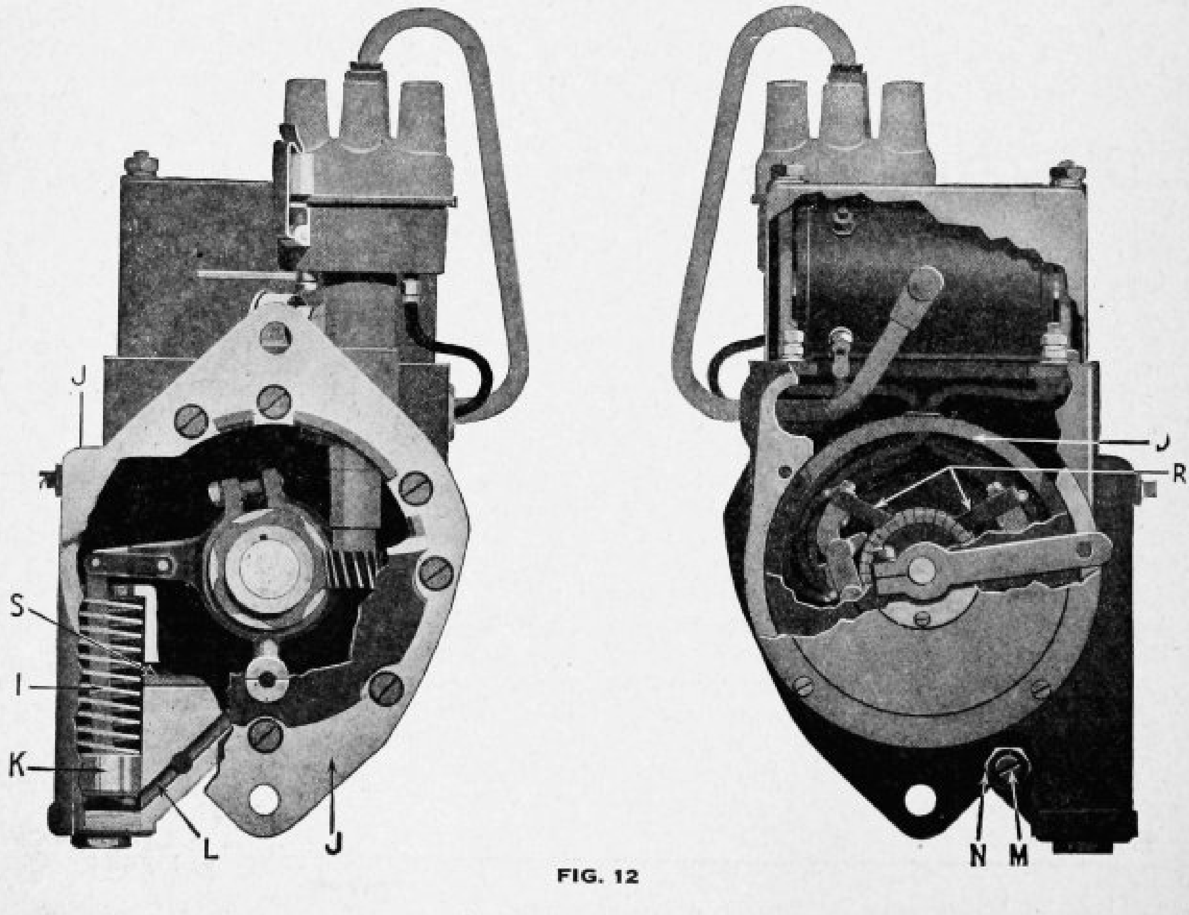


FIG. 12

fluctuates, turn screw to right until fluctuation is eliminated.

Do not adjust the speed or by-pass until motor is warm and carburetor is known to be all right.

321. Adjusting By-Pass for Intermittently Hard and Soft Soil (Fig. 12). Under extreme conditions where the soil is intermittently hard and soft, it may be necessary to open the dash pot by-pass by means of the screw M, in order to effect quicker opening of the throttle. In making this adjustment release the lock nut designated by N (Fig. 12) and turn the screw M to the left. The proper number of turns can be determined only by experiment in the actual soil itself.

The purpose of the dash pot on this Governor-Generator is to limit the opening action of the throttle only. It has absolutely no effect upon the closing action.

Any necessary adjustment of the by-pass screw should be made when the engine is thoroughly warmed up, as under cold conditions the oil thickens and has tendency to retard the downward movement of the piston K.

After making by-pass screw adjustments to compensate for extreme conditions in soil, care should be taken in operating the control box, as the sudden turning of the indicator from point one to "fast" is liketly to result in momentary over-speeding of motor and a slight hunting action of the governor.

Whenever you change the dash pot by-pass valve adjustment on account of such extreme conditions, mark the position of the screw M before changing it so that you can easily change it back to the proper position for regular work. The change should be made as soon as the work under extreme conditions is completed, or unsatisfactory results will be obtained when you use the tractor later, and you may not recall that the adjustment had been changed.

322. Oiling Governor Generator. Put four drops of clean oil in oil hole O (Fig. 9) twice a week. Turn down grease cup two turns a week. Too much oil or grease is bad.

323. Commutator and Brushes. A removable dust-tight cover Q at the top of the generator case, provides easy access to the commutator and brushes. Inspection of brushes R (Fig. 12) and commutator B (Fig. 9) for dirt should be made twice a season. The commutator wears naturally to a brownish color in normal use; but if it appears black or scored, the surface should be smoothed with a piece of fine sandpaper. **Never use emery cloth for this purpose.** Blow out all dust and clean out all dust between commutator bars. See that the brushes swing freely on their pivots, so that the spring tension holds them in good contact with the commutator.

The brushes used with this generator are of special composition, and under average conditions will last indefinitely. If replacement should be necessary for any cause, do not use cheap, inferior substitutes, but obtain new ones from the Remy factory or Service Branches.

324. Ignition Circuit Breaker. To produce a spark at the spark plug, it is necessary to close and open the battery circuit through the Ignition Coil each time, and this action is accomplished by the circuit breaker (Fig. 10).

The circuit breaker has two contact points, one, the stationary contact screw B used for adjusting the breaker point opening, being stationary, while the other, the breaker lever A, is carried at the free end of a pivoted arm, lever A. The four-faced rotating steel piece, called the cam D, has actually ground corners which bear against the fiber block in the arm as the cam turns, causing the contact points to open and close at the proper time.

325. To Adjust Contact Points. Turn the motor until contact points are wide open. The gap should then be .020 inch to .025 inch, or the thickness of the gauge on the side of the wrench furnished for adjusting the contact point opening. We recommend a periodical inspection of the points every thirty days. If found to be dirty or unevenly worn, they may be cleaned by passing between them a fine flat file. If fine sandpaper is used, the points should be wiped off with a clean cloth so as to remove any foreign substance that may remain. **Do not use emery cloth.**

When parts are needed for the control box, be sure to give the Model number of the Control Box and Governor-Generator, including the Letters following the number. Otherwise your order cannot be filled.

Adjustment of the gap between the contacts is made by loosening the lock nut C (Fig. 10) next to the post with the wrench furnished, turning the adjustment screw B, and then locking the nut again.

326. Do Not Oil These Contact Points. Every week, however, a slight trace of vaseline placed on the fiber block or on the cam will keep the cam from rusting and wearing the fiber block.

327. Condenser. The condenser is simply an electrical reservoir which prevents injurious arcing or flashing at the circuit breaker contact points. The condenser is sealed up in the coil case, permanently protected. It is electrically connected across the circuit breaker points, through the lower coil terminal and ground, as may be seen in the wiring diagram (Diagram 13).

328. Ignition Distributor. Each spark plug of the engine is connected by a heavily insulated wire which runs to one of the terminals on top of the distributor cap. These terminals have metal extensions on the under side of the cap as shown E (Fig. 10). The center terminal for the high tension cable to the ignition coil has a carbon button G on the under side of the cap, and makes electrical contact with the spring I which is attached to the segment J and segment

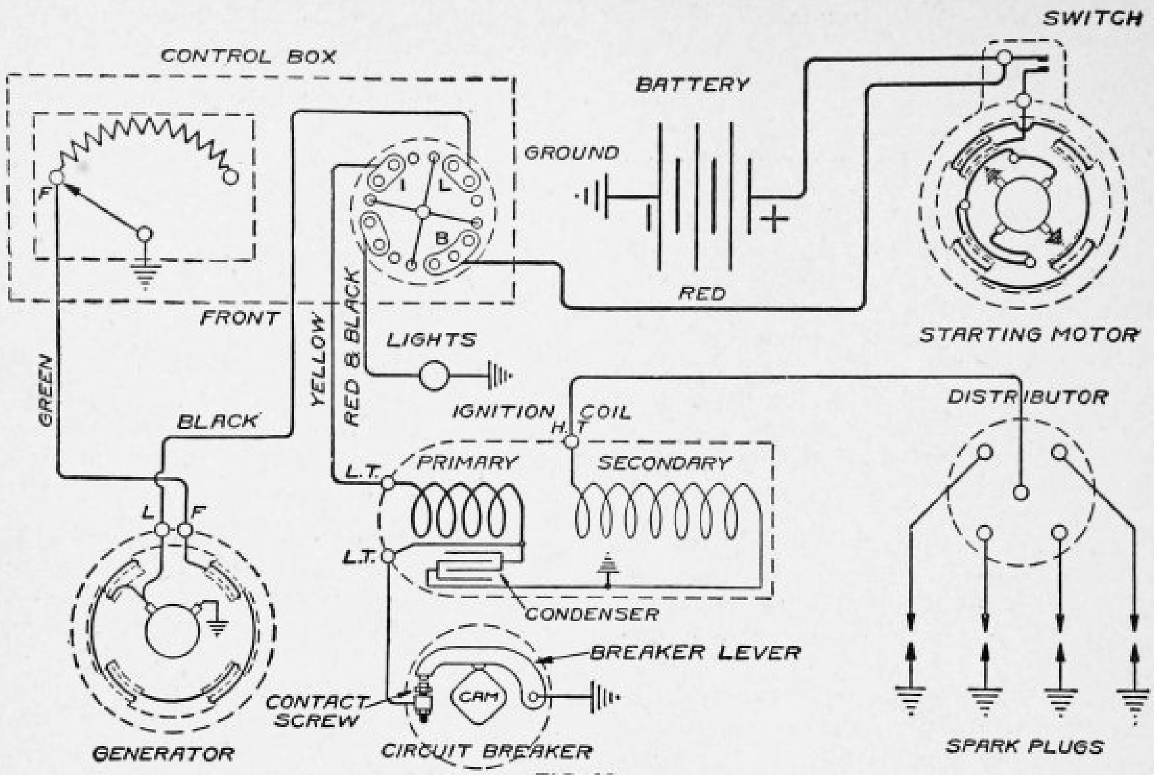


FIG. 13

holder K. Button G. can be placed on the cam in only one position.

The outer edge of the distributor segment rotates close to the terminal extensions E without quite touching them, so that there is no wear due to rubbing contacts.

329. **Distributor Oiling.** A grease cup P (Fig. 9) is provided for the distributor shaft, which should be kept full of medium grease. It should be given two or three turns to the right every week of running, to force a little grease into the bearing.

330. Ignition Timing. With the circuit breaker in full retard position, the circuit breaker contact points should just start to separate or open when the motor is turned to top dead-center of firing stroke.

If it should ever be necessary to retime the ignition, proceed to put cylinder No. 1 on dead-center, then place the spark advance lever in full retard position.

Remove the distributor segment by pulling it up off the shaft, disclosing the nut that locks the cam. Unscrew and remove this nut. Loosen the cam from its snug fit on the taper shaft by prying up gently with a wrench provided for that purpose. Use care not to mar the smooth surface of the cam. Replace distributor segment on cam and turn in a clockwise direction until segment points to pin M (Fig. 10) in rim of distributor body casting, and breaker points are beginning to open. Rap cam down to make it fit snugly on the taper. Replace the nut and tighten it down.

When the segment holder is placed back upon the shaft, the metal blade or segment will be opposite the extension of the distributor cap terminal directly over the locating notch in the edge of the distributor cap. This terminal is to be connected to the spark plug of cylinder No. 1.

The other terminals in the direction of rotation in their order should be connected to the other plugs according to the firing order of the motor. Some four-cylinder, four-cycle motors fire 1, 2, 4, 3—others 1, 3, 4, 2. Some six-cylinder, four-cycle motors fire 1, 5, 3, 6, 2, 4—others 1, 4, 2, 6, 3, 5.

The ammeter in this cut is not a part of the equipment. It is included to show where the ammeter is to be connected for testing. The dotted line indicates th correct connection without the ammeter.

The wiring as shown is correct for our complete equipment when the 259-A-B-C-D Governor-Generator is used. Some tractor manufacturers will ground the negative side of the battery while others will ground the positive side.

When we do not supply a starting motor, the red wire will go direct from the post B on the combination switch to the storage batatery.

331. Check. Turn the crank shaft until piston No. 1 is on top firing dead-center again, and see that the breaker points open at this time with spark lever at full retard.

Failure to get a spark is sometimes due to the gap in the spark plug becoming clogged with carbon or oil. This gap should measure .030 inch, about 1-32 inch.

332. Ignition Coil. The current from the battery does not have sufficient pressure or "voltage" to jump the gap of the spark plug. Therefore, the ignition coil N (Fig. 10) is provided, which transforms the battery current into high tension current. The high tension current is conducted by a heavily insulated wire from the terminal HT on the side of the coil to the center terminal of the distributor. Then the segment J on the segment holder K directs the spark to the cylinders in proper firing order. The return circuit for the high tension current from the spark plug is through the motor and metal parts of the tractor back to the metal base of the coil. See circuit diagram (Fig. 13).

an ammeter in series with the battery by disconnecting the line wire from terminal L (Fig. 9) under the generator cover, and connect it to one side of the ammeter. Then run a wire from the other side of the ammeter to terminal L.

You will note we have indicated these connections with dotted lines. If after making these connections the ammeter hand shows charged with the switch on and the motor not running, you will know that the wires on the ammeter should be reversed.

If the ammeter does not show a discharge of about 15 to 20 amperes when the engine is not running and the switch is turned to "On" or "Run" with the control on "Point" 1, look for the following:

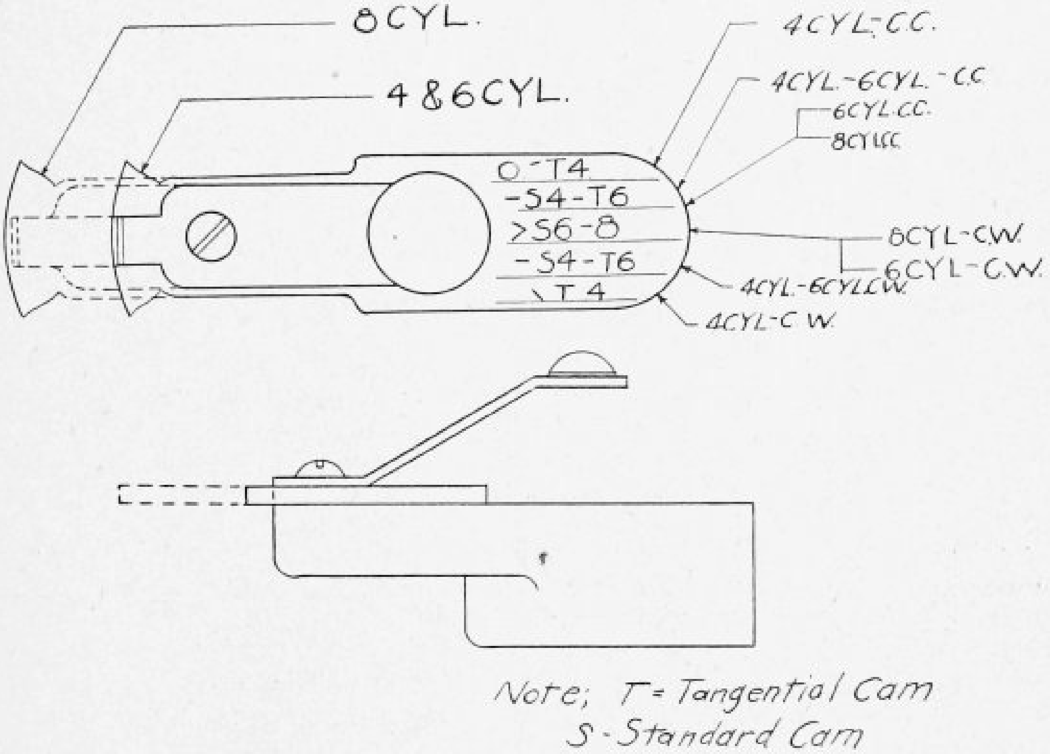


FIG. 14

333. Segment Holder Used With Waterproof Distributor Cap. The segment holder is designed for 4, 6 or 8-cylinder ignition distributors. It may be used with tangential or standard cams and for either clockwise or counterclockwise rotation, the only difference being the position of the hole for cam pin and the length of segment. A longer segment is used for the 8-cylinder than for the 4 and 6-cylinder distributor.

A diagram of the segment holder is shown in Fig. 11. To determine the rotation of the ignition distributor with which a segment holder is intended to be used, follow the direction of arrow nearest drill hole in bakelite. This hole at the end of the line opposite the letters and figures, indicates the type of cam (tangential or standard) and number of cylinders with which the segment holder is to be used.

334. Locating Trouble. To test the generator put

(1) A weak storage battery.

(2) A corroded storage battery terminal.

(3) A ground or short circuit in the Starting Motor switch or somewhere in the wiring between the ammeter and the storage battery.

(4) A poor ground or poor connection between the control box and the tractor frame or in the wiring.

(5) Poor contact between the control handle and the control box, or the contact spring and the contacts to which the rheostat resistance is connected.

(6) Loose or dirty connections at the terminal posts in the control box starting motor switch, under the generator cover or where the wire is soldered to a terminal.

(7) If all but a very few strands of the wire are

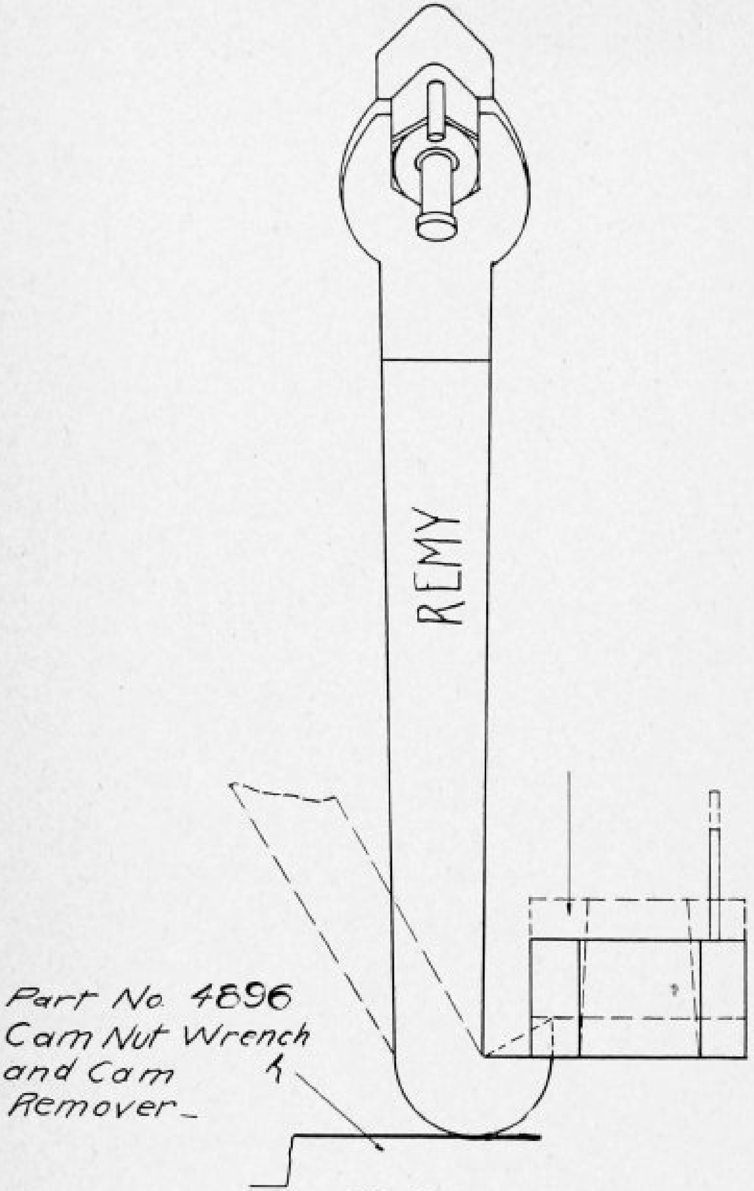


FIG. 15

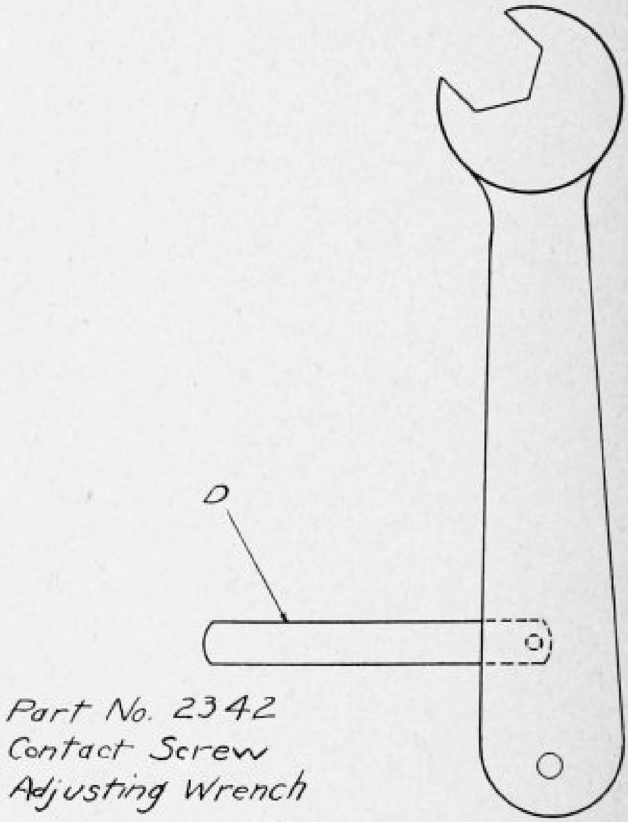


FIG. 16

broken off at the terminal, a new connection should be made and soldered.

(8) Sometimes all or most of the strands of wire are broken inside of the insulation at a point where the wire is subject to much movement. This condition can only be determined by feeling the wire.

(9) In such cases the wire should be put at the point where it is bad, cleaned well, twisted together, soldered and taped well, or a new piece of wire should be used with terminal properly soldered on.

(10) A poor contact in the combination lighting and ignition switch.

If the discharge rate is much more than 20 amperes, look for the following:

(a) Broken down insulation at terminal post L due to a crack in the insulation, dirt, or an insulating bushing that is being out of place and so causing a short circuit.

(b) Line (insulated) brush or leads connected to it that have been shorted.

(c) Grounded or shorted field.

If the discharge rate does not decrease as the control is turned towards point "Fast" and stands at about 15 to 20 amperes, you can be sure that the trouble is due to a short circuit somewhere between the field winding where it is connected to post F under the generator cover, and post F inside of the control box.

335. Testing Ignition if Motor Fails to Fire. To test for spark failure:

(1) Crank the motor and remove one of the spark plug wires—if when you hold it about 1-8 inch from the spark plug or a clean part of

the motor you get a good spark, you may rest assured that the ignition is O. K. You should then inspect the spark plugs, carburetors, and the compression.

If you fail to get a good spark, stop the motor and check the contact point opening as instructed on Page 170 under "To Adjust Contact Points," and proceed as follows:

(2) Turn the motor until the contact points A and B (Fig. 10) are closed and the fiber block in the cam lever is not touching the cam D.

(3) The discharge through the generator when the switch is in "On" position, control box on 1 and motor not running is 15 amperes. Therefore, when making this test it is advisable to disconnect the black lead from the post L (Fig. 10) and be very careful not to drop the nut or anything inside of the housing. Also pull the rubber sleeving over the metal terminal to keep it from becoming grounded while you are making the tests.

(4) Turn on the ignition switch.

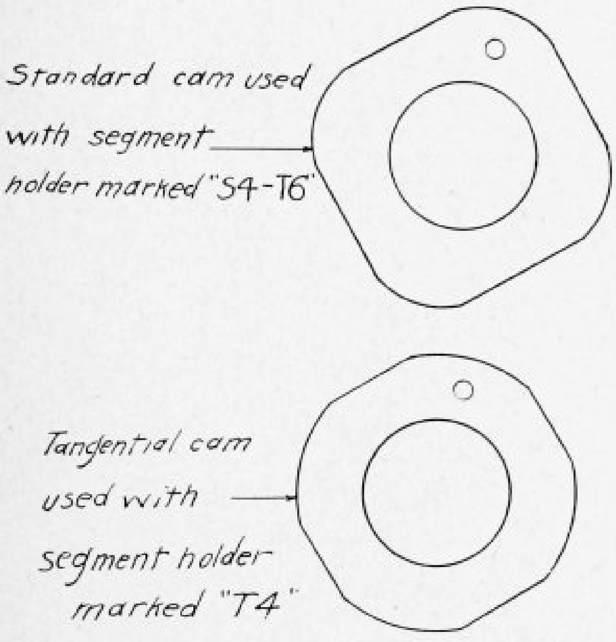


FIG. 17

(5) Remove from the distributor cap the high tension lead HT that connects to the carbon button G (Fig. 10), and hold it about 1-8 inch from a clean metal part of the generator or motor.

(6) Separate the contact points A and B quickly with your fingers. If you get a good spark it is evidence that the coil is O. K.; then examine for the following conditions:

(a) Dirty or oily spark plugs, size of gap, or broken down insulation.

(b) If the spark jumps from plug wire to ground before reaching the spark plug the insulation is probably cracked and possibly the spark plug gap being too large.

(c) Spring I may not be touching carbon button G. If it is not, bend the spring until it does; but take care not to bend it all at one point as that will cause it to break.

(d) See that segment holder K is in good condition.

When parts are needed for the ignition, be sure to give the Model number of the generator and the Letter following it—A-B-C, etc.

(6) Failure to get a spark from the HT lead, but at the same time a spark occurring between the contact points, would indicate one of the following:

(a) That the coil is loose on the housing.

(b) That dirt is under the coil preventing a good ground.

(c) That the secondary winding insulation has broken down, in which case a new coil should be obtained.

(7) Failure to get a spark from the HT lead or between the contact points indicates one or more of the following:

(a) Dirt on the surface of points A and B.

(b) A corroded battery terminal.

(c) A loose connection or short circuit.

(d) Poor contacts in the ignition switch.

(e) Completely discharged battery.

(f) Open or grounded circuit within the coil which would be evident if current can be traced up to the upper LT terminal marked "switch," and does not show at the lower LT terminal.

(8) Failure to get a good spark from the HT terminal and at the same time a bright flash occurring at the contact points when opening them, indicates one or more of the following:

(a) Condenser has broken down.

(b) Open circuit in condenser line (loose connection or broken wire).

(c) Poor condenser circuit caused by coil being loose on the frame or dirt under it causing a poor ground.

(9) After completing the above test be sure to turn the ignition switch "Off" and connect the black lead to post L.

336. Starting Motor. The Remy starting motor is of the four-pole, series wound type, of very compact and sturdy construction. The starting motor is designed to furnish ample power to crank the motor at a high rate of speed, consuming the minimum amount of current commensurate with the demand for positive operation.

A Bendix transmission is used to automatically engage and disengage the starting motor with the motor flywheel. The extended shaft of the starting motor carries a hardened steel sleeve upon which is cut a screw thread. Operating upon this sleeve is a steel pinion, having a lateral travel of about one and one-half-inches for engaging with the gear teeth on the flywheel. A helical steel spring serves as a flexible coupling between the starting motor and the motor, and absorbs practically all shocks.

When the starting motor is supplied with current, its armature being free, starts to revolve at a high rate of speed. The pinion, by reason of its counterweight, tends to lag behind the rotation of the shaft, whose screw thread thus draws the pinion into mesh with the flywheel gear teeth. As soon as the motor starts firing, its increased speed threads the pinion back in the opposite direction, thus disengaging the starting motor from the motor.

Switch ignition on after the motor has been turned by starting the motor. In this way, it will not always be necessary to retard the spark in starting, unless it is cold or there is much carbon in the cylinders. The position of the rocker-ring upon which the brushes are mounted should never be changed, as the ring is accurately set at the factory.

***337.* Oiling.** A few drops of clean light oil should be given each oil hole of starting motor twice a week.

***338.* Commutator.** The commutator should be cleaned about once a season by an experienced man, the same as for the generator. The removable cover makes the commutator and brushes easily accessible.

***339.* Starting Motor Fails to Turn Motor.** If the starter fails to crank the motor, do not blame the starter, ignition or the carburetor, but proceed as follows:

(1) See that the battery terminals are clean and that all connections in the starting circuit are tight, especially the starter lead where it is soldered into the terminal that connects it to the battery. If you are able to twist the wire in the terminal, it should be re-soldered.

(2) Then note if a flash occurs at the starter switch contacts when releasing the switch.

(a) If it does not, or is very weak, that is evidence of a very weak battery or poor connections.

(b) If a good flash occurs and the starter does not turn the motor, remove the commutator cover by taking out the screw X83 and see if the armature is free to turn with your finger.

(c) If it is, and the armature turns when the switch is closed, the trouble is no doubt due to heavy grease on the Bendix worm 5001 which prevents the pinion 5063 from going into mesh with the teeth in the flywheel.

There is a drain hole in the bottom of the flywheel gear case that should be kept open to prevent the grease from collecting therein and causing the above trouble.

(d) If the armature will not turn, have someone crank the motor by hand; and if teh armature then turns, you will know that the Bendix pinion is in mesh with the flywheel teeth and it may be necessary to use both the starter and the hand crank to start the motor. The pinion should then be thrown out of mesh with the flywheel automatically when the motor starts.

The starter is not intended to crank the motor without first gathering a little momentum made possible by the time required for the pinion to travel into mesh with the flywheel gear teeth. Therefore, if you close the starter switch momentarily and the starter does not have time to turn one cylinder past compression, the Bendix pinion will very likely stay in mesh with the fly-wheel gear, and the next time you try to use the starter it will be trying to start with a dead load.

You should not think of starting the motor with the tractor in gear and the clutch connected, as the load would be too great.

(e) If the battery is nearly discharged and the lights are turned on, they will be dim when the starter switch is closed. The lights will also be dim if you try to use the starter when the Bendix pinion is standing in mesh with the flywheel gear.

DON'TS.

Do not crank tractor by hand with the spark advanced.

Keep out dirt when adjusting breaker points.

Avoid excess lubrication on breaker box—oil or carbon on the breaker points will prevent a spark.

Do not play with the generator. It is a thoroughly tested machine and its adjustment should not be changed.

Do not allow terminals to become corroded. If trouble is experienced such as weak lights, sluggish starter or poor ignition, examine all terminals to see that they are tight and clean, especially the storage battery terminals.

Do not remove the ignition distributor from the governor generator housing unless necessary, because it will change the timing.

Do not change the ignition timing unless it is absolutely necessary due to having removed the ignition distributor or governor generator from the motor.

Do not hold the carburetor throttle open and cause the motor to race when the control is on a low point as the field will then be strong permitting the voltage and output to run up very high and possibly burn the rheostat resistance in two. Then there would be no control of the motor speed as the field circuit would be open, and no current could be generated to operate the governor.

Do not remove or change wires of this equipment without referring to the wiring plans.

Under proper conditions the motor should start after 1 to 3 seconds cranking. If it does not start after 10-15 seconds cranking there is something wrong. Do not crank further without investigating or the battery will soon become discharged.

Do not fail to test ignition if the motor refuses to fire.

VERY IMPORTANT.

Every tractor owner and service man should have a hydrometer to test the specific gravity of the storage battery.

All service men should also have an Ammeter, a revolution counter, the special tools for adjusting and several instruction books. They should make it a point to see that every owner visited has an instruction book. Also encourage him to read it.

STARTING MOTOR WHEN STORAGE BATTERY IS DEAD.

340. Crank by Hand. If the battery is so low that there is not enough current for ignition to start the motor, then proceed as follows:

(1) Remove the line wire from terminal L under the generator cover; and be sure the terminal does not touch any metal, thereby causing a ground.

(2) Place the control on point 5 or 6.

(3) Turn the ignition key to "On" position for daylight running.

(4) Do not use the starter, but crank the motor by hand, and do so as soon as possible after turning the switch on. If there is no trouble other than a low battery, the motor will start and race until the line wire is replaced on terminal L, unless the battery is completely discharged, in which case—

(a) Turn the switch to "Off."

(b) Replace the line wire on terminal L under the generator cover.

(c) Connect 3 to 5 dry cells, depending upon their condition, in parallel with the ignition circuit from the terminal marked "switch" on top of the ignition coil to a convenient ground, preferably the circuit breaker control lever.

(d) Crank the motor by hand.

(5) As soon as the motor starts, turn the ignition key to "On" position and after the motor runs a few seconds, disconnect the dry cells, as the generator will furnish enough current for ignition and for charging the storage battery.

(6) If it has been necessary to crank it by hand, the motor should be run for about one-half hour at a speed of approximately 675 motor R. P. M. to put a little life into the storage battery before trying to do actual work.

So long as you get good ignition and good governing you can rest assured the battery is being charged, as it is the charging that does the governing.

Note: Do not run the generator with an output greater than 8 amperes, for even one hour.

341. Recharging the Battery. To recharge the battery quickly, without removing it from the tractor or running the motor fast, proceed as follows:

(1) Place the control on point 1.

(2) Turn the carburetor valve stop screw one full turn to the right.

(a) The motor will then run approximately 675 R. P. M. and should be charging the battery at about 6.5 amperes.

(b) The generator should not be run for even an hour with an output greater than 8 amperes.

Running the motor as suggested above for two or three hours should bring the battery up to a point where it would operate the starter, unless it had been completely discharged, in which case six hours, or longer, may be required.

A loose connection anywhere in the line, or a corroded battery terminal, will very likely prevent recharging of the battery and cause overheating of generator and possible damage, in which case it will soon become discharged.

Caution: After recharging the battery as above, be sure to return the screw to orignial position to avoid injuring the storage battery or other equipment.

If you have an ammeter, put it in series with the battery by disconnecting the line wire from terminal L under generator cover, and connecting it to one side of the ammeter. Then run a wire from the other side of the ammeter to terminal L.

With the ammeter you can judge the motor speed, in many cases, by output shown.

The generator output will always be from 1 to 2 amperes more than the battery charging rate.

The motor speed controller on point 1 should be between 400 and 500 R. P. M., which should give a generator output of 1 to 2 amperes.

The governor is set on point "Fast" to govern the motor at the maximum speed specified by the motor or tractor builder and the output should be approximately 7 amperes.

The ball joints in the linkage between the carburetor and the governor lever should work freely. Therfore, they should be kept clean and be oiled often to prevent rusting.

CHAPTER IX

COOLING MOTORS

342. Cooling of Motors. From the foregoing lessons we find that power is generated in an internal combustion motor by a series of explosions caused by burning gases. The temperature in the combustion chamber is as high as 2700 degrees Fahr. Thus the cylinder piston and valves are heated to a high temperature. Which will cause preignition if it were not for an efficient cooling system. This system makes possible proper lubrication, so that the parts will not become overheated. It is very important that the motor should not get too hot, or the cylinder too cool, as this would cause a loss of heat in the motor, and a consequent loss of power. The greater the difference between the temprature in the combustion and the cooling system, the more rapid the penetration of heat.

343. Cooling Systems. Cooling systems are divided into two classes; (A) Liquid cooled; (B) Air cooled.

Liquid Cooled. In this system a liquid is circulated through a cylinder jacket absorbing the heat from the cylinder wall. It circulates through a radiator and is cooled by air drawn through the radiator by a revolving fan. Water is usually used, since it is so easily obtained, and is the greatest known absorber of heat. Some manufacturers use oil.

344. Air Cooled. Some of the smaller motors, such as motorcycles, small stationary motors, and a few automobiles and truck motors are air cooled. In this system the outer surface of the cylinder is increased by the addition of flanges or splines cast integral with the cylinder, and a current of air is circulated by these flanges by means of a fan. In the larger motors the air is directed against the heated portion of the cylinder by an outer jacket.

345. The Thermo Syphon of Circulation. When water is used as a cooling agency, two systems are employed to circulate the water through the system. First by the thermosyphon system. In this system is utilized the natural principle that hot water is lighter than cold water, and that it will tend to rise to the top of the cylinder and through a duct leading to the radiator naving a constant encline toward the radiator. The cooled water returns through a duct or tube leading from the bottom of the radiator to the bottom of the cylinder and should have a constant decline toward the cylinder, thus keeping the water in constant circulation. The duct or pipe connecting the motor with the radiator should be large and have no obstructions to prevent proper circulation.

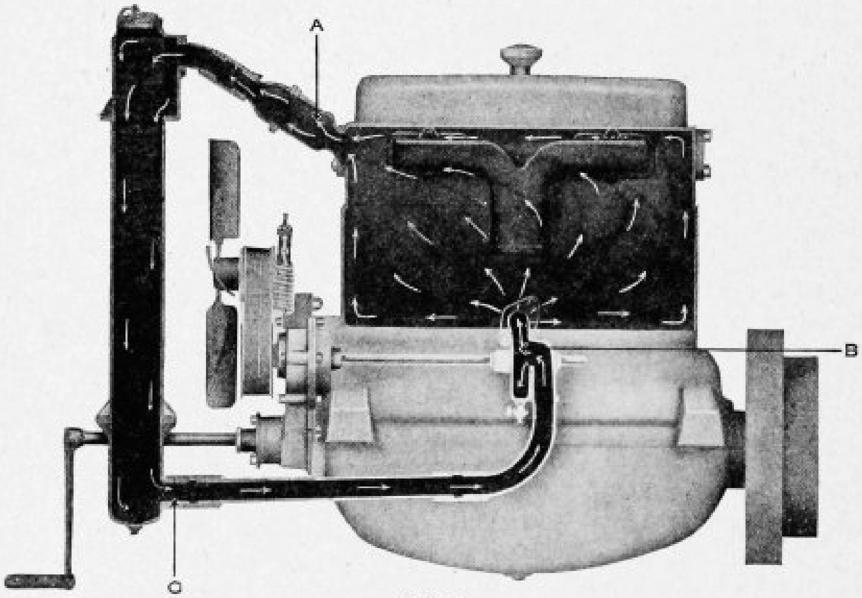


FIG. 1.

346. The Positive Water Circulation Systems. In the positive water circulation system a pump is employed, usually a centrifugal pump driven by a gear train from the crank shaft. In this system the natural law of centrifugal force is utilized. This pump consists of a propeller and a wheel having veins extending from its center to the outer circumference. The water enters at the center of the propeller, and as the propeller is revolved the centrifugal force throws the water to the outer circumference, and through the discharge pipe to the lower portion of the cylinders, and out of the top to the radiator where it is again cooled by the absorption of the heat by the air passing the cooling surface of the radiator. A typical modern water-cooling system in which a pump is depended upon to promote circulation of the cooling liquid is shown at Fig. 1. The radiator is carried at the front end of the tractor frame, in most cases and serves as a combined water tank and cooler. It is composed of an upper and lower portion joined together by a series of tubes which may be round and provided with a series of fins to radiate the heat, or which may be flat in order to have the water pass through in thin sheets and cool it more easily. Cellular or honeycomb coolers are composed of a large number of bent tubes which will expose a large area of surface to the cooling influence of the air draught forced through the radiator by some type of fan. The cellular and flat tube types have almost entirely displaced the flange tube radiators which were formerly popular because they cool the water more effectively, and may be made lighter than the tubular radiator could be for motors of the same capacity.

347. Cooling Action of Radiator. The water is drawn from the lower tank of the radiator by the pump and is forced through a manifold to the lower portion of the water jackets of the cylinder. It becomes heated as it passes around the cylinder walls and combustion chambers and the hot water passes out of the water jacket to the upper portion of the radiator. Here it is divided in thin streams and directed against comparatively cool metal which abstracts the heat from the water. As it becomes cooler it falls to the bottom of the radiator because its weight increases as the temperature becomes lower. By the time it reacnes the lower tank of the radiator it has been cooled sufficiently so that it may be again passed around the cylinder of the motor. In most cooling systems, especially those employing cellular type coolers, it is necessary to use a cooling fan to draw currents of air through the interstices of the cooler.

348. Thermostatic Temperature Regulators. As before stated the greater the difference in temperature between the gases in the cylinder and the water jacket, the rapider the heat penetrates through the cylinder into the circulation water in the jacket. Therefore the circulating water should be kept at as high a temperature as possible, in order to induce higher efficiency. The average circulating system is so designed as to keep the water at a temperature just below the boiling point, (212 degrees Fahr). Owing to the changeable weather it would be impossible to design a cooling system that would maintain a constant temperature without some kind of an automatic temperature control. The most efficient cooling system is one that would maintain a temperature just below the boiling point, 200 degrees Fahr. To do so it would be necessary to have thermostatic control, especially in motors using low grade fuels, where it is necessary to maintain a high temperature to prevent fuels from condensing on the cylinder walls, and working by the piston into the crank case. The thermostatic control will also make it unnecessary to heat the water in the entire system in order to change over from gasoline to kerosene.

On some tractors thermostatic control devices are provided to regulate the temperature of the water and prevent such rapid circulation that the cylinders will be unduly cooled. A device of this character is

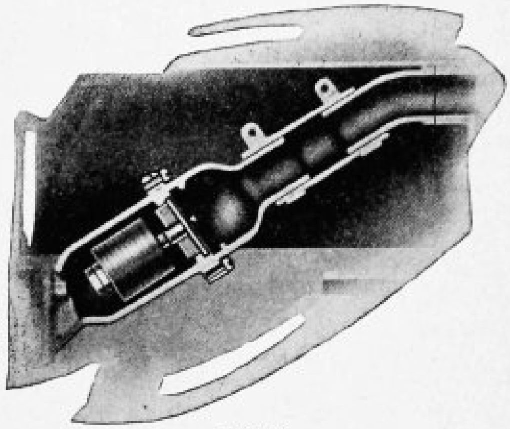


FIG. 2.

shown in Figs. 1, 2 and 3. The thermostatic element controls valves so that when the water passing through the device is too cold, the valve shuts off the passage to the radiator. When it becomes heated to a predetermined temperature the valve is opened by the expansion of the thermostatic element, and the water allowed to circulate through the entire cooling system.

349. Radiator Construction. Most radiators are now constructed with the flat tube type of core and brass tanks and steel shell, the tubs are corrugated or honeycomb type, and direct radiation. In some cases the shell and tanks are of cast iron with cooling flanges cast integrally which are becoming most popular for tractor service. Improved methods of radiator suspension by using springs are now followed to minimize danger of leakage by vibration. The effort is made to have the cooling section or core removable for repairs, and in some cases it is possible to remove a section of the core to make repairs without disturbing the radiator. A new radiator which has recently been placed on the market, will freeze solid without injury to the core.

350. Precautions in Cold Weather. It will be seen from the action of the Syphon Regulator that there is no circulation through the radiator until the jacket water has become hot. The radiator should therefore be covered up to prevent freezing until the water has become hot and circulation has started.

It is always advisable to keep radiator partly covered in cold weather. In that manner the temperature of the motor may be maintained at or near the proper temperature at all times.

351. To Drain the System. The entire cooling system should be drained when the tractor is stopped, whenever there is any possibility of freezing weather.

To drain open the radiator pet cock and the cock at bottom of water pump, and also the radiator. Allow to drain until water stops running and then start motor and run for a few seconds. In this manner the entire system will be thoroughly drained and there will be no danger of bursting the water pump in freezing weather.

352. Danger of Freezing. It is advisable to drain the tractor immediately after stopping while water is warm. This water should be drained into a barrel or a large bucket so that it may be put back when tractor is started again. This may be prevented from freezing in the container by properly covering.

353. Overheating. Overheating is due either to improper operation of the motor or cooling system. The motor may overheat to such an extent that the cooling system, although in good condition, does not carry the heat away fast enough. Or, the motor may be in good order and the cooling system impaired to such an extent that the normal quantity of heat is not being dissipated.

The most common causes of motor overheating are: retarded spark or late ignition; carbon deposit in cylinders; poor motor oil or impaired oiling system; oil having been used too long in motor or neglect to flush out oiling system thoroughly; bearings rough or binding; cylinders scored; carburetor adjusted for too lean a mixture.

Some of the common causes for an impaired cooling system are: Low water; fan slipping; circulation clogged; cylinder jackets and pipes scaled up from the use of hard water; running on a hot day in the direction of the wind.

354. Anti-Freezing Mixtures. Denatured alcohol is without doubt the best substance to use as it does not have any destructive action on the metals or rubber hose, will not form deposits of foreign matter, and has no electrolytic effect. A solution of sixty per cent water and forty per cent alcohol will stand twenty-five degrees below zero without freezing. The chief disadvantag to its use is that it evaporates easily and its boiling point is quite low. Alcohol volatilizes more rapidly than water and the solution is liable to become too light as proportion of alcohol to water is concerned. The percentages required are shown in the following:

Water ninety-five per cent, alcohol five per cent, freeze at 25 degrees Fahr., water eighty-five per cent, alcohol fifteen per cent, freeze at 11 degrees Fahr., water eighty per cent, alcohol twenty per cent, freeze at 5 degrees Fahr., water seventy per cent, alcohol thirty per cent, freeze at 9 degrees Fahr. below zero; water sixty-five per cent, alcohol thirty-five per cent, freeze at 16 degrees Fahr. below zero.

Various mixtures have been tried of alcohol, glycerin, and water, and good results obtained. The addition of glycerin to a water-alcohol solution reduces liability of evaporation to a large extent, and when glycerin is used in such proportions it is not liable to damage the rubber hose.

The proportions recommended are a solution of half glycerin, half alcohol to water. The glycerin in such a solution will remain practically the same, not being subject to evaporation, and water and alcohol must be supplied if amount of solution in radiator is not enough. The freezing temperatures of such solutions of varying proportions are as follows: Water eighty-five per cent, alcohol and glycerin fifteen per cent, freeze at twenty degrees above zero; water seventy-five per cnt, alcohol and glycerin twenty-five per cent, at 8 degrees Fahr., water seventy per cent, alcohol and glycerin thirty per cent, freeze at 5 degrees Fahr. below zero; water sixty per cent, alcohol and glycerin forty per cent, freeze at 23 degrees Fahr. below zero.

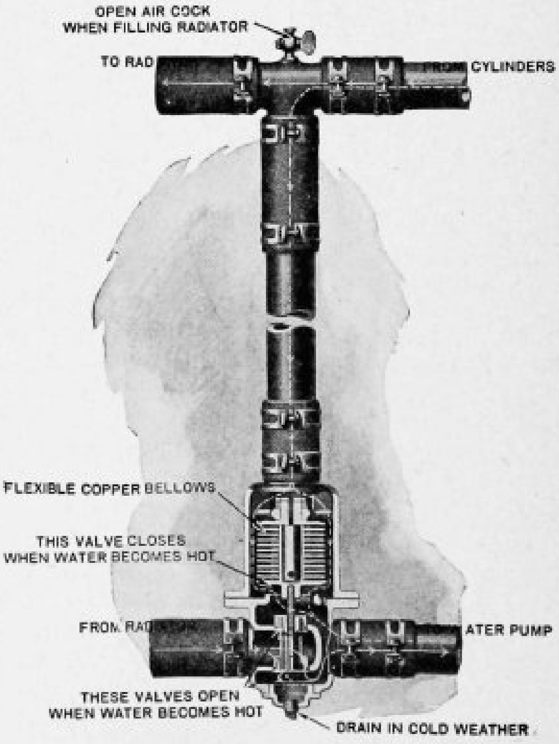


FIG. 3.

Sylphon Regulator Showing Path of Circulation, as used on J. I. Case Tractors.

CHAPTER X

LUBRICATION

355. Lubrication. The importance of proper lubrication and minimizing friction at the various bearing surfaces of a tractor to maintain the highest mechanical efficiency is of utmost importance. The pro-lubrication of all working parts of the tractor is a very essential factor upon which the durability and successful operation of the tractor depends.

The revolving parts of machinery when in motion have a tendency to stick to the stationary parts, and the very minute projections which exist on even the smoothest of surfaces would adhere or cling to each other if the surfaces were not kept apart by some lubricating substance.

356. The Theory of Lubrication. The theory of lubrication is to suspend the revolving parts on balls of oil, so to speak, the larger the balls of oil the higher the mechanical efficiency of the tractor. The size of the balls depend upon the bearing pressure per square inch, the R. P. M., the viscosity or body of the oil, and the temperatures. (See Fig. 1.)

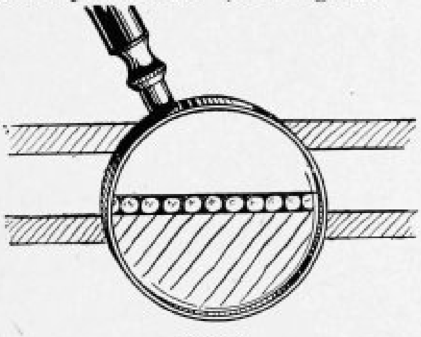


FIG. 1.

357. Friction. Friction is always present in any machine where motion is necessary, and tends to bring all moving parts to rest. The absorption of power by friction may be gauged by the amount of heat which exists at the point of bearing. Friction may be divided into two classes: Sliding friction, which exists between the piston and cylinder, or the bearings of the motor; and rolling friction, which is present when the load is supported by ball or roller bearings, or that which exists between the driving wheels and the road. Tractor designers endeavor to keep friction losses as low as possible, and much care is taken in all modern tractors to provide adequate methods of lubrication, and ball or roller bearings at all points considered practical.

358. Oil Tests, Their Relation to Correct Lubrication. As compiled by the Vacuum Oil Company refiners and distributors of Gargoyle Mobiloils. Several years ago a prominent engineer invented a machine for testing the efficiency of oils. For a time this testing machine was considered practical and helpful. But one day it was found that crude kerosene oil, by this machine's test, was the best lubricant.

That, of course, was ridiculous on the face of it.

This will indicate the difficulties which science has always met in trying to judge an oil's efficiency by anything but the practical tests of use.

Nevertheless, during manufacture, certain scientific tests are essential.

These tests are not aimed to get at the efficiency of the oil.

They are simply checks to make certain that the oil is running uniform—that every lot furnished is up to the desired standard.

Below is outlined briefly a number of the tests used for this purpose.

359. Gravity Test. In this test a weighted bulb with graduated spindle (hydrometer) is dropped into a tube of oil. The hydrometer floats. But its bottom sinks to a certain depth depending on the oil's gravity. The gravity is determined by the depth to which the hydrometer sinks, as shown by the markings on the spindle, with the oil at 60 degrees F.

This test is simply used to determine whether or not uniform weight per gallon is being maintained.

360. Flash Test. The flash test is the lowest temperature at which the vapor from an oil will ignite but not continue to burn.

If the flash test is too low, the oil will evaporate from the cylinder walls and bearings when the normal motor heat develops. This would leave the friction surfaces without lubrication.

361. Fire Test. This test is made with the apparatus used in the flash test. The fire test is the temperature at which the ignited vapor from an oil will continue to burn.

362. Viscosity Test. Viscosity is simply the technical name for what is popularly called "body," but this fact must be borne in mind: Two oils which will show the same viscosity at one temperature will often decidedly differ in viscosity at a higher or lower temperature.

The viscosity of Gargoyle Mobiloils is tested at three different temperatures—104 degrees, 140 degrees and 210 degrees Fahr.

In this test the oil is put in a tube surrounded by water, which is kept at the test temperature. When the oil reaches the predetermined temperature, a plug in the bottom of the tube is removed. This opens a small standardized tube. The oil is then allowed to flow out of this opening into a glass receptacle of known capacity.

363. Shake Test. Another purification test: A little water is put in a bottle which is about half full of oil. The bottle is put into the shake machine. The oil is churned up with the water—at the rate of 350 elevations per minute. This movement is kept up for about an hour. The oil is then examined. The water should quickly sink to the bottom of the bottle, leaving a clear separation between the oil and the water.

If the oil is improperly purified the water will not clearly separate; it will hang up in the oil, and have a yellowish, mucky look. This test is sometimes known as the "emulsion test."

364. Bubble Test. Two oils in separate bottles are compared by the following method: The bottles are quickly turned upside down. The rise of the big bubbles to the top is watched. This is sometimes believed to indicate the relative viscosities of the oils.

If this test is to be of any value, the bottles must be of the same size and the oils must be at the same temperature. But the method is crude and inaccurate. The bubbles may apparently rise to the top in exactly the same time, and the two oils still be far apart in "body" or viscosity.

365. Palm Test. A few drops of the oil are poured into the palm of the hand. The oil is rubbed with the finger. The "feel" of the oil is then supposed to indicate whether or not the oil is of proper "body" or quality.

A person of very fine sensibilities may be able to distinguish between the "bodies" of oils so tested. But that is doubtful. At best the method is inaccurate. And the important question still remains unanswered: "What 'body' is desirable for the purpose?"

366. Pencil Test. A pencil is thrust down to the bottom of a bottle of oil. It is then quickly lifted out. The flow of the oil from the end of the pencil is watched. This is supposed to be a guide to the viscosity of the oil.

At best the method is inaccurate, for oils which are far apart in viscosity would often apparently drop at the same rate from a pencil.

367. Hot Metal Test. A few drops to a teapsoonful of oil are poured on a hot piece of metal. If the oil evaporates rapidly it is considered by some oil users a sign of poor oil. If the oil evaporates slowly and spreads over the metal it is considered a good oil.

If this test is good for anything it simply indicates the boiling point of the oil. When oil boils it evaporates just as water evaporates on boiling.

Oil might be very unclean and poor in practically every other respect and still show a high boiling point on the metal.

And the high boiling point of itself proves practically nothing. For some purposes, oil of a high boiling point is distinctly undesirable.

368. Crank Case Test. Some automobilists and mechanicians try to test oil by letting it run out of the pet-cock in the crank case. If the oil comes out lighter in body than normal they consider it has failed to stand up in service.

This test is misleading.

The lightness in body may be due to either of the following causes:

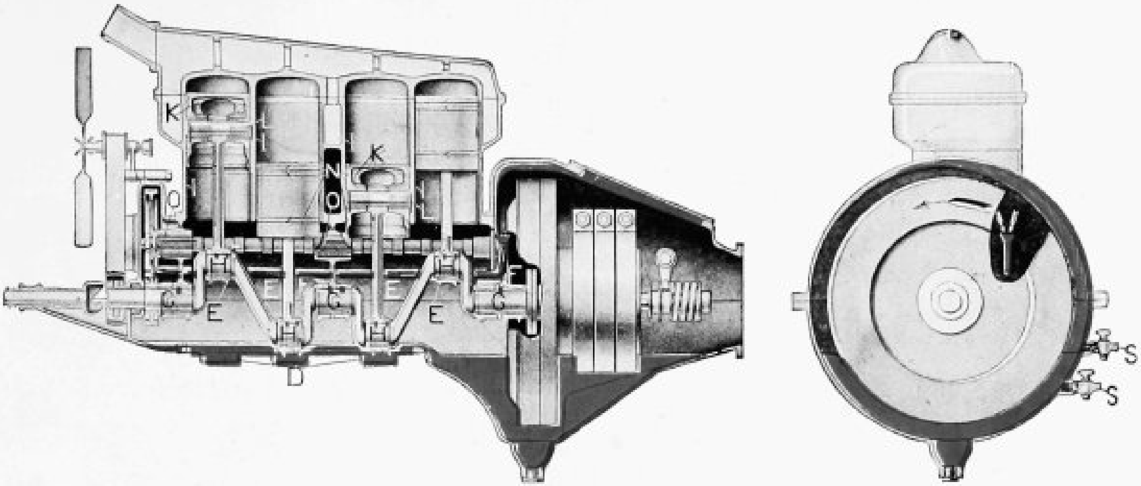
(1) **Gasoline leakage.** If the clearance around the piston rings is not properly sealed gasoline leaks down into the crank case and thins out the oil.

(2) Heat. The oil goes into the crank case cool. When the engine runs, the crank case heats. Any oil will then become more fluid. But the oil when again cooled will return to its original body.

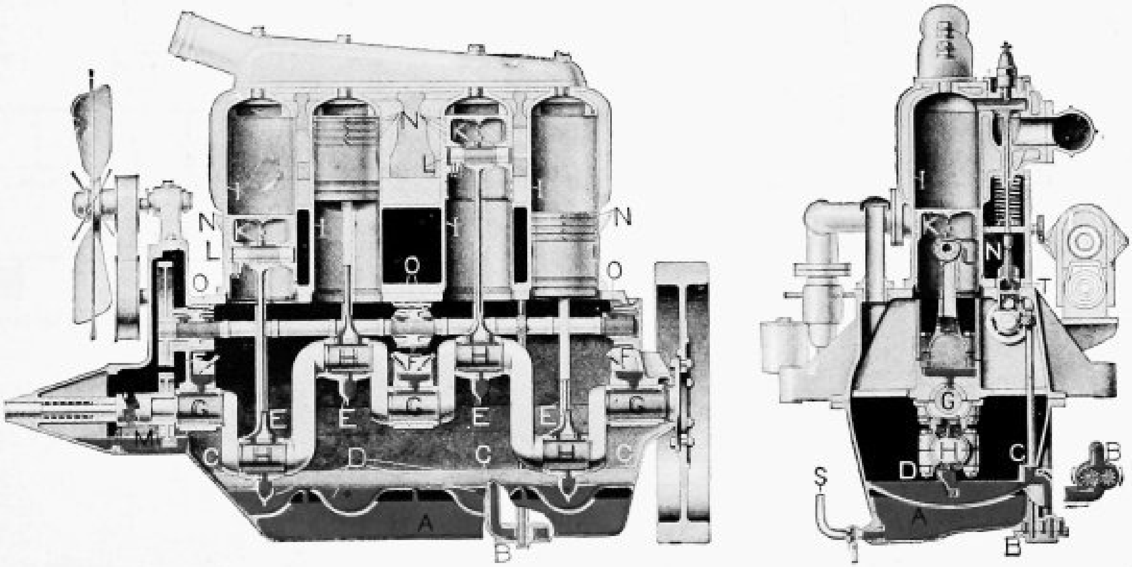
369. Division of Lubricating Systems. A study of the lubricating systems as tractor motors, with all their peculiarities of design, in connection with exhaustive tests shows that practically every lubricating system in use today can be included in the following distinct types:

(1) Full Splash.
(2) Splash, with Circulating Pump.
(3) Pump Over and Splash.
(4) Force Feed and Splash.
(5) Pump Over.
(6) Separate Force Feed.
(7) Force Feed.
(8) Full Force Feed.
(9) Direct Force Feed.
(10) Direct Force Feed and Splash.
(11) All Loss Direct Force Feed and Overflow to Gears.

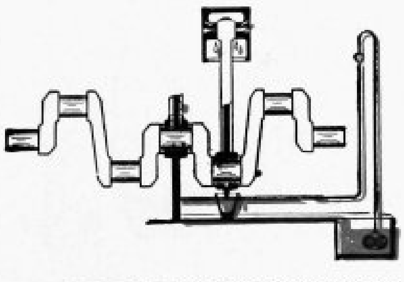
The reason for choosing such a fixed number of lubricating systems is to facilitate their proper classification and because of the effect which the details of these lubricating systems exert upon the flow of oil to the moving parts. Insofar as the principles involved go. Lubricating systems, without exception, can be divided into two general groups, "Circulating" systems and "All-Loss" systems. By "all-loss" system is meant a lubricating system in which oil is fed directly into the crank case or through the bearings into the crank case, from an outside source. In "all-loss" systems the lubrication of the parts in contact is accomplished by splash only from the connecting rod ends, and by oil under pressure as well as by splash from the connecting-rod ends. In motors employing "all-loss" systems oil is filled up to a fixed level in the crank case. The lubrication of all parts is then made continuous by splash and by feeding oil from auxiliary source into the crank case, where it is consumed at or about the same rate as the feed. "All-loss" systems are, however, much less fool-proof in many ways than are the circulating. There is a possibility with the former of feeding an excess of oil into the crank case,



SYSTEM 1—THE LUBRICATING SYSTEM OF THE FORD MOTOR



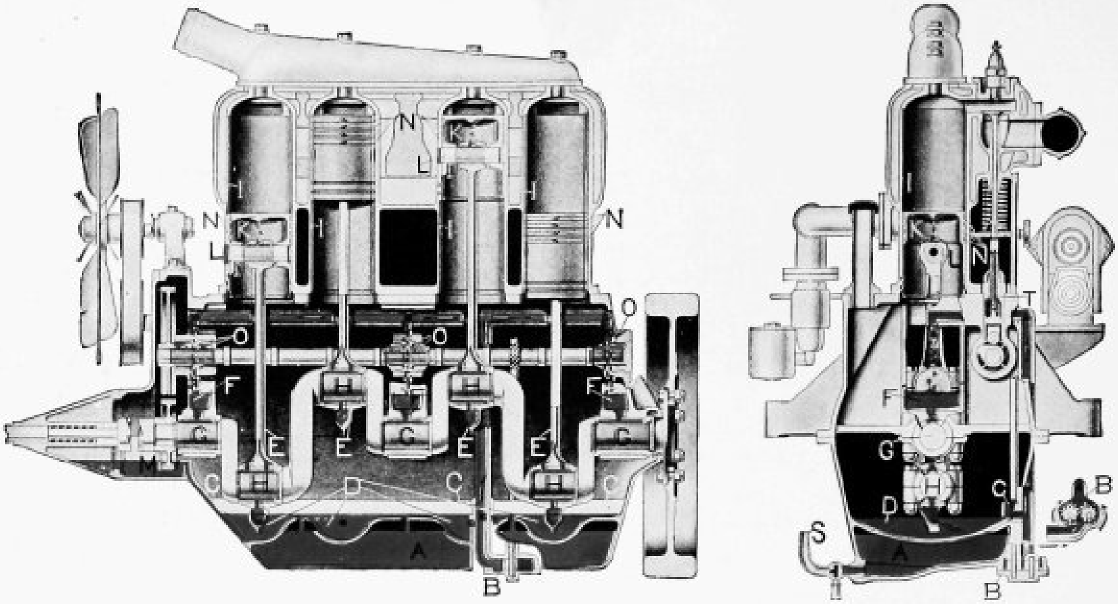
SYSTEM 2—SPLASH, WITH CIRCULATING PUMP



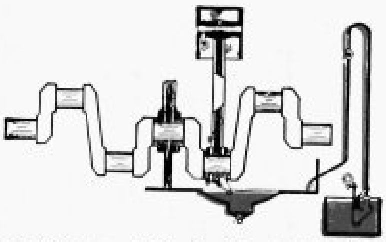
SPLASH CIRCULATING SYSTEM

PLATE 1

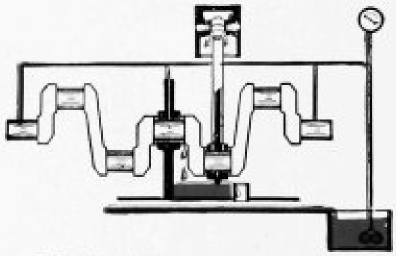
COURTESY OF THE VACUUM OIL CO.—THE TIDEWATER OIL CO.



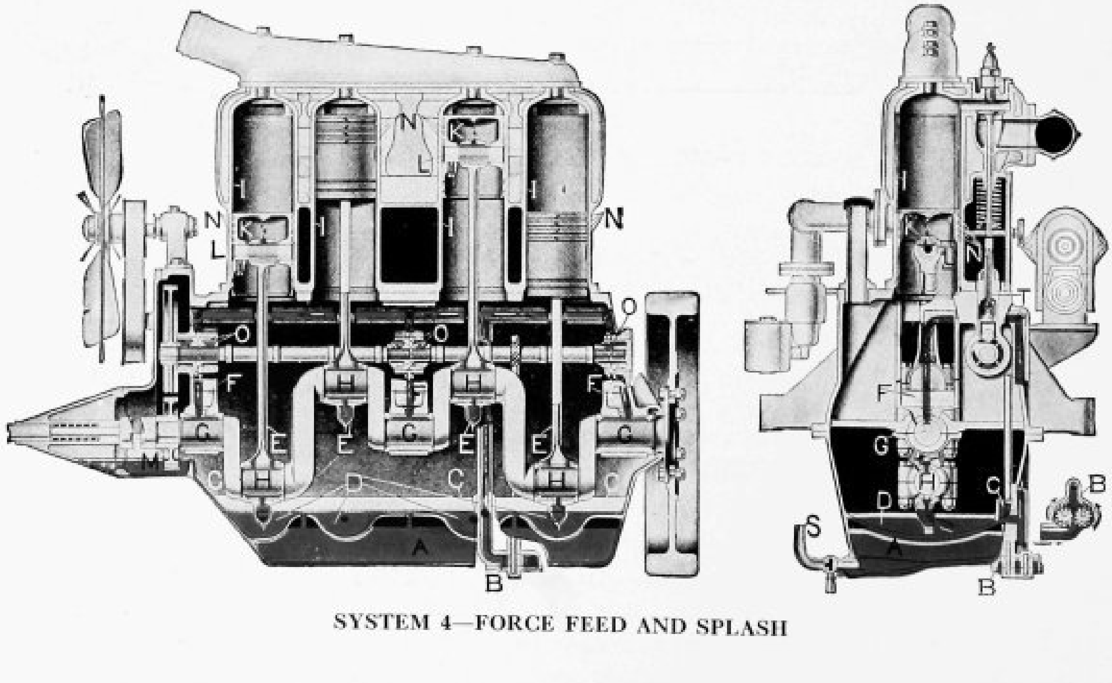
SYSTEM 3—PUMP OVER AND SPLASH



Pump Over and Splash Circulating System



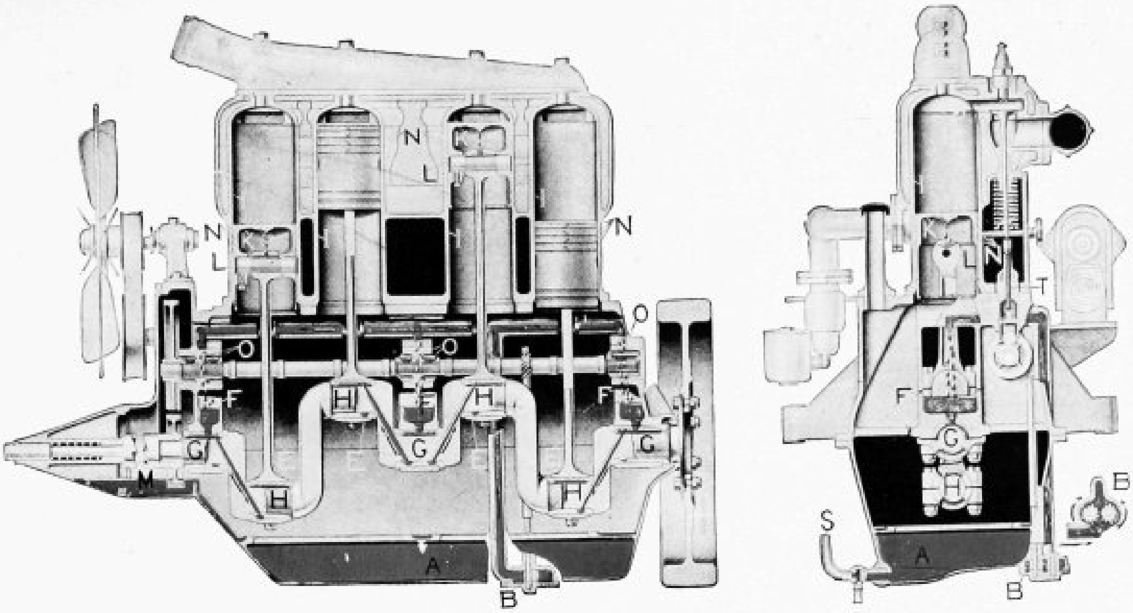
Force Feed and Splash Circulating System



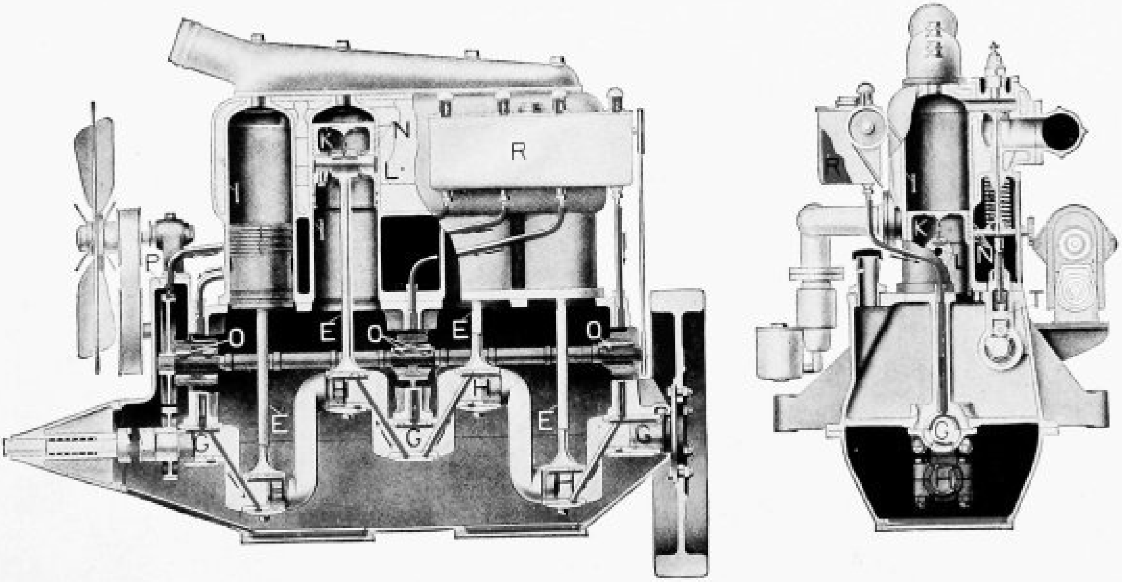
SYSTEM 4—FORCE FEED AND SPLASH

PLATE 2

COURTESY OF THE TIDEWATER OIL CO.—THE VACUUM OIL CO.



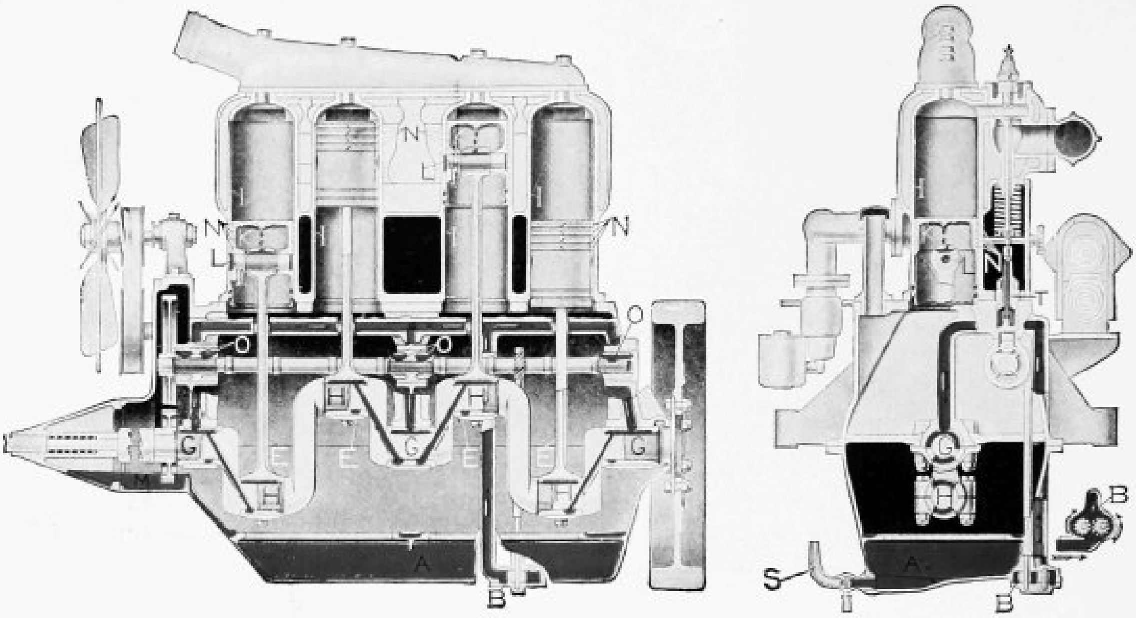
SYSTEM 5—PUMP OVER



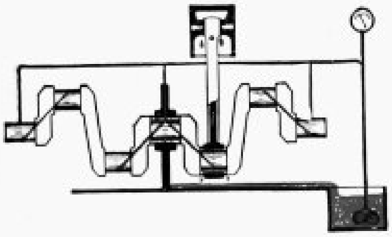
SYSTEM 6—SEPARATE FORCE FEED

PLATE 3

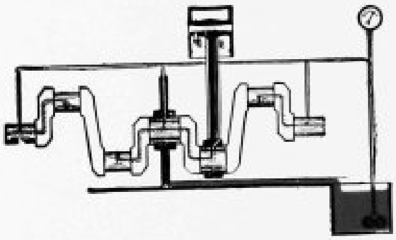
COURTESY OF THE VACUUM OIL CO.—THE TIDEWATER OIL CO.



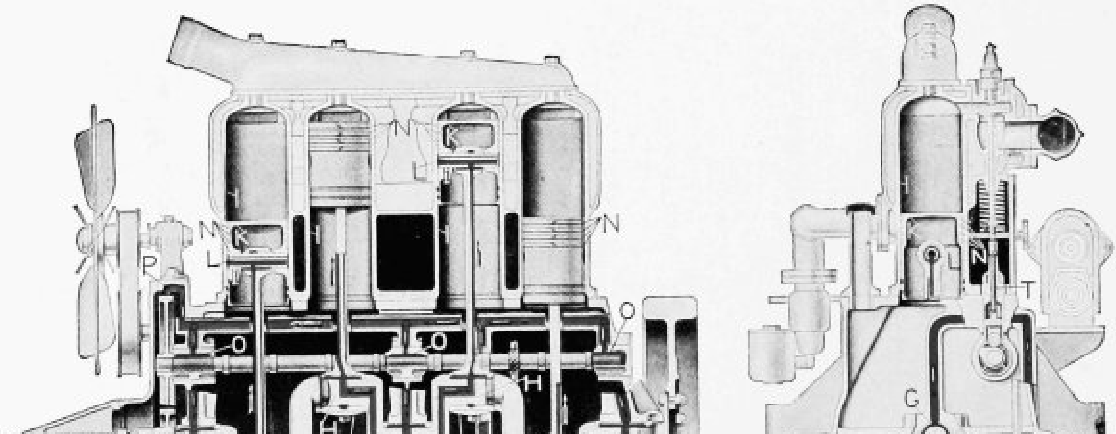
SYSTEM 7—FORCE FEED



Force Feed Circulating System



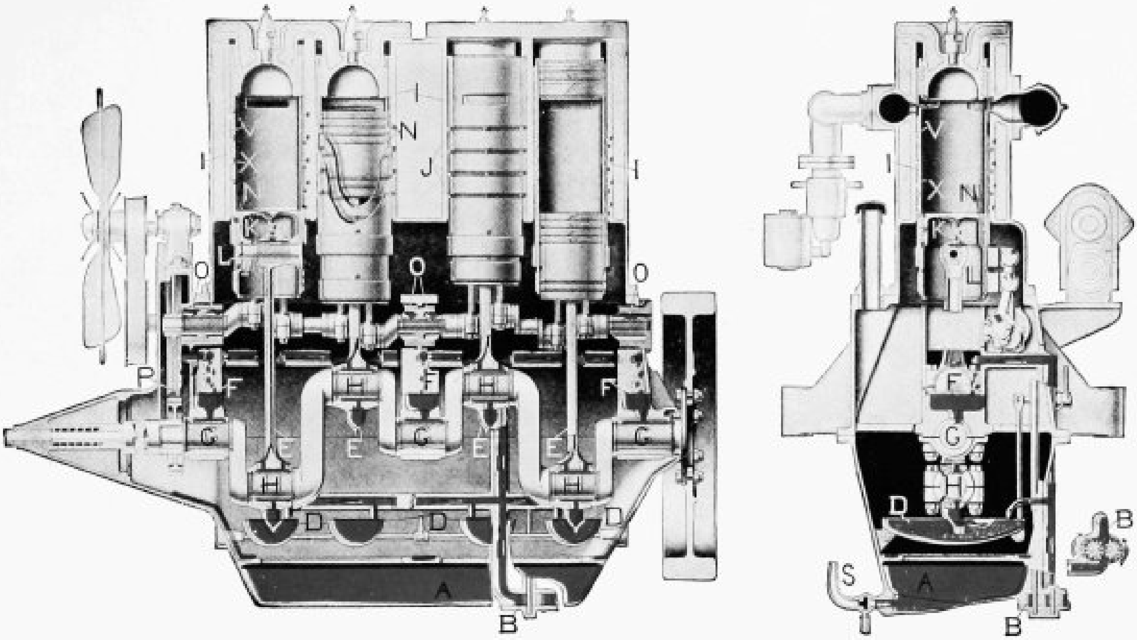
Full Force Feed Circulating System



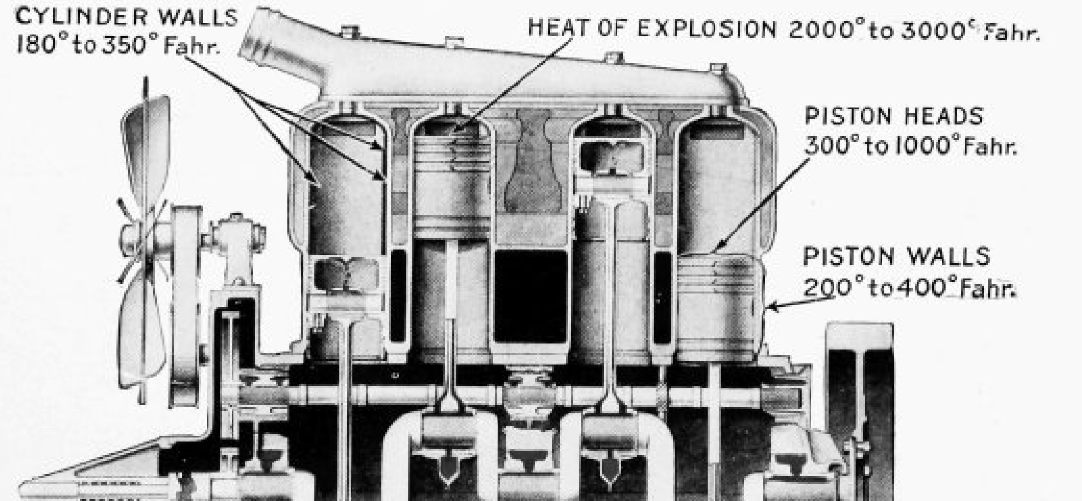
SYSTEM 8—FULL FORCE FEED

PLATE 4

COURTESY OF THE VACUUM OIL CO.—THE TIDEWATER OIL CO.



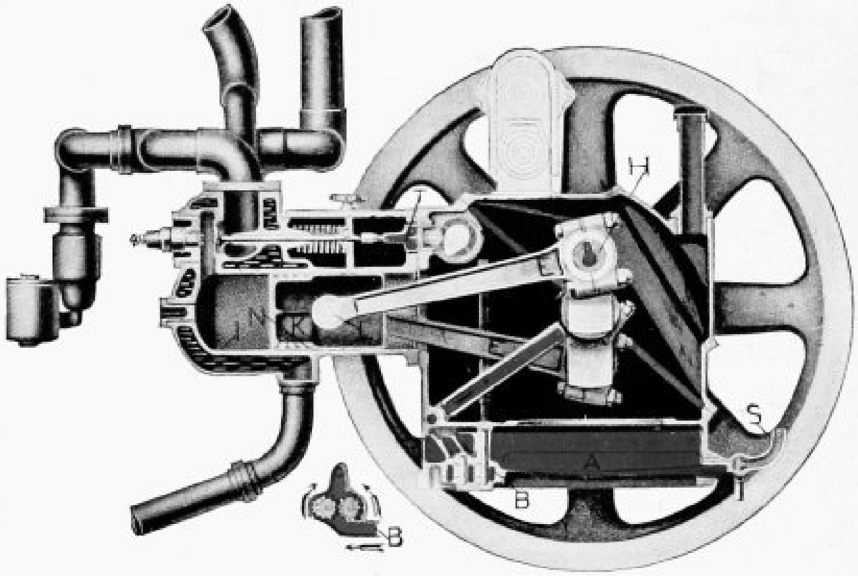
SYSTEM 9—KNIGHT SLEEVE VALVE MOTOR



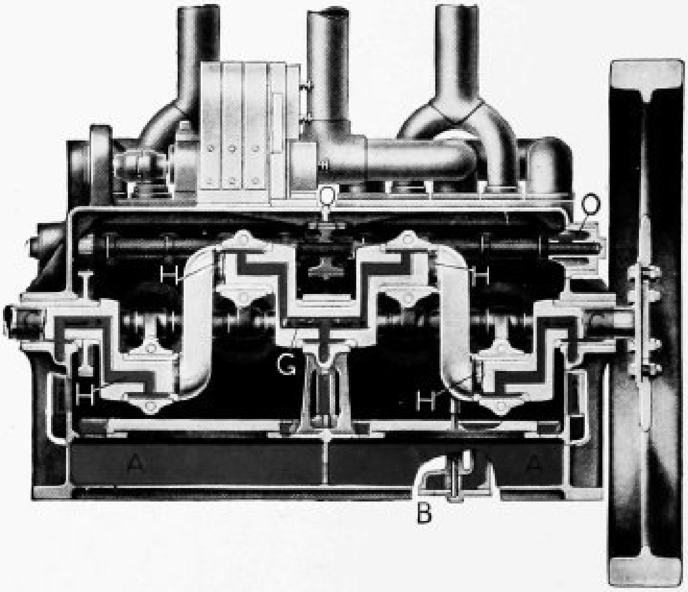
OPERATING TEMPERATURES OF MOTOR PARTS

PLATE 5

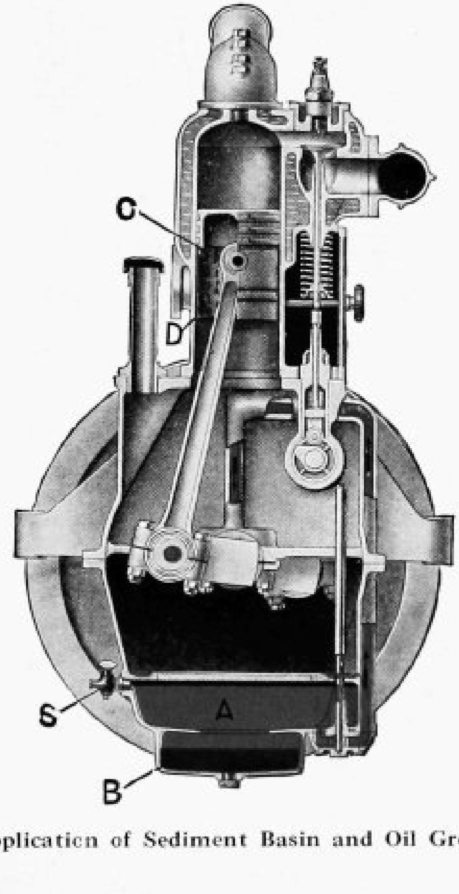
COURTESY OF THE VACUUM OIL CO.—THE TIDEWATER OIL CO.



SYSTEM 10—FORCE FEED



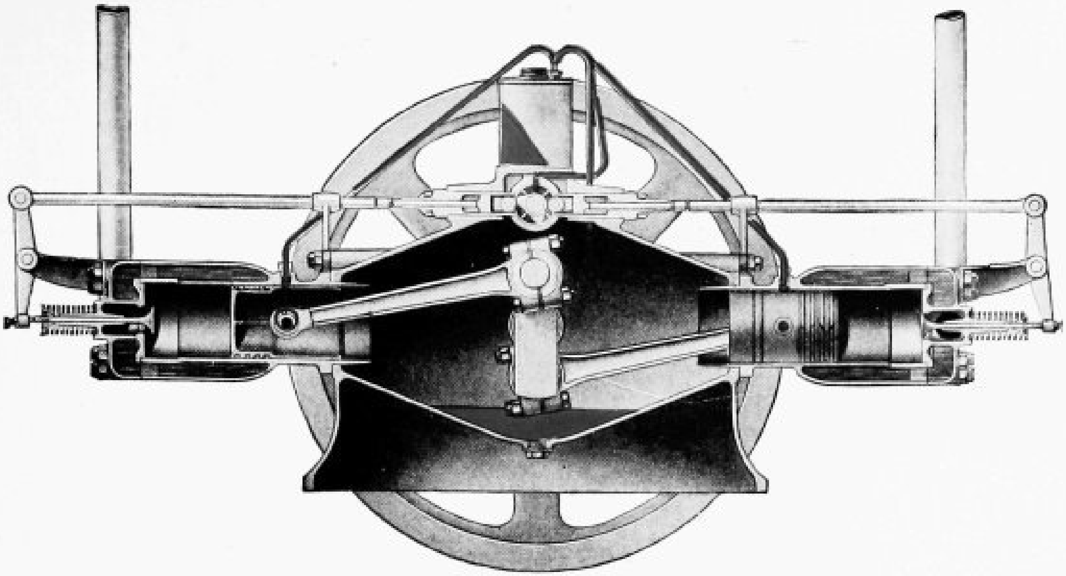
Application of Sediment Basin and Oil Grooves



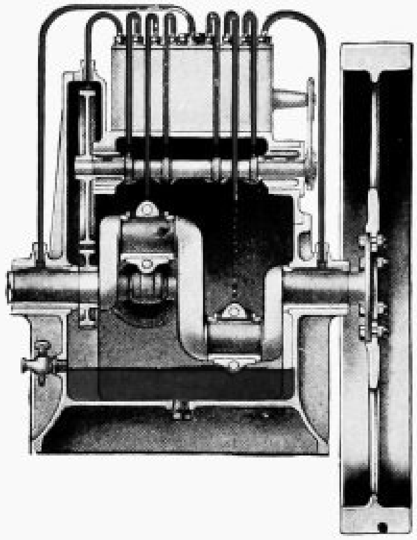
Application of Sediment Basin and Oil Grooves.

PLATE 6

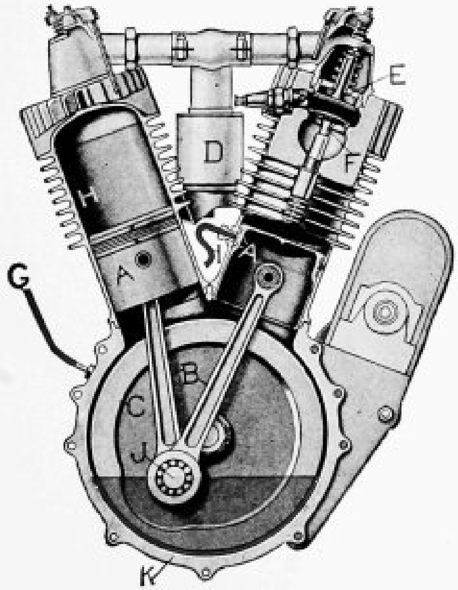
COURTESY OF THE VACUUM OIL CO.—THE TIDEWATER OIL CO.



SYSTEM 11—SEPARATE FORCE FEED HORIZONTAL TYPE MOTOR

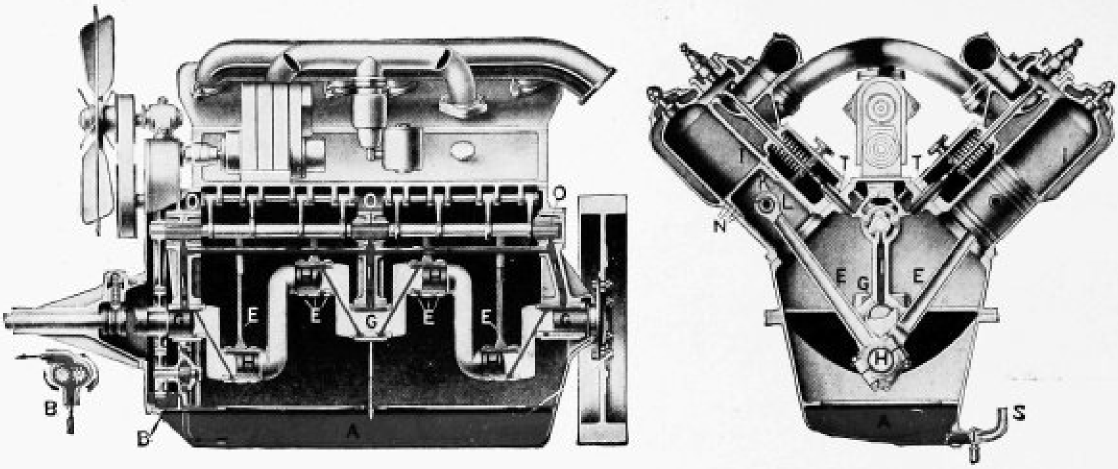


Cross Section—System 11

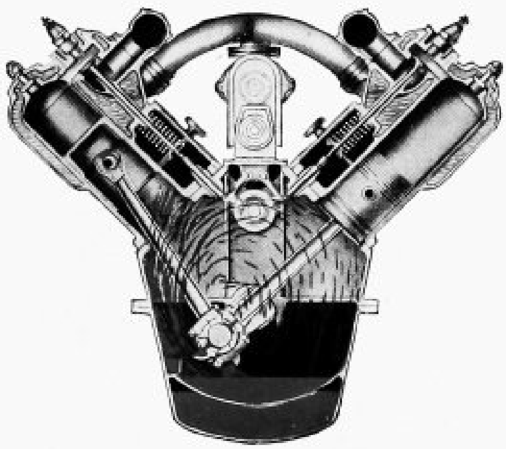


SYSTEM 12—MOTORCYCLE LUBRICATION

COURTESY OF THE TIDEWATER OIL CO.—THE VACUUM OIL CO.



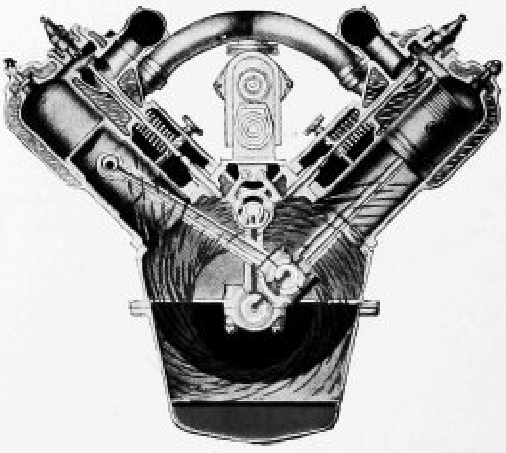
SYSTEM 12—TYPICAL "V" TYPE MOTORS



Oil projection by the dippers on the connecting rod ends from constant level troughs is uhnequal upon the cylinder walls of the opposite cylinder blocks. This gives rise, on one side of the engine, to under-lubrication, and, on the other side, to over-lubrication. This is true of all modifications of splash lubricating systems when applied to "V" Engines.

SPLASH SYSTEM (Now Obsolete)

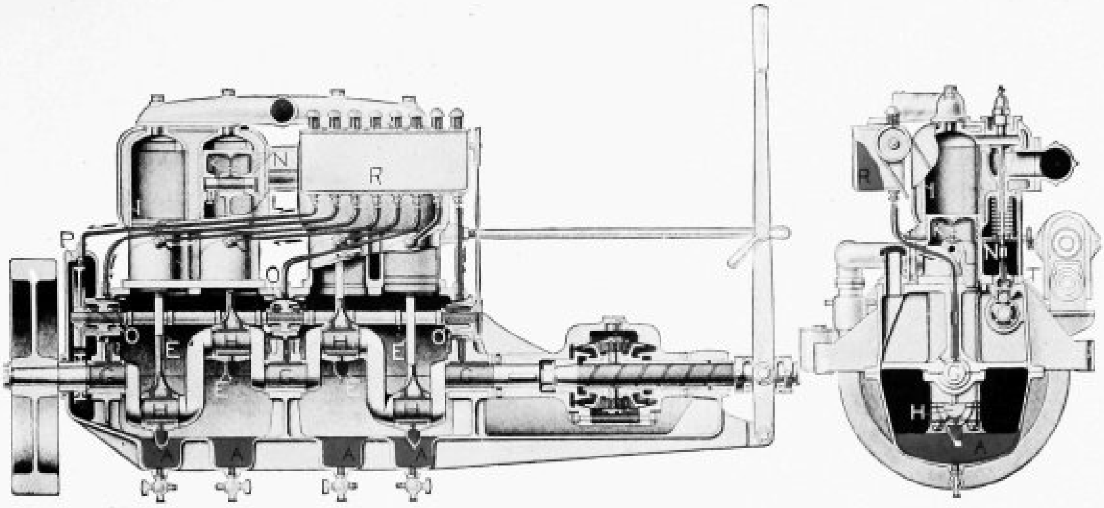
When a force feed lubricating system is ued the oil, escaping past the cheeks of both ends of the crank pin berainings, is thrown off at a tangent to the crank pin circle in all directions supplying the cylinders on both sides with an equal quantity of oil.



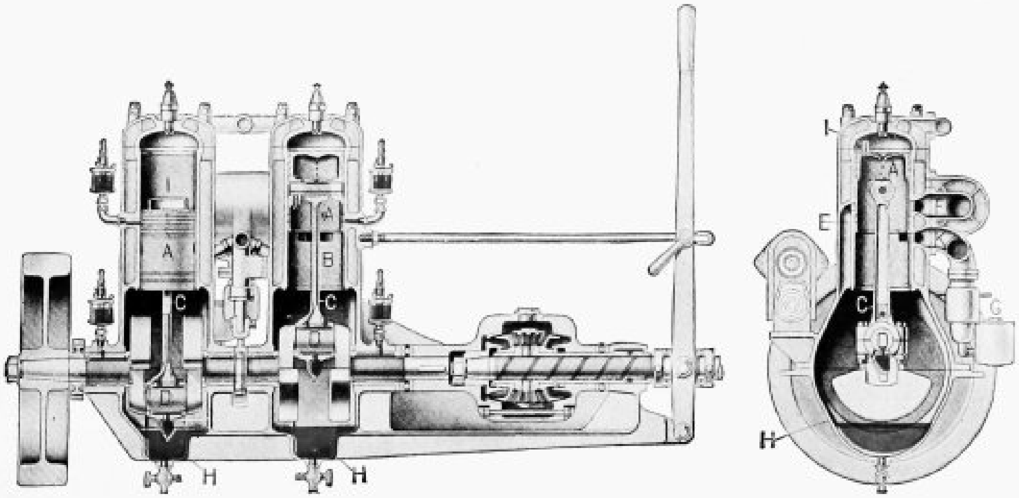
FORCE FEED SYSTEM

PLATE 8

COURTESY OF THE VACUUM OIL CO.—THE TIDEWATER OIL CO.



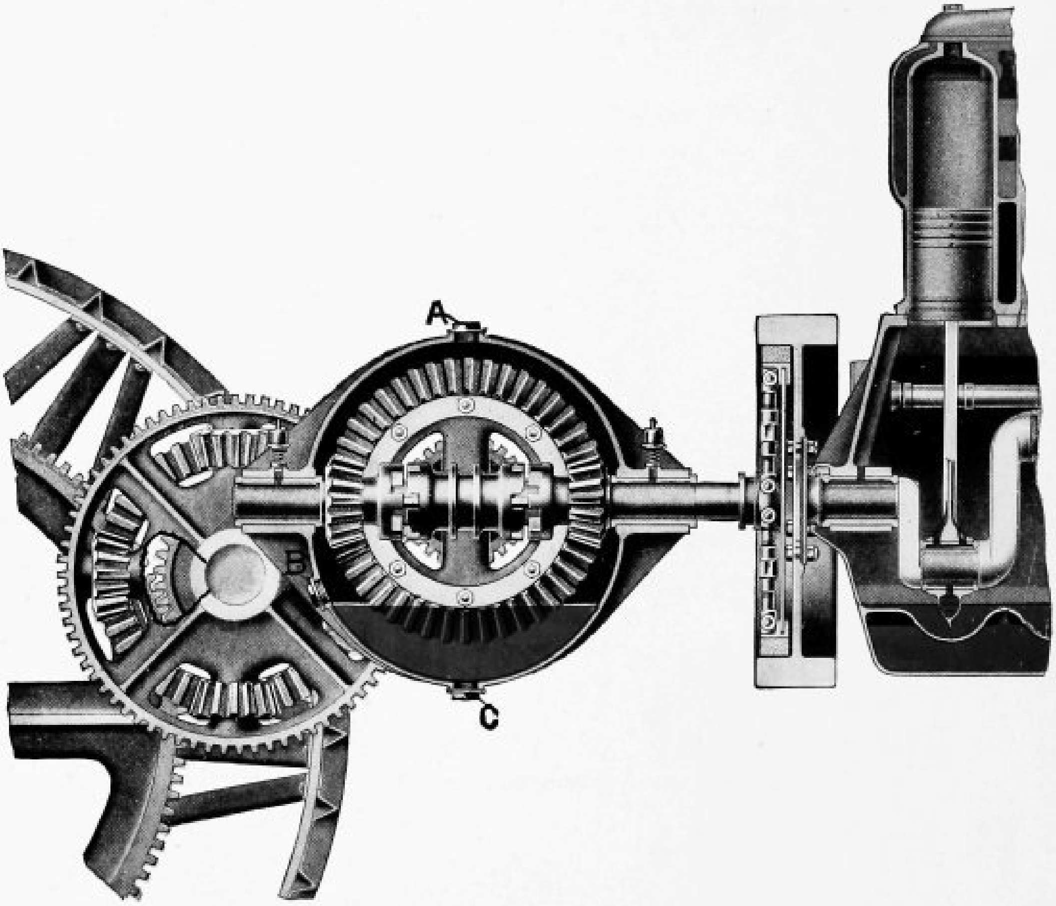
FOUR STROKE CYCLE MARINE MOTOR



TWO STROKE CYCLE MARINE MOTOR

PLATE 9

COURTESY OF THE VACUUM OIL CO.—THE TIDEWATER OIL CO.

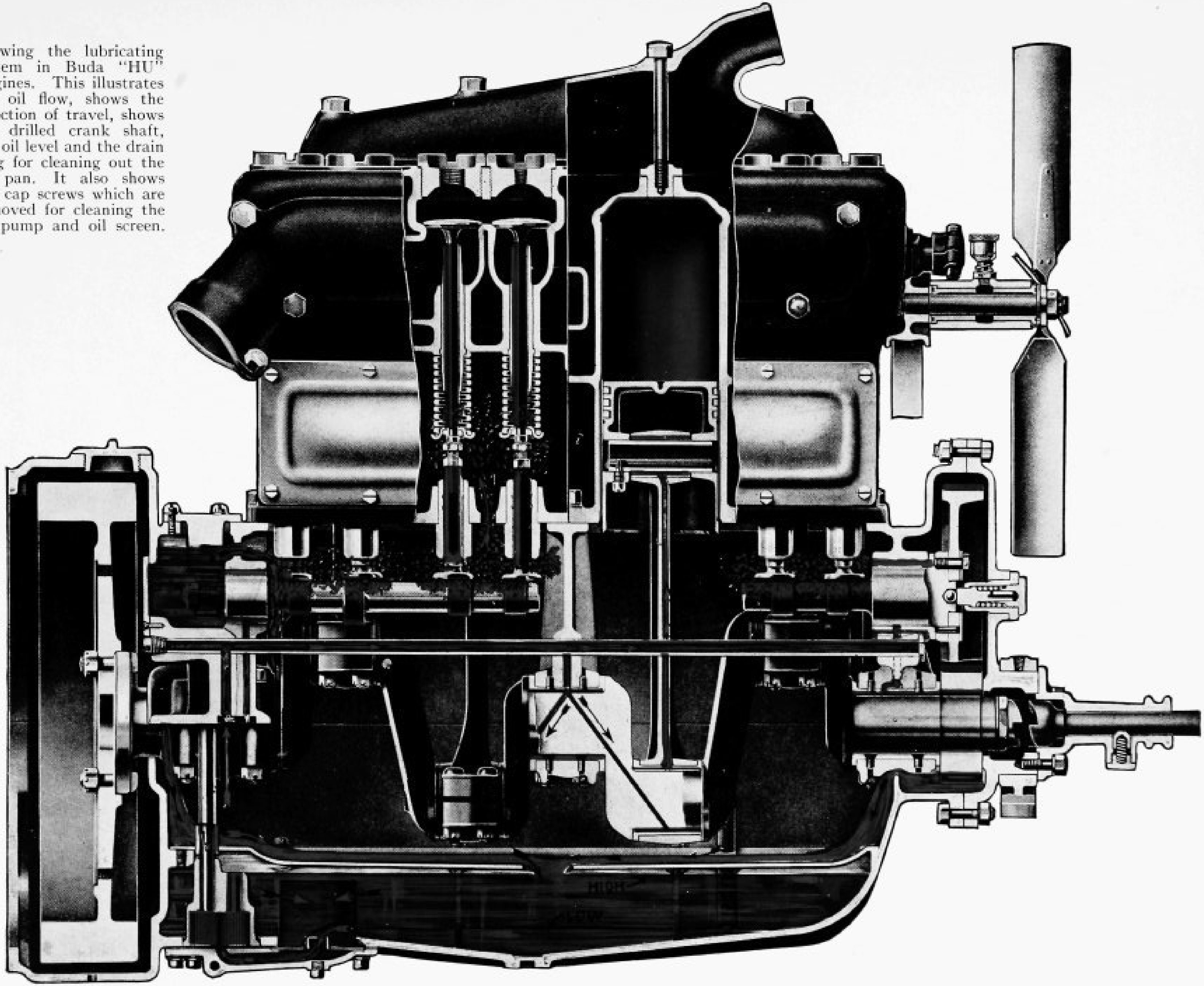


FARM TRACTOR TRANSMISSION AND DIFFERENTIAL LUBRICATION

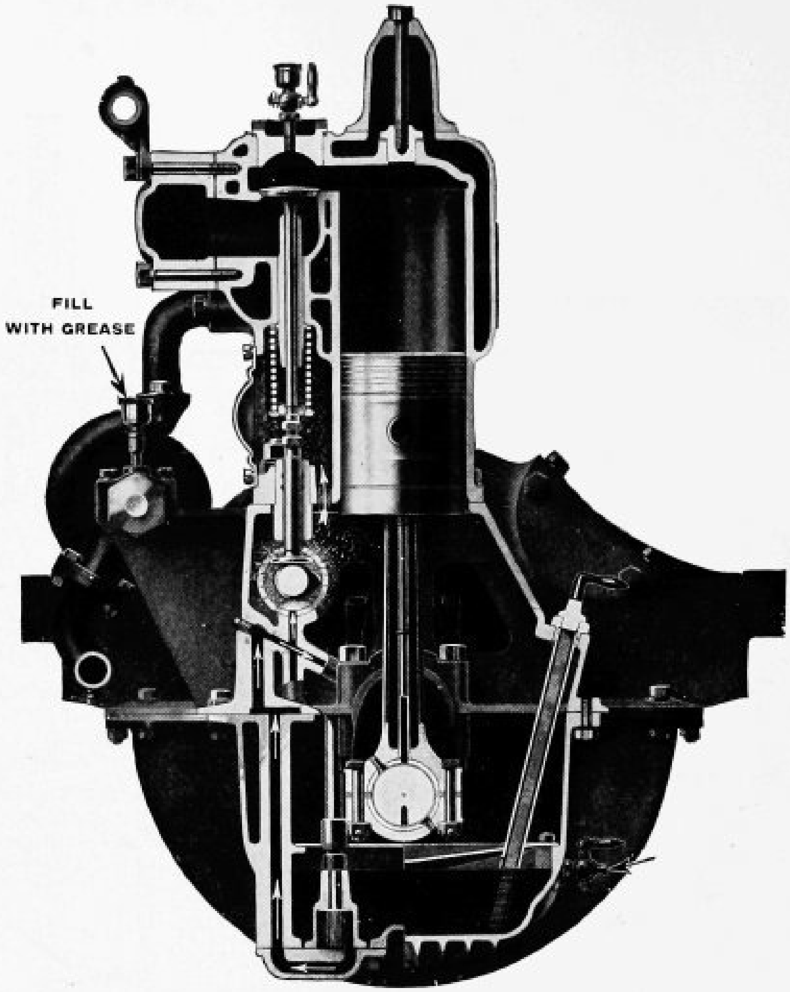
Plate 10

COURTESY OF THE VACUUM OIL CO.—THE TIDEWATER OIL CO.

Showing the lubricating system in Buda "HU" Engines. This illustrates the oil flow, shows the direction of travel, shows the drilled crank shaft, the oil level and the drain plug for cleaning out the oil pan. It also shows the cap screws which are removed for cleaning the oil pump and oil screen.



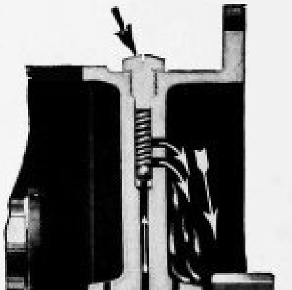
OILING SYSTEM OF BUDA MOTOR



CRANK CASE
BREATHER
AND
OIL FILLER TUBE

This is the forced feed oiling system employed in Buda model " H U" engines. The illustration is drawn from the timing gear end, the operation of the geared oil pump and the saber type of oil gauge can be ascertained. It also illustrates the splash to the cam shaft, push rods and valves, as well as the tubing arrangement to the piston pins.

PRESSUSE CONTROL



OILING SYSTEM OF BUDA MOTOR

which may cause a rapid carbon deposit in the cylinders, or, on the other hand, of feeding too little oil, thereby causing unduly rapid wear, or, perhaps, serious injury to the parts from want of lubrication.

By circulating system is meant a lubricating system in which a quantity of oil is filled to a fixed level into the crank case sump, whence it is circulated by some type of pump or by the flywheel to all parts requiring lubrication. In circulating systems the oil is applied to the moving parts by splash alone from the connecting-rod ends, or by pressure, and splash from the connecting-rod ends.

of the connecting rods, or dippers on the connecting rods, strike the oil and splash it in all directions, thus filling the cups which feed the crank shaft bearings. The lower ends of the connecting oil and feed it to the crank pin bearings through holes bored in connecting rods. Part of the oil is splashed onto the walls of the cylinders and lubricates the cylinders, and piston rings. Another part is splashed into the hollow pistons where it collects under the piston heads and drops through slots cut in the upper ends of the connecting rods and lubricates the piston pins. In designs where piston pins oscillates in piston the oil is fed by splash through

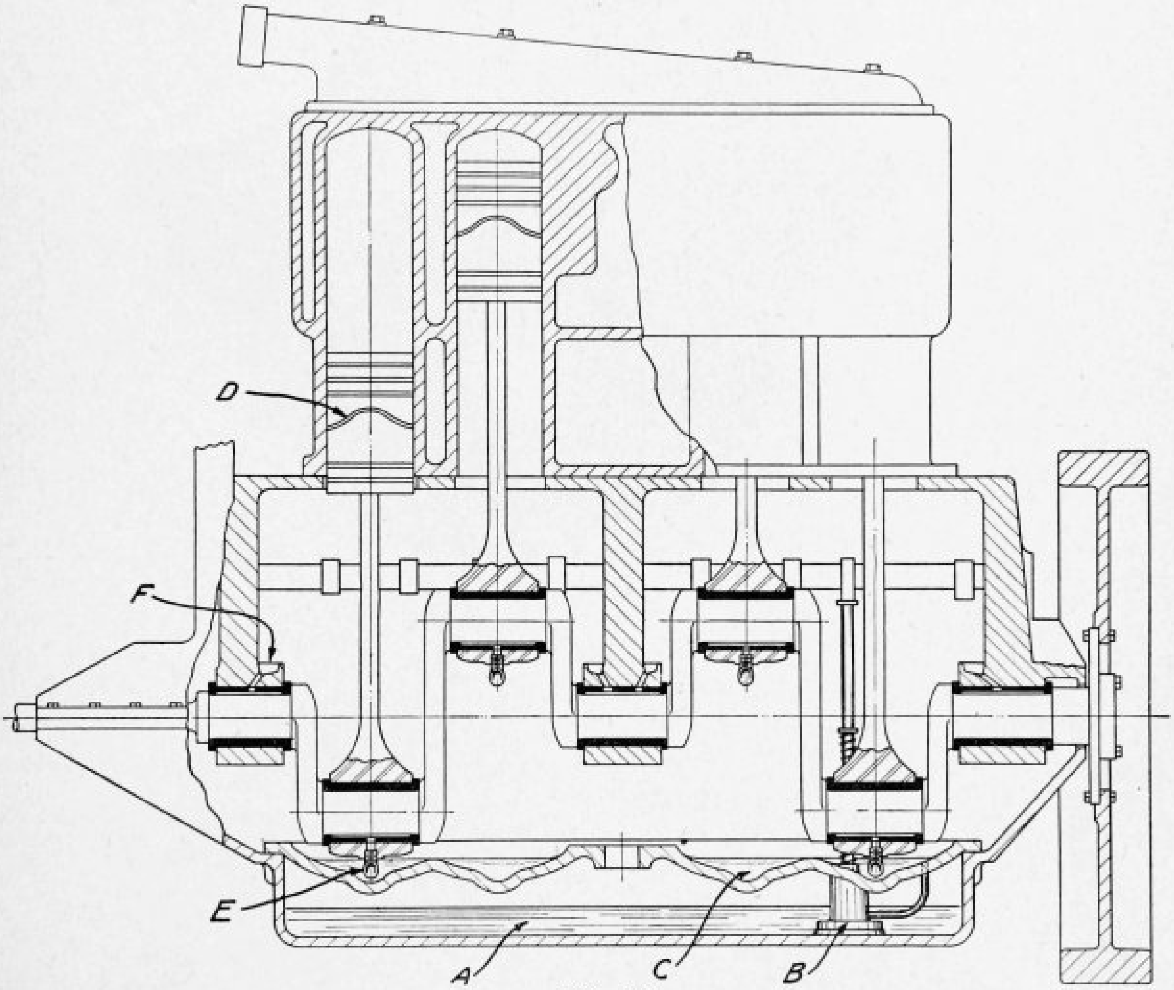


FIG. 3-A

Oil Fed With Fuel. Oil fed with fuel, consists of mixing approximately one pint of oil with each five gallons of fuel. In rare instances, oil is fed from a drip cup into the inlet manifold and carried to the cylinders by the in rushing charge. The following descriptions of eleven (11) lubricating systems, the colored drawings show these systems as applied to four cylinder motors, but the description of their operation applies equal to all multi-cylinder motors.

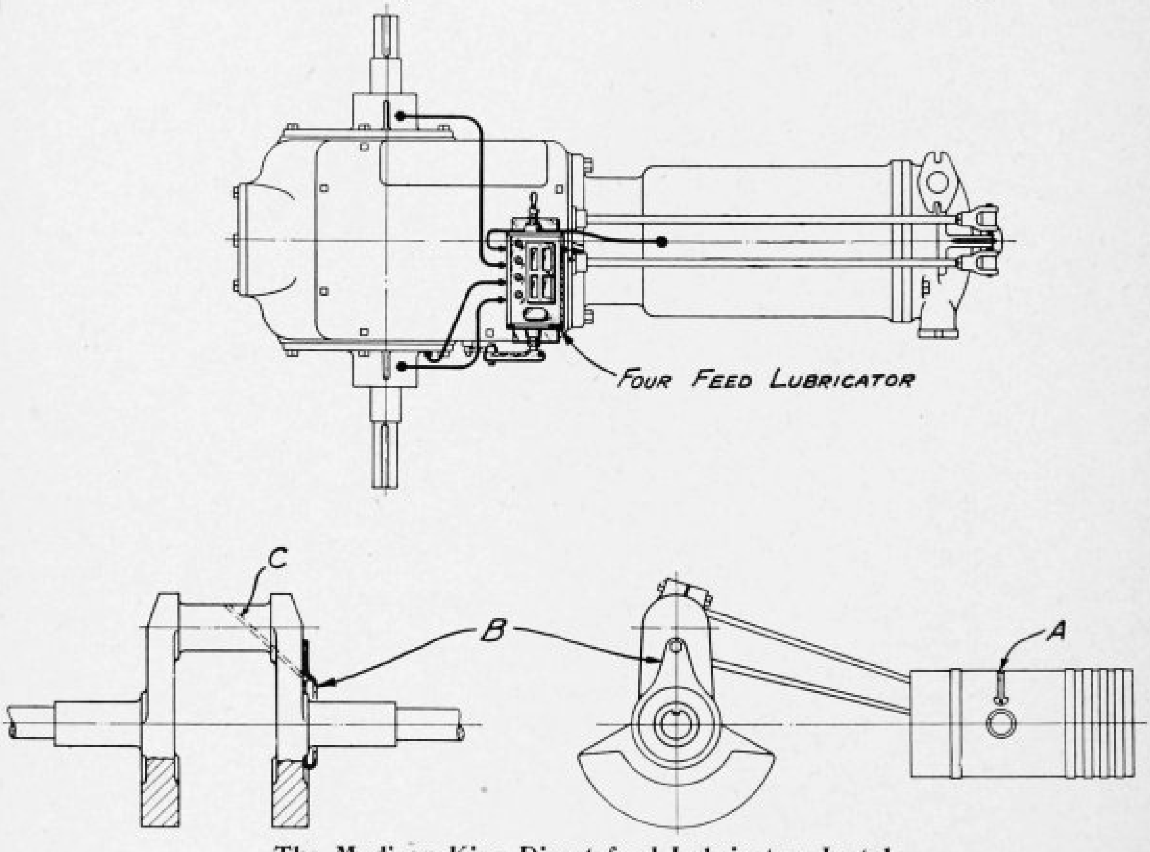
370. The Full Splash System. Oil is poured directly into the crank case until it overflows from the oil level drip cock. As the motor turns, the lower ends

holes or grooves, properly arranged, to the piston pin bearings in piston. The cam shaft bearings catch the oil in pickets and feed it through holes bored in them, to the bearings. The distribution gears and push rods are lubricated by the oil which splashes over them. (See Fig. 3.)

371. The Splash, With Circulating Pump. Oil is filled into crank case of motor, usually through a strainer, up to a fixed level, indicated by a drain cock or gauge. The oil, shown in a reddish tint, is drawn from the reservoir in sump of motor or from a separate reservoir, sometimes employed, by a circulating pump and delivered to a channel or trough extending the full length of the crank case. From the trough the oil overflows into four separate compartments or troughs under the connecting rods maintaining a constant level in each, the surplus oil returning to sump. The dippers on the connecting rods strike the oil as the motor turns, and splashes it in all directions, thus filling the cups which feed to the main bearings. The dippers themselves catch part of the oil which feeds to the crank pin bearings through holes bored in connecting rod ends. Part of the oil is splashed onto the walls of the cylinders and lubcricates the cylinders, pistons and piston rings. Another part is splashed into the hollow pistons where it collects under the piston heads

In many motors the oil passes from the circulating pump through a sight feed on the dash before flowing into the main trough. In this way the operator can always make sure that the motor is being properly lubricated. (See Fig. 4.)

372. The Pump Over and Splash. Oil is filled into crank case of motor usually through a strainer, up to a fixed level indicated by a drain cock or gauge. The oil is drawn from reservoir in sump of motor by a circulating pump and froced through tubes or ducts leading to pockets from whence it feeds by gravity to the main bearings. Part of the oil circulated by the pump is sometimes discharged over the distribu-



The Madison Kipp Direct feed Lubricator, Installation, on a single cylinder horizontal motor.

and drops through slots cut in the upper ends of the connecting rods, thus lubricating the piston pins. The cam shaft bearings catch the oil in pickets and feed it through holes bored in them, to the bearings. Part of the splash fills up the basin in which the crank shaft gear runs. This gear throws the oil on to the other distribution gears. The push rods are lubricated by the oil which splashed on them.

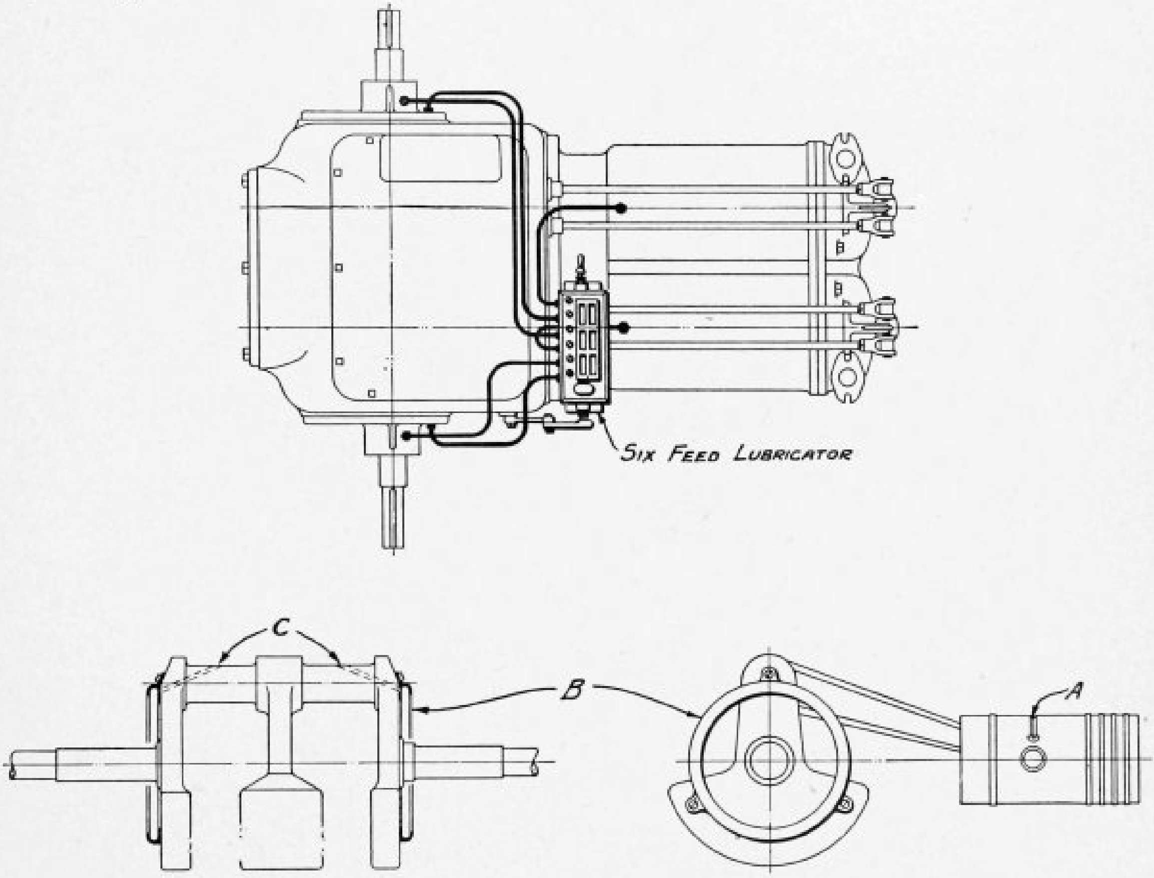
After having passed through the various bearings the oil is usually returned to the sump where it enters the circulating pump and travels again as described. Some motors have provision for adjusting the quantity fed by the pump in which instance the oil remains in crank case until consumed.

tion gears for their lubrication. Another part is forced by the pump into a channel extending the full length of the crank case. From this channel, the oil feeds into connecting rod troughs maintaining a constant level in each, the surplus oil overflowing and returning to sump. The dippers on the connecting rods strike the oil as the motor turns and splashes it in all directions. The dippers themselves catch part of the oil which lubricates the crank pin bearings through holes bored in the connecting rod ends. Part of the oil is splashed onto the walls of the cylinders and lubricates the cylinders, pistons and piston rings. Another part is splashed into the follow pistons where it collects under the piston heads and drops through slots cut in the upper ends of the connecting rods thus lubricating the piston pins. The cam shaft bearings catch the oil in pickets and feed it through holes bored in them to the bearings. Part of the splash fills up the basin in which the crank shaft gear runs. This gear throws the oil on to the other distribution gears. The push rods are lubricated by the oil which splashes on them.

After having passed through the various bearings the oil is returned to the sump through a strainer, where it enters the circulating pump and travels again as described.

For the guidance of the operator the oil usually passes through a sight feed before flowing through bearings. (See Fig. 5.)

rod troughs, maintaining a constant level in each, the surplus oil overflowing and returning to sump. The dippers on the connecting rods strike the oil as the motor turns and splashes it in all directions. The dippers thus catch part of the oil which lubricates the crank pin bearings through holes bored in the crank pin bearings, through holes bored in the connecting rod ends. Part of the oil is splashed onto the walls of the cylinders and lubricated the cylinders, pistons and piston rings. Another part is splashed into the hollow pistons where it collects under the piston heads and drops through slots cut in the upper ends of the connecting rods, thus lubricating the piston pins. The cam shaft bearings catch the oil in pockets and feed it through holes bored in them, to the bearings. Part



The Madison Kipp Direct Lubricator, Installation, on a Twin Cylinder Horizontal Motor

373. **The Force Feed and Splash.** Oil is filled into crank case of motor, usually through a strainer, up to a fixed level indicated by a drain cock or gauge. The oil is drawn from reservoir in level indicated by a drain cock or gauge. The oil is drawn from reservoir in sump of motor by a circulating pump and forced under pressure through tubes or ducts to main bearings which it lubricates. Part of the oil circulated by the pump is sometimes discharged over the distribution gears for their lubrication. Another part is forced into a channel extending the full length of the crank case. From this channel the oil feeds into connecting of the splash fills up the basin, in which the crank shaft gear runs. This gear throws the oil into the other distribution gears. The push rods are lubricated by the oil which splashes on them.

After having passed through the various bearings, the oil is returned to the sump through a strainer, where it enters the circulating pump and travels again as described.

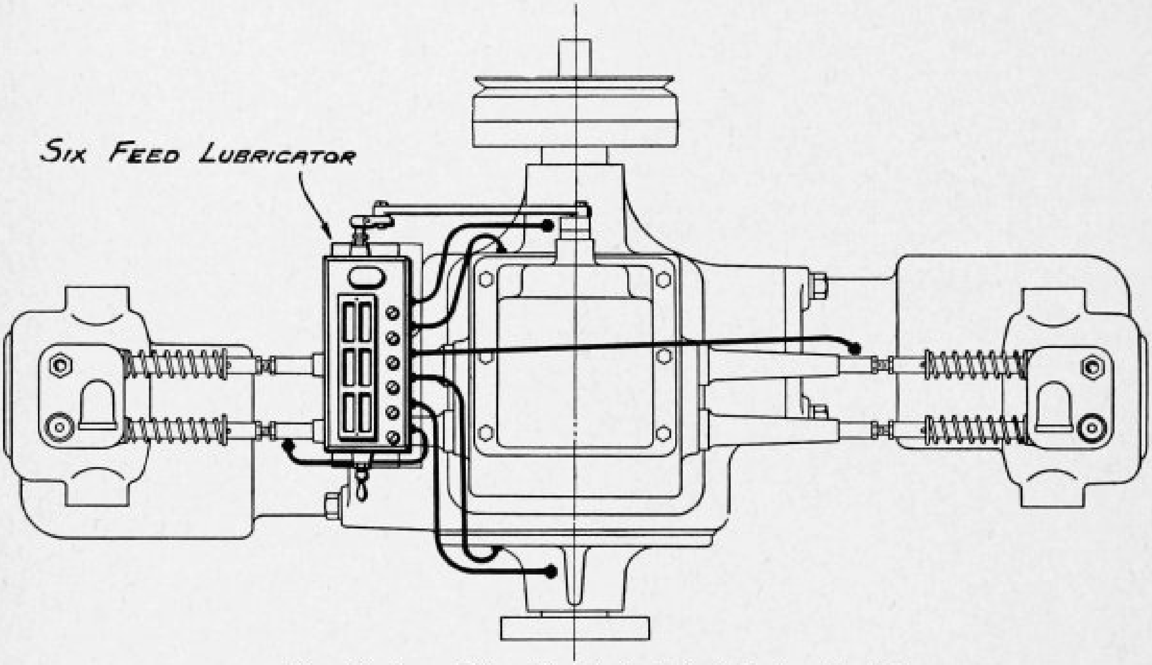
For the guidance of the operator a tube usually connects oil pressure line with pressure gauge mounted on dash. (See Fig. 6.)

374. The Pump Over. Oil is filled into crank case of motor, usually through a strainer, up to a fixed level indicated by a drain cock or gauge. The oil is drawn from reservoir in sump of motor by a circulating pump and forced through tubes or ducts leading to pockets, from whence it feeds by gravity to main bearings which it lubricates. Part of the oil circulated by the pump is sometimes discharged over the distribution gears, otherwise the splash oil fills up the basin into which the crank shaft gear dips and throws oil onto the other distribution gears. Oil from the main bearings is thrown by centrifugal force through ducts bored in the crank shaft to crank pin bearings. The oil escaping from each side of the crank pin bearings is thrown off in all directions, thus lubricating the cylinders, pistons and pistonrings. Another part is splashed into the hollow pistons where it collects under the piston heads and drops through slots cut in the upper end of connecting rods, thus lubricating the piston pins. Cam shaft bearings catch the oil in pockets and feed it through holes bored in them, to the bearings. Push rods are lubricated by the oil which splashes on them.

After having passed through the various bearings the oil is returned to the sump through a strainer, where it enters the circulating pump and travels again as described. (See Fig. 7.)

375. The Separate Force Feed. Oil is filled into the reservoir of the separately driven lubricator. This lubricator may be positively driven by chains or gears or may be driven by a belt. The oil is forced under pressure, through tubes leading from lubricator to the main bearings and usually there is a pipe discharging oil over the distribution gears. From the main bearings the oil is forced through ducts bored in crank shaft to the crank pin bearings which it lubricates. The oil under pressure, escaping from each side of the crank pin bearings is thrown off in all directions. Part of the oil is splashed onto the walls of the cylinders and lubricates the cylinders, pistons and piston rings.

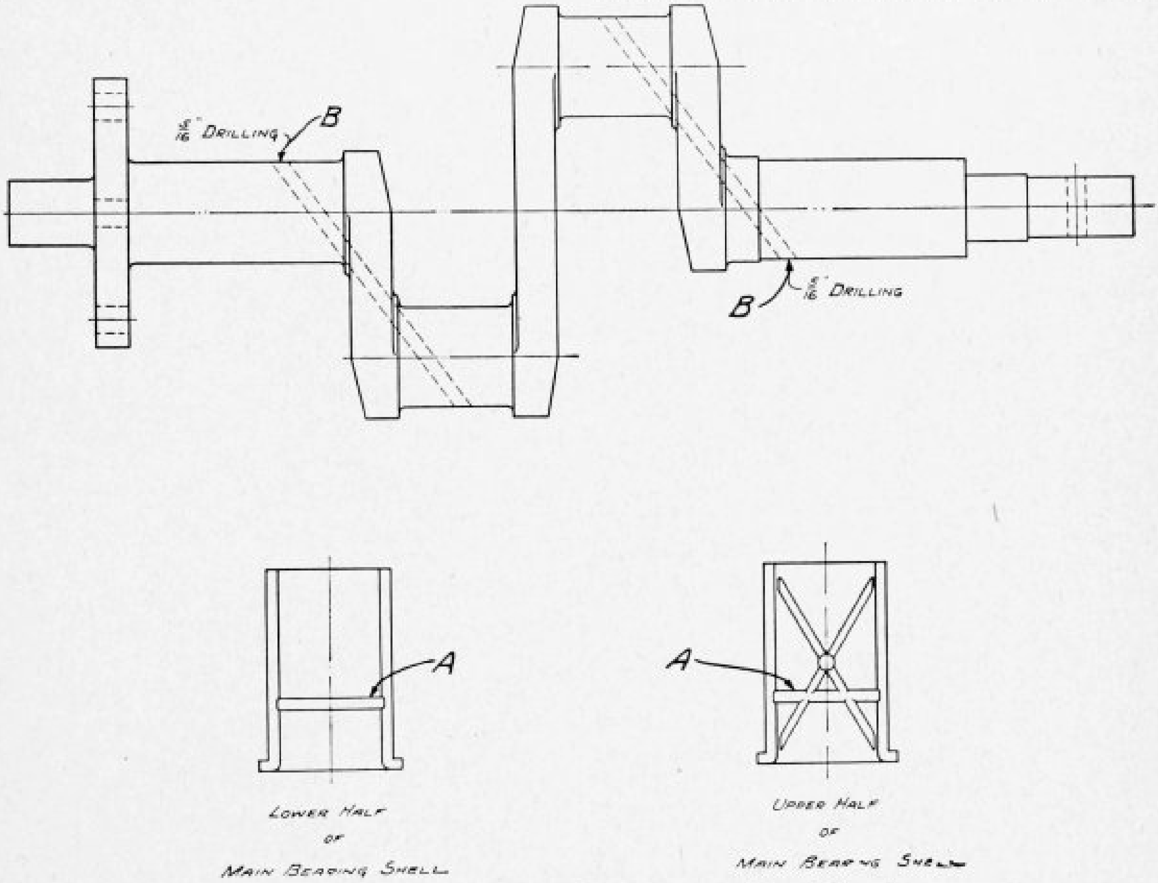
Another part is splashed into the hollow pistons where it collects under the piston heads and drops through a slot cut in the upper end of the connecting rods, thus lubricating the piston pins. The cam shaft bearings catch the oil in pockets and feed it through holes bored in them, to the bearings. The push rods are lubricated by the oil which splashes on them.



The Madison Kipp Direct feed Lubricator, Installation, on a two cylinder horizontal opposed motor.

In passing through the bearings the oil falls to the bottom of the crank case where it accumulates. The rapidity of oil feed from the lubricator is usually regulated to suit the severity of the work which the motor has to do. If the character of the work is very severe the oil level in the crank case is allowed to attain a height such as to give additional lubrication by splash (by dippers or connecting rod ends). When used for lighter work the oil is only fed at the rate of its consumption without splash. (See Fig. 8.)

376. The Force Feed. Oil is filled into crank case of motor, usually through a strainer, up to a fixed level indicated by a drain cock, or gauge. The oil is drawn from the reservoir in sump of motor by a circulating pump and forced under pressure, through tubes or ducts to main bearings which it lubricates. Part of the oil from the front main bearing feeds into a basin into which the crank shaft gear dips. This gear splashes oil onto the other distribution gears. The surplus oil in this basin overflows and returns to the sump. From the main bearings the oil is forced under pressure, through ducts bored in the crank shaft to crank pin bearings. The oil under pressure, escapes from each side of the crank pin bearings and is thrown off in all directions. Part of the oil is splashed onto the walls of the cylinders and lubricates the cylinders, pistons and piston rings. Another part is splashed into the hollow pistons where it collects under the piston heads and drops through slots cut in the upper end of the connecting rods, thus lubricating the piston pins. The cam shaft bearings catch the oil in pockets and feed it through holes bored in them, to the bearings. The push rods are lubricated by the oil which splashes on them.



Also a type of crank shaft arrangement and bearing grooving for conducting surplus oil from main bearings to crank pins.

After having passed through the various bearings the oil is returned to the sump through a strainer, where it enters the circulating pump and travels again as described.

In this system the connecting rods do not dip into the oil.

For the guidance of the operator a tube usually connects oil pressure line with a pressure gauge. (See Fig. 7.)

377. The Full Force Feed. Oil is filled into crank case of motor, usually through a strainer, up to a fixed level indicated by a drain cock or gauge. The oil is drawn from the reservoir in the sump of motor by a circulating pump, and forced under pressure, through tubes or ducts to cam shaft bearings and to main bearings which it lubricates. Oil is delivered in a stream which pours over distribution gears. From the main bearings the oil is forced under pressure, through ducts bored in the crank shaft to crank pin bearings. Oil feeds under pressure, from crank pin bearings through ducts or tubes attached to connecting rods to piston pins. Oil escaping through the hollow piston pins lubricates the cylinders. The oil under pressure, escapes from each side of the crank pin bearings and is splashed onto the walls of the cylinders and lubricates the cylinders, pistons and piston rings. The push rods are lubricated by the oil which splashes on them.

Some motors, employing this system, have provision for additional oil feed, under pressure, to each cylinder; the feeds being controlled by the speed of the motor.

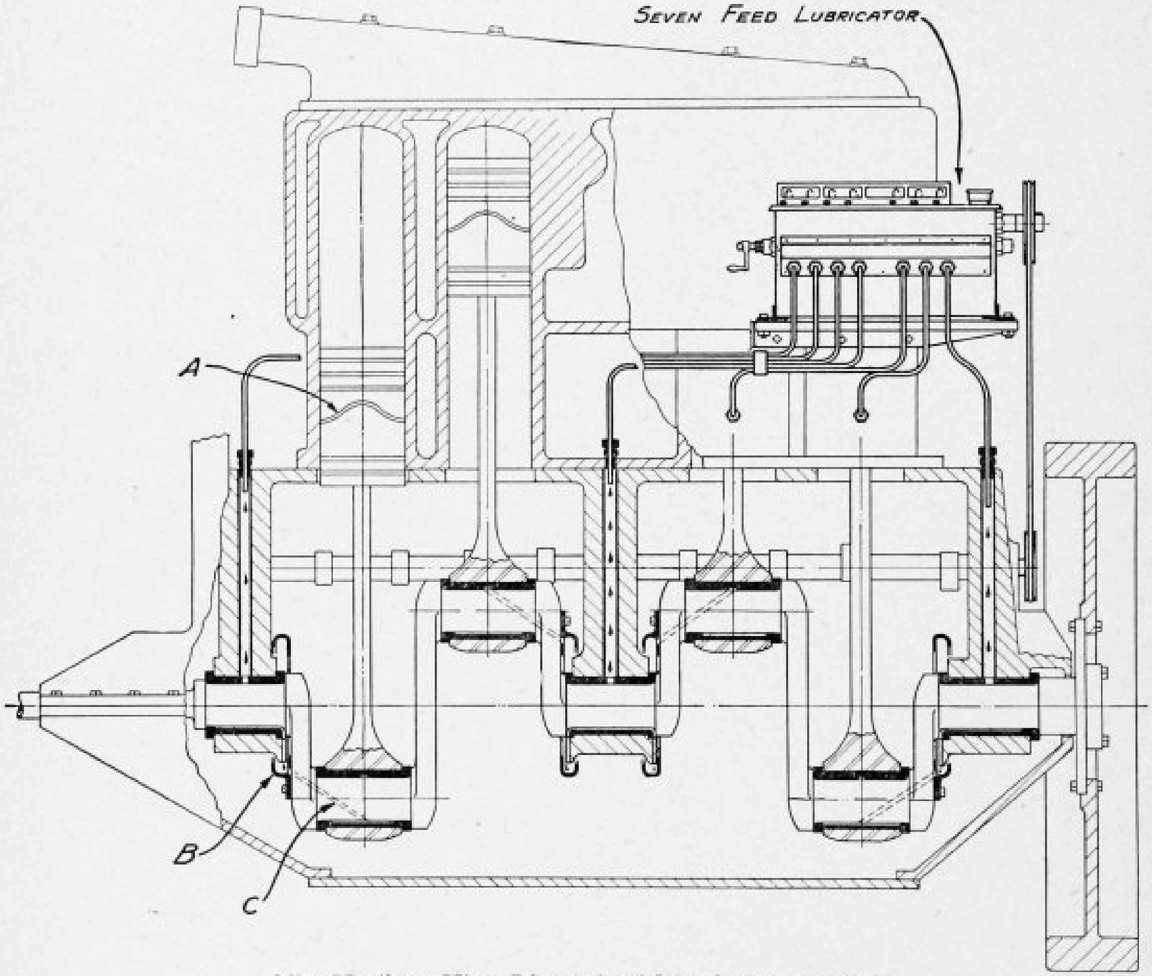
After having passed through the various bearings the oil is returned to the sump through a strainer, where it enters the circulating pump and travels again as described.

In this system the connecting rods do not dip into the oil.

For the guidance of the operator a tube usually connects oil pressure line with a pressure gauge. (See Fig. 9.)

378. The Direct Force Feed. In this system the fresh oil lubricator and crank case are both applied to the four cylinder vertical motor. Fig. 10 illustrates a method of applying a seven feed lubricator to this type of motor. There is one feed to each cylinder and to each main bearing. The piston pins are lubricated by means of groves (A) on the pistons which drilled to carry it to the shaft. A separate oil feed to each crank pin is a more dependable method than that illustrated, and it is to be recommended in all cases possible to use it.

379. Direct Force Feed and Splash. In this system a lubricator is furnished as shown in Fig. 10, and as described in the direct force feed system, Paragraph 375. After the oil has passed through the system it returns to the oil pan. The lower ends of the connecting rods, or dippers on same, catch part of the oil which is splashed on the cam shaft bearings, in oil pockets, and feed it through holes bored in them, to



The Madison Kipp Direct feed Lubricator, Installation, on a Four Cylinder Vertical Motor.

collect surplus oil from the cylinder walls and deliver it through drillings in the pistons to the pins. The crank pins receive surplus oil from the main bearings which have shells grooved to carry this oil to rotating rings (B) secured to the cheeks of the crank shaft. The oil is carried from the rings by centrifugal force through crank shaft drillings (C) to the crank pin. The cams are oiled by the surplus that flies from the crank pins. The upper cam shaft bearing housings are equipped with wells to collect surplus oil and the bearings. The distributing gears and push rods are lubricated by the oil which splashes over them.

380. All Loss Direct Force Feed and Overflow to Gears. Oil is filled into the reservoir of the separately driven lubricator. This lubricator may be positively driven by chain of gears or may be driven by a belt. The oil is forced under pressure, through tubes leading from lubricator to the main bearings also to the cylinders, and usually there is a pipe discharging oil over the distribution gears. From the main bearings the oil is forced through ports drilled in the crank shaft to the crank pin bearings which it lubricates. The oil under pressure, escaping from each side of the crank pin bearings is thrown off in all directions. Part of the oil is splashed into the hollow pistons where it collects under the piston heads and drops through a slot cut in the upper end of the connecting rods, thus lubricating the piston pin. The cam shaft bearings catch the oil in pockets and is fed through holes bored in them, to the bearings. The push rods are lubricated by the oil which splashes on them. The surplus oil falls to the bottom of the crank case where it accumulates to a fixed level and overflows to the transmission gears. The rapidity of oil feed from the lubricator is usually regulated to suit the severity of the work which the motor has to do. If the character of the work is very severe the oil is fed at an increased number of drops per stroke of the oil pump, which may be increased or decreased at the will of the operator.

381. The Kipp Valveless Lubricator Principle. The Madison-Kipp principle is the original patented method of pumping and forcing oil without the use of ball and spring valves.

Although the valve type of lubricator can be built and sold more cheaply, it has proved to be unsatisfactory in service that needs dependable lubrication. Slight particles of foreign matter lodging on the valve seat cause failure in operation.

The unique Kipp valveless action is accomplished by a double eccentric which imparts not only a reciprocating but also an oscillating motion to the plunger, operating as follows:

The oscillating motion is accomplished by the position of the plane of the eccentric as shown in Figure 11. The plane is at an angle of 27 degrees to the shaft which rotates the eccentric. The eccentric element raises and lowers the ring which is fitted into the eccentric at the 27 degree plane; and the angle of the plane imparts an oscillating motion to the ring. Figure 11-B illustrates the eccentric in a postion after having been rotated one-half turn past position A.

Figures 12 and 13 illustrate the pumping principle with the Kipp eccentric "C," intake port "D," and discharge port "E." In Figure 12 the plunger is in position to draw in a supply of oil through slot 1, which is registered with intake port "D." As the plunger is raised, the oil is drawn into the barrel.

In Figure 13 the plunger has been raised and oscillated at the top of the stroke, so that it is in position to descend and discharge the oil from the barrel through the discharge port "E." It is evident that slot 1 has been turned away from intake port "D," sealing it. Slot 2 has been turned to register with discharge port "E," opening it. At the end of the down stroke the plunger will be again oscillated back to its original position as in Figure 12.

The importance of having the Kipp Valveless Principle in a lubricator is manifold. Slight particles of foreign matter in the oil cannot interfere with the oil delivery, because there are no valve seats upon which dirt can lodge. It permits positive lubrication in the coldest temperature. This is a feature which accounts for its unusual predominance in tractor service, where almost every kind of climatic conditions must be met. The adjustment that can be obtained is very fine, a necessary feature in air compressor service for example.

382. Features of Construction; Individual Pumping Units. Each oil feed from a Madison-Kipp lubricator is an individual pumping unit. The blind feed type unit has its own eccentric, barrel, and delivery plunger. The sight feed type has its own eccentric, barrel, delivery plunger and also a measuring sight feed plunger. These units are located inside of the steel tank, secured to one side and driven by a steel shaft which extends through the eccentrics.

The multiple feed lubricator has a number of these standard units, as displayed in Figure 14. Note that the driving mechanism consists of a heavy ratchet

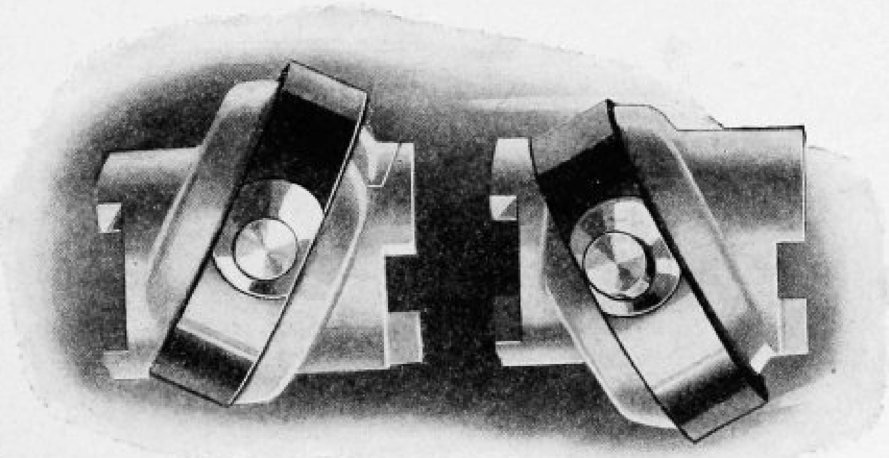


FIG. 11

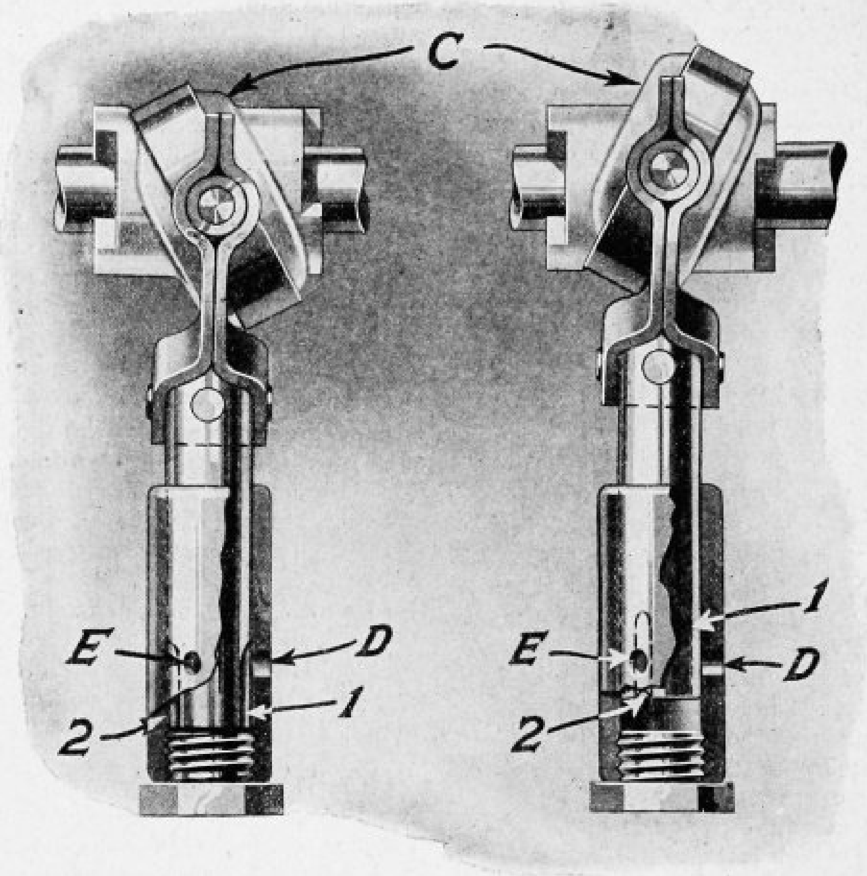


FIG. 12

FIG. 13

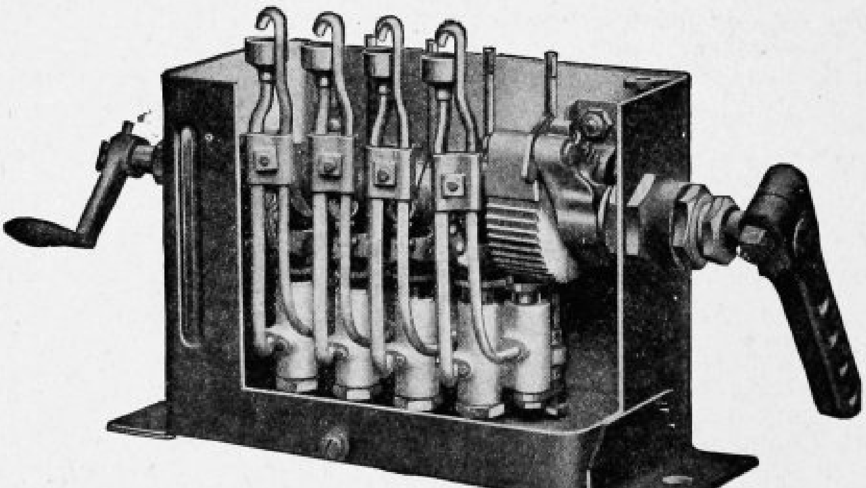


FIG. 14

wheel which carries a bushing that engages directly with clutch jaws in the eccentric. Each eccentric has clutch jaws which engage with the eccentric immediately next to it on the shaft. Therefore the driving power is transmitted through the eccentrics, not through the shaft. All parts are inside the tank operating in oil. Consider the length of life of all of these slowly moving parts of ample construction, constantly bathed in fresh clean oil.

Mechanism of the Unit.

The sight feed unit represents the Kipp Valveless Principle developed to a high degree. You will see

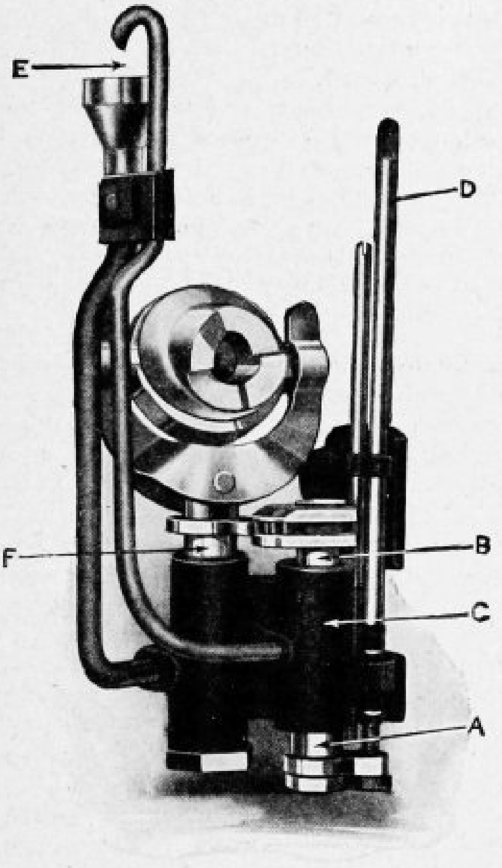


FIG. 15

from Figure 15 that this principle is made to serve the purpose of operating two plungers; a delivery plunger and a sight feed measuring plunger. The delivery plunger "F" is illustrated in detail in Figures 12 and 13.

The hollow sight feed measuring plunger "B" is operated from plunger "F" by means of gears. A steel sleeve "A" is inserted between the hollow measuring plunger "B" and its barrel "C" to provide means for regulating the amount of oil that is passed through the sight feed tube arrangement "E" to the delivery plunger. The sleeve is adjustable up and down by means of spindle "D," and its position times the registration of a combination of ports in the hollow plunger, sleeve and barrel, thereby measuring the portion of oil for the sight feed and the portion to be spilled back into the tank. The amount of oil which is passed through the sight feed is received, of course, by the delivery plunger and forced to its proper destination.

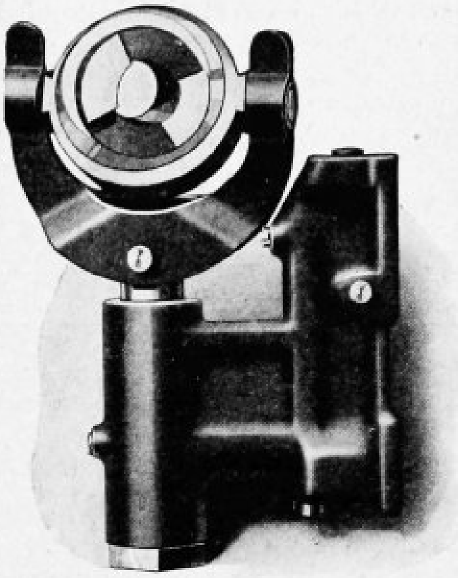


FIG. 16

The blind feed unit, Figure 16, consists of one plunger and barrel. Since there is no sight feed arrangement or fine adjustment a second plunger is unnecessary.

The process of manufacturing the plunger and barrel permits a practically perfect fit. The plunger is hardened steel, ground to within one ten-thousandth of an inch of the size of the barrel. Oil acts as the seal between the two surfaces. There is absolutely no packing.

The carefulness of this fit displays itself in the factory test. Every unit must force oil against a pressure of 2000 pounds per square inch, or it is not allowed to pass inspection. Such a test proves not only the fit of the plunger in the barrel, but also the strength of the entire mechanism.

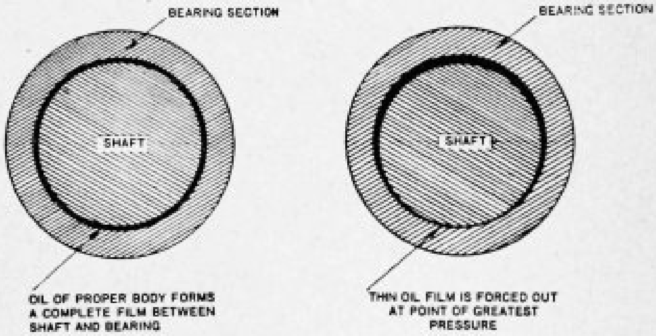


FIG. 17

383. The Kind of Oil Used. Only the best kind of an oil possessing the proper qualities should ever be used in a tractor motor. An automobile oil, even of the highest grade, would be a very poor oil for a tractor motor. The owner should consult the manufacturer of his tractor as to the oil recommended by him as the manufacturer's interest is with the owner regarding service. It is also advisable to buy a well-known brand of oil produced by a reliable manufacturer and sold through a local dealer or a supply station.

Some of the well known brands of oil that are satisfactory to use in tractor motors are listed below. There are many other oils on the market that are equally as good as the ones listed.

HAVOLINE KERO TRACTOR OIL—Indian Refining Co.

MOBILOILS—Vacuum Oil Co.

MONOGRAM Gas Engine Cylinder Oil—New York Lubricating Oil Co.

STANDARD Gas Engine Oil, Standolin Extra Heavy Polarine—Standard Oil Co.

VEEDOL, Special Heavy—Tide Water Oil Co.

VELVET Gas Tractor Oil—Pure Oil Co.

384. Condition of Oil in Cold Weather. When motor oil becomes cold it congeals or becomes so thick that it will not flow. Most oils that are satisfactory at ordinary temperatures or after the motor has warmed up become too thick to flow when freezing temperature is reached. When the oil is in this state it can not be circulated and the motor can not be lubricated.

For this reason great care must always be taken in operating a motor in cold weather. If a motor is started with the oil in the crank case solidified, burnt out bearings and scored cylinders are bound to result. The oil does not reach the bearings and there is no splashing of oil. The connecting rod dippers cut through the oil in the trays instead of splashing it.

A motor should always be warmed up slowly and the lubrication closely watched until normal conditions are reached.

In real cold weather the safest way is to drain the oil from crank case while warm and before starting the cold motor again warm up the oil to nearly boiling temperature and put back in motor. When the oil is poured back leave the residue that has settled in the bottom of the receptacle. This method involves a little trouble but it is well worth the time it requires. If a can of a convenient size and shape is used the operation will be greatly facilitated.

385. Cold Weather Oil. Unless extra precaution is taken with the motor oil when operating in cold weather a special oil must be used that does not congeal as readily as the ordinary oils. Some of the oils that do not solidify as easily as the ones contained in the former list of oils are:

Mobiloil "A"
Monogram, Medium.
Polarine, Medium.
Veedol, Heavy.

These oils are not as satisfactory for the engine as the other oils. They should also have close attention when the temperature is below freezing, as they congeal at about 25 degrees Fahrenheit.

The Mobiloil Arctic Medium, Polarine Zero and some other oils of similar properties may be used in zero weather but should never be used for any length of time in a tractor motor.

386. Change Oil. When oil is used its structure is broken or destroyed and it gradually loses its lubricating qualities. The difference between the oil taken from a crank case after it has been used for some time and fresh oil is readily felt by rubbing between the fingers.

The oil is also continually being diluted with fuel which passes the piston and thins out the supply. For these reasons the oil must be changed often. On the average it should be changed for every 75 to 100 gallons of kerosene used and 200 gallons of gasoline.

If a poor grade of oil is used or the adjustment of the motor is poor the oil should be changed oftener.

Again if a good grade of oil is used and most favorable conditions are maintained, it is safe to use the oil a little longer. The operator must always use a great deal of judgment with regards to the oil. If this is neglected an irreparable damage will be done to the motor.

CHAPTER XI

CARBURETER AIR CLEANERS

1. Carbureter Air Cleaners. The carbureter air cleaner is a device for purifying the air, as it enters the motor through the air intake, especially at certain seasons. The object of the air cleaner is to filter all air, removing dust and foreign matter, it holds in suspension. Much of this matter is of a noncombustible nature and has a tendency to collect on the cylinder walls, and consequently wear the piston and rings and score the cylinder walls, pitt the valves, work by the piston into the crank case, mingle with the lubricating oil, and cut the bearings, thus causing excessive wear and expensive repairs. In some parts of the country the dust at times is so heavy that it chokes up the lubricating system in less than a day's run. The oil has to be drained off and replenished to prevent excessive wear and overheating of the motor and bearings, this excessive friction greatly impairs the efficiency of the motor.

There are numerous methods employed to clean the air for tractor motors, and I believe no better description of the air cleaner can be made than to reproduce the following paper read by Mr. W. G. Clark, Engineer of the Wilcox Bennett Carbureter Co., before the Minneapolis section of the S. A. E.

2. The trend of engine design in the tractor and the automobile fields during the past few years has been more along the line of increased efficiency of prevailing types than toward the development of new types. This is logical in the development of a mechanism as new as the gas engine, although the demand for higher efficiency has perhaps been hastened and rendered more insistent by the war. This demand was naturally felt first by the accessory people, especially the makers of magnetos, carbureters and bearings, and the fact that it was some time before any appreciable progress was apparent showed that too much of the burden had been placed on them. It is gratifying to note that rapid progress has been made since the engine designers have cooperated by taking over their share of the work.

One of the most important factors of improving efficiency and service in automotive work, was the early recognition of the fact that dirt and carbon are the worst enemies of the internal-combustion engine. Changes in design along protective lines and the application of external preventive means in the form of air cleaners, have done much toward increasing the operating efficiency and life of field engines. I think it is not necessary to discuss the need and value of an air cleaner, especially for tractor and truck engines. Fully 80 per cent of the different tractors and several trucks have air cleaners as standard equipment. The specifications of the United States Army for trucks and tractors include adequate air cleaning devices for the carbureter. The destructive effect of dirt and other incombustible mineral matter on the cylinders is well known. The air cleaner is an important part of the field equipment. Everyone who attended the National Tractor Demonstration at Salina this year will testify that the air cleaners had plenty of work to do. Pictures taken at the time give some idea of the tremendous dust clouds in which the tractors had to work.

3. Types of Air Cleaners. The earliest form of air cleaner was merely a fine-mesh screen of considerable area attached to the carbureter air-intake. This was used several years ago, but for obvious reasons was not very efficient or satisfactory. Another of the earlier forms of cleaner was called the "rain type," of which the modern air washer or water cleaner is a development. It was a modified form of the washers and humidifiers used for cleaning and moistening air in public buildings. The cleaning was accomplished by drawing the carbureter air through a fine film or sheet of water which flowed over a screen to a reservoir and return. It was very cumbersome and impractical for field use, although if well made it was quite effective.

There are several types of cleaner now in use on tractors and trucks, namely:

(1) Cleaners having cloths or screens or both to catch the dust,
(2) Inertia cleaners,
(3) Those in which water or some other liquid is used to wash the air, and
(4) Centrifugal or gravity cleaners.

4. Cloths and Screens. The first type is practically obsolete. It is troublesome, ineffective and bulky, as to clean efficiently the cloth or screen area must be very large to cut down the air velocity and yet provide any considerable capacity. Both cloth and screen soon clog and restrict the flow of air to the carbureter, thus enriching the mixture. This creates carbon and causes overheating and other kindred troubles. There have been numerous forms of this type of cleaner, of which Figs. 1, 2 and 3 are examples.

Fig. 1 shows a cylindrical drum closed at the end connected to the carbureter, and covered at the other end by an eiderdown cloth held in the shape of a cone by a wire at the top. The air is drawn upward through the cone of eiderdown and thence into the carbureter. With this cleaner the operator would have to clean the

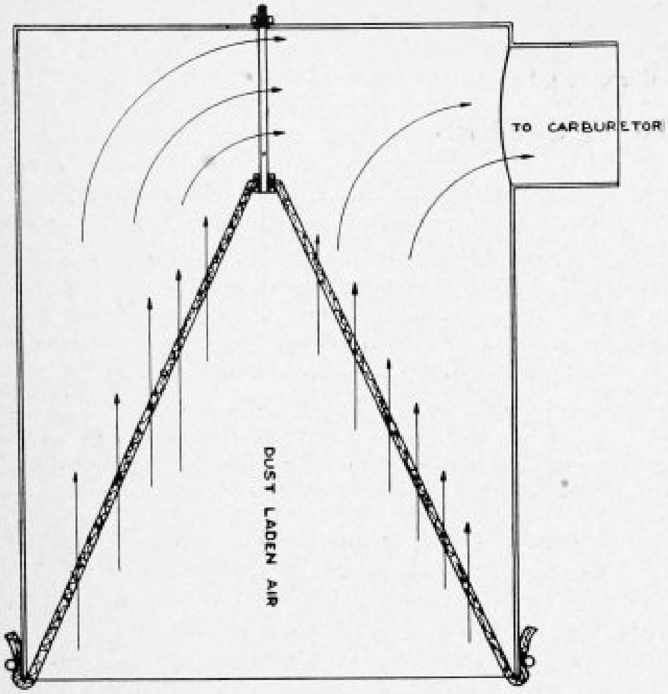


FIGURE 1

cloth very frequently in dusty field work or carry considerable cloth with him for the many changes necessary in a day's run.

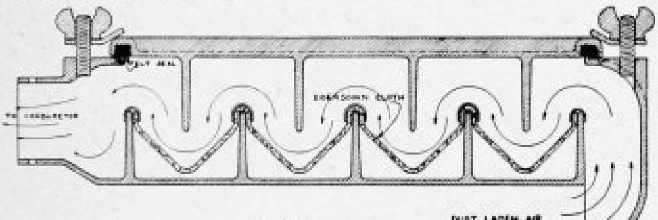


FIGURE 2

Fig. 2 illustrates a form in which an eiderdown or flannel cloth is used, but the air is forced to reverse its direction several times in passing around baffle-plates which are intended to direct the dust-laden air into contact with the cloth.

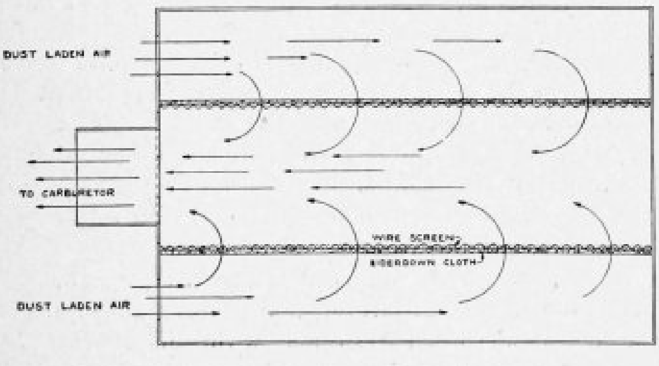
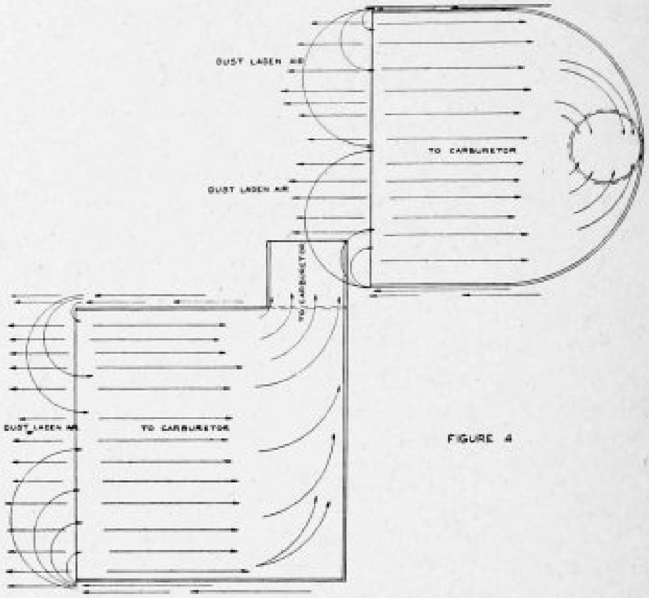


FIGURE 3

Fig. 3 shows a cleaner having both cloth and screen, the latter serving to hold the cloth in place. No provision is made for taking this cleaner apart.

5. Inertia Cleaners. The second class I have called inertia cleaners, because their action depends upon the inertia of the dust in the air to carry it out of the air-stream when the air-flow is suddenly reversed or changed before passing to the carbureter. One form of this type of cleaner, of which there are now several



varieties, is shown in Fig. 4. It consists of a rectangular metal casing with one side open and a connection from the closed side to the carbureter. The open side of the casing is placed against the outside of the radiator core facing in the direction of air-flow through the radiator, so that the carbureter air is drawn out of the air-stream in the reverse direction. The inertia of the dust being drawn through the radiator is supposed to carry it beyond the open end of the cleaner and through the radiator, not being deflected from its path by the suction of the carbureter. The actual efficiency of this cleaner is rather problematical as it is difficult to catch and measure the dust in any way. Practically the only way to test it is to try it on an engine in the field and judge of its efficiency by the condition of the cylinders.

A somewhat similar form of inertia cleaner is placed behind the fan instead of in front of the radiator, so that the air is forced through the cleaner instead of being drawn through. Its efficiency is dependent upon the maintenance of a certain air velocity for a given proportioning of the cleaner openings; a variation of fan speed interferes seriously with its effectiveness. I have no available data on these forms of inertia cleaners. There must be a considerable volumetric loss with their use, due to the fact that the carbureter air is drawn in a reverse direction from that of the fan air-stream, which possesses the kinetic energy and inertia of its velocity and direction of flow.

6. Liquid Traps. The third type comprises those cleaners or washers in which a liquid such as water or kerosene is employed to trap the dust. The demand for an air-washer or wet-type cleaner was created primarily by engine operators and owners of tractors in exceptionally dusty territories, who felt that other types of cleaners were not efficient enough for adequate engine protection. However, judging from data on most of the best air-washers and dry-type cleaners, I do not believe that the slight advantage of the wet type over the best dry types is sufficient to compensate for the extra trouble and difficulty encountered in the use and care of a wet-type cleaner. The best dry-type cleaners will catch from 95 to 100 per cent of the dust passing into them, the efficiency varying with the fineness, weight and volume of the dust. Under the most adverse conditions for the dry type, the best air washers will show not more than 2 or 3 per cent better efficiency. Such conditions are most frequently encountered in some of our Western States, where the dust is largely composed of volcanic ash—lava dust. This dust is very light and fine, whic makes it hard to stop. It also contains considerable vegetable matter, so that of the small percentage that escapes the dry-type cleaner, the major portion is combustible vegetable matter that will burn in the cylinders without deposit.

I think that many have been misled as to the efficiency of the air-washer by comparing it with building air-washers and humidifiers. While their action is somewhat similar, they differ in a very important respect. The ordinary building air-washer deals with air at low velocities through which finely divided water particles are passed. The carbureter air-washer deals with air at a high velocities which must be pulled through a quantity of water. In one case the surface of a large number of water particles comes in contact with a slowly moving volume of air, affording ample time, when properly designed, to wash all the air thoroughly. In the other case a volume of air is forced through water at high speed. This forms air bubbles which trap within themselves particles of dust. These never get into contact with the water and are carried through into the carbureter. The best carbureter air-washers are those in which these air bubbles are broken up and reduced to a minimum. Their presence accounts for the fact that even the best air-washers are not always 100 per cent efficient, especially under the extreme conditions mentioned. I know of two carbureter air-washers that are not as efficient as some dry-type cleaners because of this defect. Under ordinary field conditions the difference in efficiency between the wet and dry-type cleaners is very slight. I think that if the truth were known most tractor owners now using the wet-type cleaner do so on account of the moisture which these furnish to the intake air, rather than because of any really better operation. For some engines which do not cool any too well, especially when using kerosene, the heavily moistened and cool air from a water cleaner is almost as much a necessity as freedom from dust.

This heavy moisture content which some air-washers impart causes a large water consumption, the amount varying with the temperature. One well-known air-washer is said to use up 30 quarts of water in a day's work, under ordinary summer temperatures. All air-washers are not as bad as that, but it is both troublesome and inconvenient to refill them twice a day. This fact and their susceptibility to freezing in cold weather form two of the main objections to an air-washer.

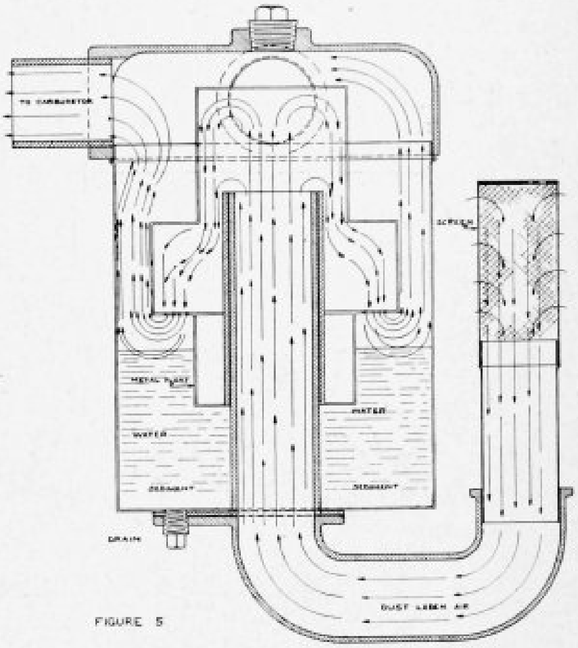


FIGURE 5

Figs. 5 and 6 are two forms of air-washer now in use. The first has an additional objection to those already mentioned, in that it employs a floating member with a large bearing surface exposed to the wearing action of the dust entering the cleaner. These surfaces are in the direct path of the dust, which must effect some wear if not actual clogging of the bearing.

Fig. 6 is a water cleaner brought out over a year ago to satisfy certain demands for a wet-type cleaner. It embodies several novel features designed to eliminate so far as possible some of the objectionable properties of the wet-type cleaner. It consists essentially of a centrifugal air-cleaner suspended within a cylindrical casing containing a quantity of water. This water is made to revolve within the container by the whirling action of the air drawn into it by the suction of the carbureter. The water rotates because the air is drawn into it tangentially through two spiral tubes in the inner circumference of the casing. The dust-laden air enters as shown and passes into the water compartment through openings in the spirals at A. The rapidly whirling air causes the whole mass of water to revolve so that it piles up against the sides in approximately the position shown by the dotted

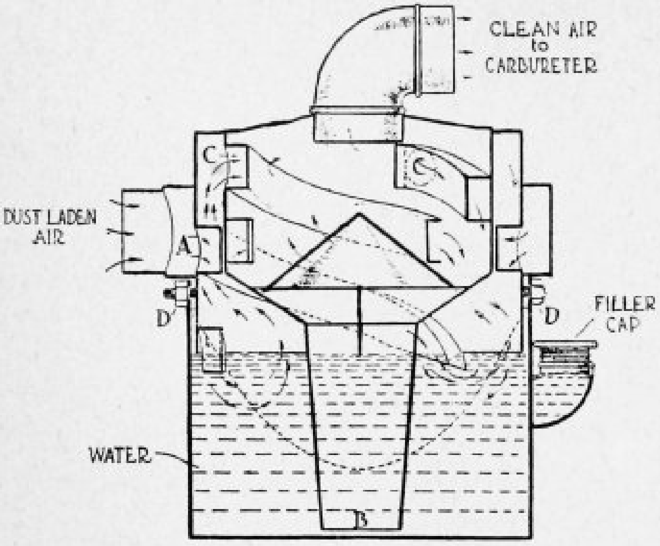


FIG. 6.

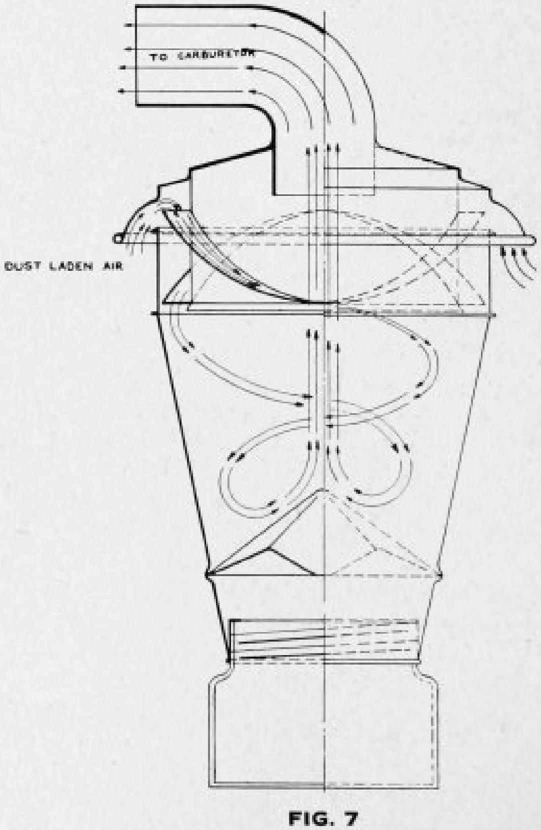
FIG. 6-A

line. This completely submerges the lower ends of the spirals in a heavy spray, so that all the air must pass through the water spray before escaping upward into the openings C of the inner air cleaner.

The air-cleaner has three spirals on its inner circumference through which the air and entrained moisture pass. The centrifugal action set up in the inner cleaner breaks up any air bubbles, completes the cleaning of the air and also throws down any drops of water that may have been picked up in the air. These water drops are thrown downward and back into the water container through the open end of tube B. This reduces the humidity of the washed air and also prevents excessive water consumption. The clean air after passing out of the spirals in the inner cleaner escapes upward and out through the elbow at top to the carbureter air-intake.

As long as there is any water in the container, the whirling of this keeps the end of tube B, which is very close to the bottom of the container, sufficiently open for the thrown-down water to re-enter the reservoir. However, if the water supply is allowed to evaporate entirely, enough mud and dirt will settle under the open end of B to seal it, so that even if the container should run dry, the inner air-cleaner will collect the dust as a dry-air cleaner. Of course, if the water container is dry and also clean, no such cleaning action is possible unless opening B is closed. Under normal summer temperatures one filling of water should last a full day's run of a tractor in the field.

The reservoir holds about 1 gal., which is a very low water consumption in comparison with others. The air contains so little moisture that it does not interfere with the carbureter action on gasoline, as is the case with some other water cleaners. The whirling action of the water in the reservoir creates a heavy spray over the openings of the spirals so that all the air must pass through the water spray instead of bubbling through a volume of water. This practically eliminates the formation of bubbles, thereby increasing efficiency. Furthermore, any particles of water containing dust are thrown out of the air while



FIGURE

FIG. 7

passing through the inner cleaner and drop back into the water reservoir again. This also accounts for the low water consumption. Except at the instant of starting, the frictional resistance of this water cleaner is no greater than that of an equivalent one of the dry type, because when once started it requires but little force to keep the body of water revolving.

7. Centrifugal-Type Cleaners. The fourth type of cleaner and the most widely used works on the centrifugal or gravity principle. Figs. 7 and 8 are examples of this type. Fig. 8 shows a centrifugal or gravity cleaner that is used on a large percentage of the makes of tractor which use air-cleaners. The air is drawn by suction through openings in the sides of the cleaner into the spiral tubes. These spiral tubes have a downward pitch which gives the dust-laden air a whirl, so that centrifugal action and gravity throw the dust out of the air under the cone and into the container below, while the clean air passes upward through the top and into the carbureter.

FIG. 8

Fig. 8 is a centrifugal cleaner of the same type, differing only in outward appearance and size. The principle and action are identical and the construction nearly so.

There are several other forms of the four types of cleaner, but the ones shown and described are representative and serve to illustrate the principles and design involved.

During the discussion following the reading of the paper, the following questions were asked by the members present, and answered by Mr. Clark.

8. The Discussion.

Question. Do you really think that the dirt thrown down in the cleaner will be solid enough to make an airtight seal?

Answer: It becomes solid as the water evaporates.

Question: Will it be airtight?

Answer: It will if you get any considerable quantity of it. The bottom of the tube is about 1/16 in. from the bottom of the container, and if ¼ in. of dust collects there it becomes airtight. Of course, if the reservoir is clean and empty at the same time, you get no cleaning effect from the water, but if there is dust there and the water does evaporate, the farmer still has a cleaner.

Question: How much of a deposit will there be on the bottom at the end of a 10-hr. run when operating in heavily laden air?

Answer: Judging from what the dry cleaners will catch under the worst conditions, about a pint in five hours. That is the worst I have ever had reported to me. I was out on an experimental job west of St. Louis a month or two ago where we had conditions as bad as I ever saw. We emptied the air cleaner and got approximately 1 in. of dust for every half-mile round.

Question: Do you have to stop the engine when you take the glass off to clean it?

Answer: It is better to do so.

9. Effect of Dust on Engine.

Question: Has any accurate test been made to determine what damage dust going through an engine of that kind causes?

Answer: I have some pistons at the office which are sufficient evidence on that point. The rings at the top and the ring grooves are worn deepest at the top and the injury is less at the bottom of the piston. Some of the rings are cut into and worn bevel-edged. A representative of one of the prominent piston companies told us that this was impossible. We sent them the pistons to prove our point. If you have any doubt as to the destructiveness of dust take a tractor to the Western coast, or one of the Western States, like Idaho. There are some places in the West where a tractor cannot run for two hours without clogging. Tractors have been known to quit cold on account of clogging up of the lubricating oil-holes, cutting out the bearings. There have been cases where the bearings were scooped out.

Question: I have seen the pistons to which Mr. Clark referred. You could easily lay the lead of an ordinary pencil, after you had sharpened it in the usual way, in beside the piston under the upper piston ring. The next one was a little less worn; the third still less, the fourth one a little looser than it ought to be. The pistons had been run about four weeks.

Answer: There was a thick deposit of dirt on the rings, which just about proves the case.

10. Decrease of Power.

Question: What is the effect of the air cleaner on the power?

Answer: In tests made on engines equipped with them, the loss of horsepower was so small we could not measure it. An engine developing 40 hp. would give a power loss of a little less than 1/40 hp. Of course, there is a slight restriction of the air. If the carbureter is adjusted to the change in air velocity, power loss cannot be detected.

Question: Is that true of the water cleaners?

Answer: We have been able to detect very little difference between our water cleaners and the air cleaners. Very little power is required to keep the water revolving.

Question: I have heard several manufacturers protest against the amount of power lost with the water cleaners.

Answer: I have not tested any of the makes other than ours as to friction.

11. Installation.

Question: Are there any points regarding the installation of the air cleaner that it would be to our advantage to know?

Answer: The object in installing an air cleaner is to get one with the greatest efficiency and the fewest drawbacks. One of the drawbacks is loss of power. The farther the cleaner is placed away from the carbureter the more power is lost, no matter what system is used. Flexible steel tubing is one of the best means of clogging a cleaner. It figures about one hp. lost for every 4 ft. If the carbureter and air cleaner must be connected with steel tubing, the closer they are the better and the straighter the tube the better. The cleaner should be supported from its body, not hung from the top. Most cleaners are made of sheet metal because of its light weight. Hang the cleaner on the engine and not the engine on the cleaner.

Question: Have you made any tests on the flexible metal tubing to determine how nearly airtight it is?

Answer: No. I have been assured by makers that with packing in the joints it is airtight.

Question: I have heard that an air cleaner should not be placed in front of the breather or opposite the flywheel because the oily vapor it gets will mix with the dust and clog it.

Answer: That is true.

Question: Mr. Clark has stated that in very hot weather the water cleaner tends to cool the engine. When some water cleaners are used in cold weather the engine cools too much and after a while it will not run at all, so I think the combined air and water cleaner is an improvement over the water type because, even with the water let out there is still a cleaner. Otherwise it would be necessary to disconnect the carbureter from the cleaner.

Question: We used to make a number of oil separators to take oil out of steam. Why not use the principle of these to keep dust out of tractor engines?

Answer: That could be done, but the volume or area you would have to use would be too great. The cleaner would no longer be an accessory.

Question: That is one of the chief points. The air cleaner must be small enough to fit in close to the engine and not be in the way of anything else. On one tractor the air cleaner is installed in such a way that to run on the belt the cleaner must come off.

Answer: And that is when it is needed most.

Question: How fast does the water revolve?

Question: How near does it attain the velocity of the incoming air?

Answer: That would be rather hard to measure. We do not aim at an air velocity greater than 4500 ft. per min. Whether the water attains that speed I do not know.

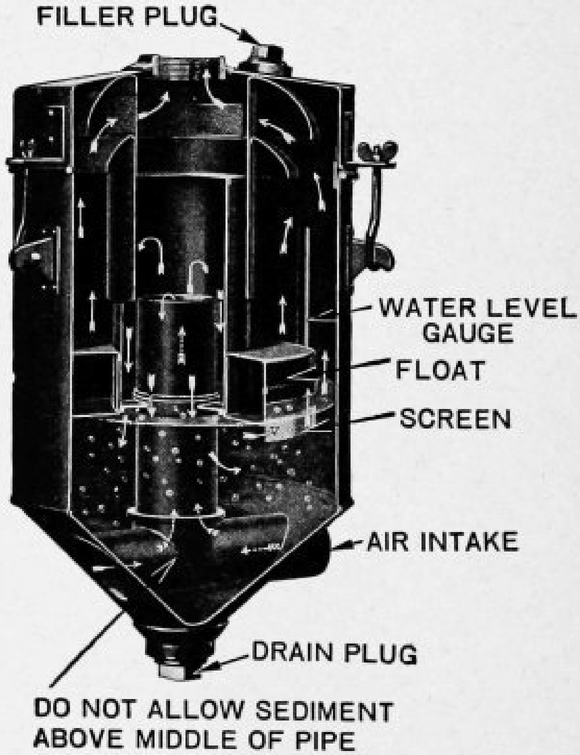


FIG. 9

12. Air Washers. Used on all J. I. Case Tractors. A sectional view is shown in Fig. 9. In this cleaner all the air taken into the motor must be drawn through the washer; the operator is therefore cautioned to guard against possible leaks between the air washer and the carbureter, as this would result in dust being taken in at such places.

In the Case Washer the air is drawn through the water and through a fine submerged screen, which breaks up the bubbles and thoroughly rids the air of all dust. The air after passing through the water is dense and moist, which aids the operation of the motor.

Under ordinary operating conditions and temperature the air washer, when filled with water to the upper mark, should operate for approximately five hours without the addition of fresh water. It will be found, however, that more water will be required when the weather is hot. The water level should be watched by the operator and not allowed to fall be low the level of the lower mark. This is very important as the effectiveness of this device depends upon the proper level of the water being maintained.

13. To Clean. Dirt should not be allowed to gather in the air washer to the height of the flange on the collar, and the operator will soon learn by experience how often to clean under different conditions.

It is advisable occasionally when cleaning the air washer to flush it out thoroughly with clean water, as the dirt often clings firmly to the submerged surfaces. When operated too long without proper cleaning the dirt will become caked so that it must be cleaned out with a stick. It should be made a practice to always clean washer immediately after stopping motor at noon or at night, as the dust will then be prevented from settling to the bottom.

14. Operating Without Water. In cold weather when there is danger of freezing, or when operating on stationary work where there is no dust, the air washer can be operated without water. When this is done the drain plug should be removed to allow the air to enter more freely.

It is obvious, however, that the air washer when operated without water will not act as a dust strainer and should only be operated in this manner where conditions are such that there is little dust to contend with.

15. Air Heater. After the air has passed through the washer it is conducted through a heater surrounding the exhaust pipe. In this manner the air is heated before it is taken into the carburetor, which assists the carburetor action and the vaporization of the fuel.

CHAPTER XII

BELTS AND PULLEYS

1. Belts and Pulleys. A study of the Gas Tractor should also include a study of belts and pulleys. The Department of Agriculture, Washington, D. C., found from 38,000 questionaires sent to gas tractor owners that belt work was found to be the largest single item of service the gas tractor was used for. While maintaining the highest working efficiency of the motor we must understand and maintain its efficient application to all kinds of work. As belt driven machinery is usually located some distance from the motor, belts are employed to transmit the power from the motor to the machine. Belts are the most efficient means of transmitting power from one shaft to the other, where the shafts are considerable distance apart. In order to use a belt for this purpose, a pulley must be placed on the drive and driven shafts. As the two shafts seldom run at the same revolutions per minute (R. P. M), the pulleys are of different diameters. Therefore it is first necessary to select the proper diameters of pulleys, as the diameter and R. P. M. of the pulleys determine the speed width and thickness of the belt necessary to transmit a given power. In selecting the pulleys bear in mind that the area of contact on the smaller pulley determines the tension required on the belt. All of these conditions enter into the rule for determining the horsepower transmitted by the belt, as well as the speed of the driven shaft in relation to the drive shaft.

2. Rules for Determining the Diameter and Speed of Pulleys. No. 1. The diameter of the driver and driven being given, to find the number of revolutions of the driven:

Rule. Multiply the diameter of the driver by its number of revolutions and divide the product by the diameter of the driven; the quotient will be the number of revolutions.

No. 2. The diameter and the revolutions of the driver being given, to find the diameter of the driven, that shall make any given number of revolutions in the same time:

RULE. Multiply the diameter of the driver by its number of revolutions, and divide the product by the number of revolutions of the driven; the quotient will be its diameter.

No. 3. To ascertain the diameter of the driver.

RULE. Multiply the diameter of the driven by the number of revolutions you wish to make and divide the product by the revolutions of the driver; the quotient will be the diameter of the driver.

(Above rules are practically correct. Though owing to the slip, elasticity, and thickness of belt, circumference of driven seldom runs as fast as driver.)

Example: The drive pulley is 20 inches diameter and makes 500 R. P. M. and the driven pulley is 10 inches diameter, what is the R. P. M. of the driven shaft?

Formula: $\frac{20 \times 500}{10} = 1000$ R. P. M. Ans.

Example. The drive pulley is 20 inches diameter and makes 500 R. P. M. and the driven shaft is to make 1000 R. P. M. What is the size of the driven pulley?

Formula: $\frac{20 \times 500}{1000} = 10$ inches diameter. Ans.

Example. The driven pulley is 10 inches diameter and makes 1000 R. P. M. and the drive shaft makes 500 R. P. M. What is the diameter of the drive pulley?

Formula: $\frac{10 \times 1000}{500} = 20$ inches diameter. Ans.

3. The Coefficient of Friction. The friction of a belt on a pulley varies as the tension and area of contact, independent of surface area; i. e., if one pulley has twice the circumference of the other, the friction is the same for the same area of contact, although the surface in the last case is twice that of the other. The tension on a belt, which still depends upon the amount of friction between the belt and pulley. If the coefficient of friction is 40 per cent, or the difference in tension between the working and slack sides of the belt is 40 per cent, of the working side, the tension on the sides of the belt, when still, is four-fifths of the tension on the working side. This working tension for a single leather belt of good quality is given as 67 pounds per inch of width; double thickness belts, as 108 pounds. Belts are sometimes made double at the edges, when the tension can be anywhere from 67 to 108 pounds per inch in width, depending upon the extent to which they are doubled. Rubber belts will convey about one-fifth more power than leather, but are not so durable. The difference between tight and slack sides, divided by the tension on the tight, or working, side, will give the coefficient of friction. This is generally considered as .42. One-half the difference in tension of the sides subtracted from tight side will give the tension on sides when the belt is still.

EXAMPLE.—The working strain per inch in width of belt is 70 pounds; slack side, 30 pounds. What is the coefficient of friction, and what is the tension on the sides of belt when still?

70 — 30 = 40
40 ÷ 70 = .57 = coefficient of friction.

$$70 - \frac{30}{2} = 55 \text{ pounds.}$$

4. The Working Strain on the Tight Side of the Belt and Coefficient of Friction given, to find the tension at which the belt is to be laced. Rule: Multiply the working strain by coefficient, and subtract one-half the product from the working strain.

The tension at which the belt is laced and coefficient of friction given, to find the working strain. Rule: Divide twice the tension at which the belt is laced by 2 minus the coefficient of friction.

5. To Find the Speed of Belt Per Minute in Feet. Rule: Multiply the diameter of either pulley, in inches by revolutions per minute and by .26.

Example: The diameter of pulley is 20 inches; revolution, 300 per minute. What is the speed of belt per minute in feet?

300 X 20 = 6000
.26 X 6000 = 1560 feet. Answer.

6. Horsepower Transmitted by Belts. While the H. P. of a belt varies as the arc of contact, it does not vary directly as that arc; i. e., when the arc of contact of belt is 60 degrees, the power of the belt is about 8/21 of the total power of whole circumference; at 120 degrees, about 1321; at 180 degrees, about 16/21; while the power for the whole circumference is less than 2½ times the power at 60 degrees.

To Find the H. P. of a Belt. Rule: Multiply the working strain per inch by width in inches, by velocity in feet per minute, and divide the product by 4488, divided by arc of contact (small pulley, open belt) plus 17, plus 1/60 of arc of contact. Point off three figures from the quotient.

Formula:

$$\frac{.001\ Twf}{\dfrac{4488 \times 17 \times 1/60\ a}{a}}$$

in which T indicates working strain on belt; w, width in inches; f, feet per minute; a, arc of contact in degrees.

Example.—The tension on working side of belt is 75 pounds; width, 10 inches; speed, 2500 feet per minute; arc of contact, 150 degrees. What is the H. P. transmitted?

10 X 75 = 750
2500 X 750 = 1875000
4488 ÷ 15 = 29.92
29.92 + 17 = 46.92
150 ÷ 60 = 2.5
46.92 + 2.5 = 49.42
1875 ÷ 49.42 = 37.94 H. P. Answer.

7. To Estimate the Horsepower a Belt Will Transmit, the Diameter of Pulley and Width of Belt Being Given.

As the position in which principal belts are generally placed is such that the arc of contact will not vary to any considerable extent from 180 degrees, and as the H. P. of belts varies but slightly for a considerable variation of arc of contact from 180 degrees, simple approximate rules can be given for H. P. of belts.

RULE.—Multiply the diameter of the pulley by the number of R. P. M. and this product by the width of the belt, and divide this total by 2,750 for single and by 1,925 for double belts.

8. To Estimate the Width of a Belt, the Horsepower, Diameter of Pulley and Number of R. P. M. Being Given.

RULE. Multiply the horsepower by 2,750 for single and 1,925 for double belts, and divide this product by the product of the diameter of the pulley multiplied by the number of R. P. M.

Example: What width of belt is required to transmit the power of a motor developing 94 H. P. at 488 R. P. M. and a 16-inch pulley.

Formula: 2,750 X 94 = 258500
488 X 16 = 7808

$$\frac{258500}{7808} = 33 \text{ inch. Ans.}$$

9. Selection of Belting. Oak-tanned leather is usually considered the best for belting, although many high-grade belts are no longer tanned by the use of oak bark. Assuming that a good grade of leather is used, uniformity in the material is of first importance; that is, the different sections of which the belt is made should all be of the same grade. The belts should also be thoroughly stretched so that they do not have to be "taken up" every few days. The leather for the best grades of belting is taken from the central part of the hide along the back of the animal. That part of the hide extending along the spine and for some distance down the sides is firm and close in texture and the strongest for a belt. If the leather is taken too far down the side, it will be flexible and lack strength and closeness of texture. If the strips are cut too long, the ends will be taken from the neck of the animal, which is also inferior stock. A "short lap" belt is one made entirely from that part of the hide which comes from the back of the animal and the strips are not long enough to include any portion of the neck stock.

10. Rubber Belting. Rubber belts are used in places exposed to the weather or the action of steam, as they do not absorb moisture of stretch as readily as leather belts, under like conditions. The quality of rubber belting depends on the mixture (containing more or less rubber) that forms the coating, the cotton duck that gives strength to the belt and the method of manufacture. As to the rubber mixture, there are, in general, two kinds, one composed entirely of new rubber, and the other containing some, if not all, "re-worked" rubber. The latter is derived from discarded rubber articles such as rubber shoes, etc., and has lost much of its life. The best grades of rubber belting contain nothing but new rubber; the cheapest grades are composed largely of reclaimed rubber. The weight of the cotton duck is an important consideration. High-grade belts contain what is known as a 32-ounce cotton duck· and the cheaper grades have either a 30-ounce or 28-ounce duck. If the proper weight of duck is used, a 3- or 4-ply rubber belt is equal in strength to a single leather belt; a 5- or 6-ply rubber belt is equal to a double leather belt, and a 7- or 8-ply rubber belt is equal to a triple leather belt. A test commonly made to determine what is known as the "friction' 'of the belt, or the tenacity with which the different plies are held together by the rubber mixture, is as follows: The belt is cut so that the different plies of cotton duck can be pulled apart, and the amount of pull necessary to separate the plies determine the frictional value.

11. Canvas Belting. Canvas belting is made of several laps or plies of cotton duck stitched lengthwise and the belt is afterwards treated with a compound made principally of linseed oil. This oil saturates the cotton duck· which is thus protected from dampness, and the belt is not easily injured by heat, cold, steam, gas or acid fumes. Canvas stetched belting is often used where the material coming in contact with the belt or the surrounding atmosphere would ruin an ordinary leather, cotton or rubber belt. It is applicable to belt conveyors· when the material to be handled will not cut the cotton fiber.

12. Belt Dressings. Belts should be cleaned and greased every five or six months to give the grain side a soft adherent surface. The following mixtures are recommended: Take two parts of beef tallow to one part of cod liver oil (by weight); melt the tallow and allow it to cool until the finger can be inserted without burning; then add the cod liver oil and stir until cooled. A light coat of this mixture should be applied to the driving side of the belt after it has been cleaned. Rosin or rosinous mixtures should never be used to prevent belts from slipping. They will cause temporary adhesion, but the belt soon becomes glazed and slips more than before the rosin was applied. Lubricating oils should not be permitted to drop onto belts. If a belt has become saturated with oil, scrape it and pack it in dry sawdust or some other absorbent material for three or four days. When belting becomes dry, all surface dirt should first be removed before applying the dressing; this usually can be done by rubbing the belt with a cloth dampened with kerosene. If necessary, use a wooden or metal scraper. A dressing recommended for rubber belts consits of equal parts of red lead, black lead, French yellow and litharge, mixed with boiled linseed oil and enough japan to make it dry quickly. Animal oil or grease should never be used on rubber belts.

13. Thickness and Width of Belts.—Narrow, thick belts are more desirable and work more satisfactorily than wide and thin belts. It is advisable to use double belts on pulleys 12 inches in diameter or larger; triple belts on pulleys 20 inches in diameter or larger, and quadruple belts on pulleys 30 inches in diameter or larger. If thin belts are operated at high speed, they tend to run in waves on the slack side and travel laterally, especially if there are sudden load changes. This waving and snapping wears the belt rapidly and can be practically eliminated by having the thickness in proper proportion to the width. The speed at which belting runs has comparatively little effect upon its life until the velocity is higher than 2500 to 3000 feet per minute. The life is affected principally by the power transmitted· the method of fastening the ends, and the care of the belting.

14. Horsepower Transmitted by Leather Belting.

TABLE GIVING NUMBER OF HORSEPOWER TRANSMITTED BY BELTS ONE INCH WIDE.

Speed in Feet Per Minute.	Single.	Double.	Triple.	Four-ply.
100	0.14	0.24	0.33	0.44
200	0.27	0.48	0.67	0.88
300	0.41	0.37	1.00	1.32
400	0.54	0.96	1.33	1.75
500	0.68	1.21	1.66	2.19
600	0.81	1.44	1.99	2.62
700	0.95	1.68	2.31	3.05
800	1.08	1.93	2.64	3.48
900	1.21	2.15	2.96	3.90
1000	1.34	2.38	3.28	4.32
1100	1.47	2.61	3.59	4.73
1200	1.60	2.85	3.90	5.14
1300	1.73	3.07	4.21	5.55
1400	1.86	3.30	4.51	5.94
1500	1.98	3.53	4.81	6.34
1600	2.10	3.73	5.10	6.72
1700	2.23	3.94	5.39	7.10
1800	2.34	4.15	5.67	7.47
1900	2.46	4.35	5.94	7.83
2000	2.58	4.56	6.21	8.18
2200	2.80	4.94	6.73	8.85
2400	3.01	5.30	7.21	9.51
2600	3.21	5.65	7.67	10.09
2800	3.40	5.97	8.09	10.64
3000	3.58	6.25	8.45	11.14
3200	3.74	6.52	8.80	11.58
3400	3.89	6.74	9.10	11.96
3600	4.03	6.95	9.35	12.28
3800	4.14	7.12	9.55	12.57..
4000	4.24	7.26	9.70	12.73
4200	4.33	7.36	9.79	12.84
4400	4.39	7.42	9.85	12.88
4600	4.43	7.44	....	....
4800	4.45	....	....	....

This table is based on an effective pull of 45 pounds per inch of width for single belts, 80 pounds for double, 110 for triple and 145 pounds for four-ply.

The S. A. E. Standard belt speed is 2600 feet per minute.

CHAPTER XIII

GEARS

Before the student can hope to understand the Transmission of a gas tractor, it is necessary that he should familiarize himself with gears. Therefore, we will take up gears in this chapter. To understand gears we must familiarize ourselves with the following terms: Pitch Circle, Pitch, Tooth, Space, Addendum or Face, Flank, Clearance.

It is not the intention to teach the operator the technical construction of gears, but to give him a practical working knowledge of their construction and operation to enable him to maintain their highest efficiency.

TANGENT CYLINDERS.

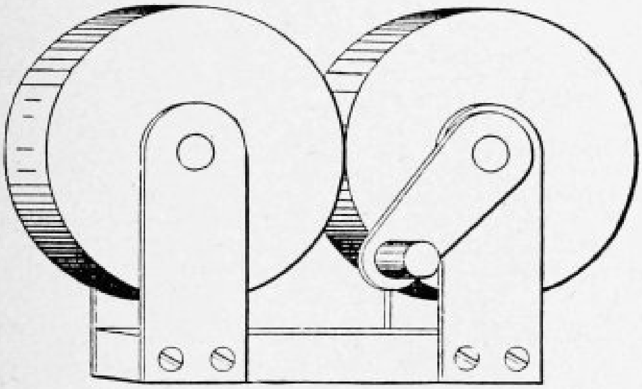


FIG. 1.

1. Original Cylinders. Let two cylinders, Fig. 1, touch each other, their axes be parallel and the cylinders be on shafts, turning freely. If, now, we turn one cylinder, the adhesion of its surface to the surface of the other cylinder will make that turn also. The surfaces touching each other, without slipping one upon the other, will evidently move through the same distance in a given time. This surface speed is called **linear velocity.**

2. Linear Velocity. Linear Velocity is the distance a point moves along a line in a unit of time.

The line described by a point in the circumference of either of these cylinders, as it rotates, may be called an arc. The length of the arc (which may be greater or less than the circumference of cylinder), described in a unit of time, is the velocity. The length, expressed in linear units, as inches, feet, etc., is the linear velocity. The length, expressed in angular units, as degrees, is the **angular** velocity.

3. Angular Velocity. If, instead of 1 degree we take 360 degrees, or one turn, as the angular unit, and one minute as the time unit, the angular velocity will be expressed in turns or revolutions per minute.

4. Relative Angular Velocity. If these two cylinders are of the same size, one will make the same number of turns in a minute that the other makes. If one cylinder is twice as large as the other, the smaller will make two turns while the larger makes one; but the linear velocity of the surface of each cylinder remains the same.

This combination would be very useful in mechanism if we could be sure that one cylinder would always turn the other without slipping.

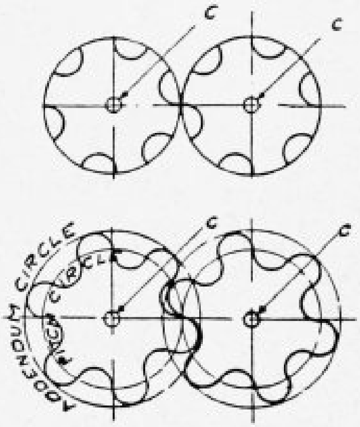


FIG 2

5. Land, Addendum, Tooth, Gear, Train, Line of Centers, Addendum Circle. In the periphery of these two cylinders, as in Fig. 2, cut equidistant grooves. In any grooved piece the places between grooves are called **lands.** Upon the lands add parts; these parts are called addenda. A land and its addendum is called a **tooth.** A toothed cylinder is called a **gear.** Two or more gears, with teeth interlocking are called a **train.** A line, **c c'**, Fig. 2 or 3, between the centers of two wheels is called the **line of centers.** A circle just touching the addenda is called the **addendum circle.**

6. Pitch Circle. Pitch Circle is also called the Primitive Circle. The circumference of the cylinders without teeth is called the **pitch circle.** This circle exists geometrically in every gear, and is still called the pitch circle or the primitive circle. In the study of gear wheels, it is the problem so to shape the teeth that the pitch circles will just touch each other without slipping.

On two fixed centers there can turn only two circles—one circle on each center—in a given relative angular velocity, and touch each other without slipping.

7. Space, Linear or Circular Pitch, Tooth Thickness. The groove between two teeth is called a **space.**

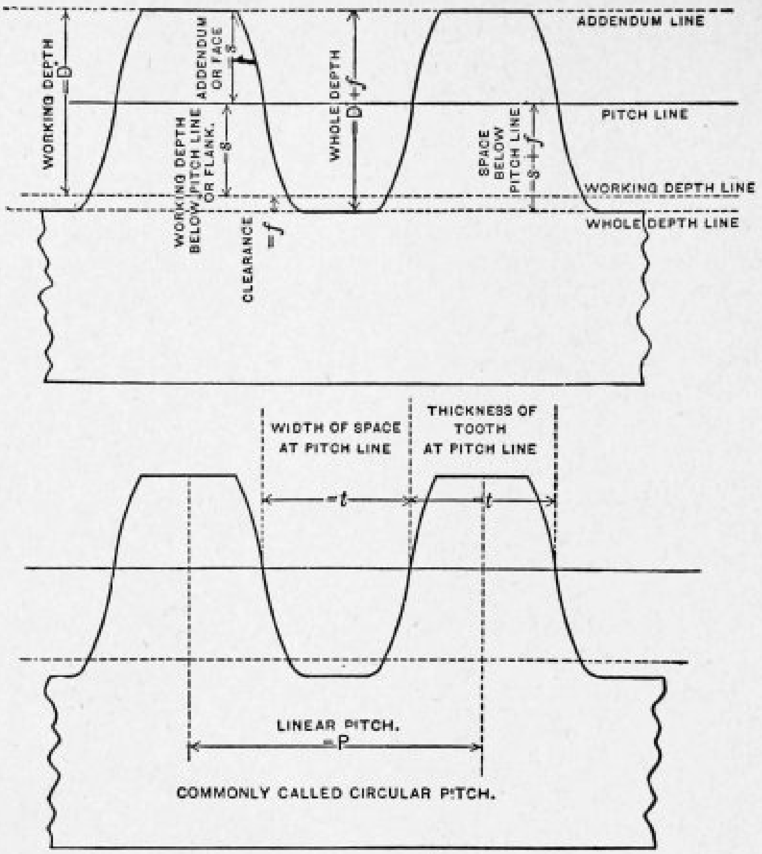


FIG. 3.

In cut gears, the width of space at pitch line, and thickness of tooth at pitch line, are equal. The distance between the center of one tooth and the center of the next tooth, measurd along the pitch line, is the **linear or circular pitch;** that is, the linear or circular pitch is equal to a tooth and a space. Hence, the thickness of a tooth at the pitch line is equal to one-half the linear or circular pitch.

8. Abbreviations of Parts for Teeth and Gear.

Let D = diameter of addendum circle.

Let D' = diameter of pitch circle.

Let P' = linear or circular pitch.

Let **t** = thickness of tooth at pitch line.

Let **s** = addendum or face, also length of working part of tooth below pitch line or flank.

Let **2s** = D" or twice the addendum, equal the working depth of teeth of two gears in mesh.

Let **f** = clearance or extra depth of space below working depth.

Let s + f = depth of space below pitch line.

Let D" + f = whole depth of space.

Let N = number of teeth in one gear.

Let π = 3.1416 or the circumference when diameter is 1.

P' is "P prime." D" is read "D second." π is read "pi."

9. To Find the Circumference and Diameter of a Circle. If we multiply the diameter of any circle by π, the product will be the circumference of this circle. If we divide the circumference of any circle by π, the quotient will be the diameter of this circle.

10. Pitch Point. The pitch point of the side of a tooth is the point at which the pitch or line meets the side of the tooth. A gear tooth has two pitch points.

CLASSIFICATION—SIZING BLANKS AND TOOTH PARTS FROM CIRCULAR PITCH —CENTER DISTANCE—PATTERN GEARS.

11. Elements of the Teeth. If we conceive the pitch of a pair of gears to be made the smallest possible, we ultimately come to the conception of teeth that are merely lines upon the original pitch surfaces. These lines are called **elements** of the teeth. Gears may be classified with reference to the elements of their teeth, and also with reference to the relative position of their axes or shafts. In most gears the elements of teeth are either straight lines or helices (screw-like lines).

These chapters treat upon **three kinds of gears.**

12. Spur Gears. First—Spur Gears, those connecting parallel shafts and whose tooth elements are straight.

13. Bevel Gears. Second—**Bevel Gears;** those connecting shafts whose axes meet when sufficiently polonged, and the elements of whose teeth are straight lines. In bevel gears the surfaces that touch each other, without slipping, are upon cones or parts of cones whose apexes are at the same point where axes of shafts meet.

14. Screw or Worm Gears. Third—**Screw or Worm Gears;** those connecting shafts that are not parallel and do not meet, and the elements of whose teeth are helical or screw-like.

15. Sizing Blanks, Etc. The circular pitch and number of teeth in a wheel being given, the diameter of the wheel and size of tooth parts are found as follows:

16. A Diameter Pitch or Module. Dividing by 3.1416 is the same as multiplying by $\frac{1}{3.1416}$. Now $\frac{1}{3.1416}$ = .3183; hence, multiply the circumference of a circle by .3183 and the produce will be the diameter of the circle. Multiply the circular pitch by .3183, and the product will be the same **part** of the diameter of pitch circle that the circular pitch is of the circumference of pitch circle. This part is called **the module of the pitch.** There are as many modules contained in the diameter of a pitch circle as there are teeth in the wheel.

17. The Module and the Addendum Measure the Same, Radially. Most mechanics make the addendum of teeth equal the module. Hence, we can designate the module by the same letter as we do the addendum; that is, let **s** = the module.

.3183 P' = **s**, or circular pitch multiplied by .3183 = **s**, or the module.

18. Diameter of Pitch Circle. Ns = D', or number of teeth in a wheel, multiplied by the module, equals diameter of pitch circle.

19. Whole Diameter. (N + 2) **s** = D; or, add 2 to the number of teeth, multiply the sum by the module, and the product will be the whole diameter.

20. Clearance. $\frac{t}{10}$ = **f**; or, one-tenth of thickness of tooth at pitch line equals amount added to bottom of space for clearance.

Some mechanics prefer to make **f** equal to 1/16 of the working depth of teeth, or .0625 D". One-tenth of the thickness of tooth at pitch-line is more than one-sixteenth of working depth, being .07854 D".

21. Example. Example—Wheel 30 teeth, 1½-in. circular pitch.

Sizes of Blank and Tooth Parts for Gear of 30 Teeth 1½-in. Circular Pitch. P' = 1.5"; then **t** = 75", or thickness of tooth, equals ¾ in. **s** = 1.5 .3183 = module for 1½-in. P'.

D' = 30 X .4775" = 14.325" = diameter of pitch-circle.

D = (30 + 2) X .4775" = 15.280" diameter of addendum circle, diameter of the blank.

f = 1/10 of .75" = .075", clearance at bottom of space.

D" = 2 X .4775" = .9549" = working depth of teeth.

D" + f = 2 X .4775" + .075" = 1.0299" = whole depth of space.

s + f = .4775" + .075" = .5525" = depth of space inside of pitch line.

D" = 2**s**, or the working depth of teeth is equal to two modules.

In making calculations it is well to retain the fourth place in the decimals, but when drawings are passed into the workshop, three places of decimals; are sufficient.

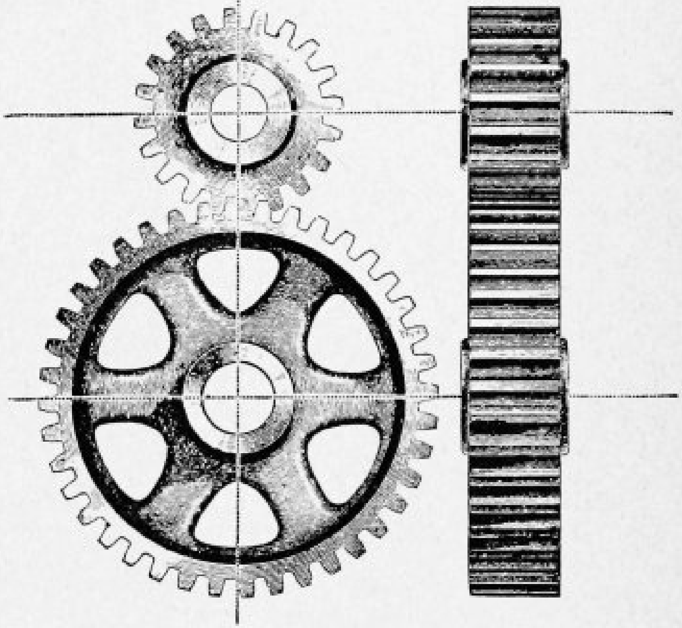
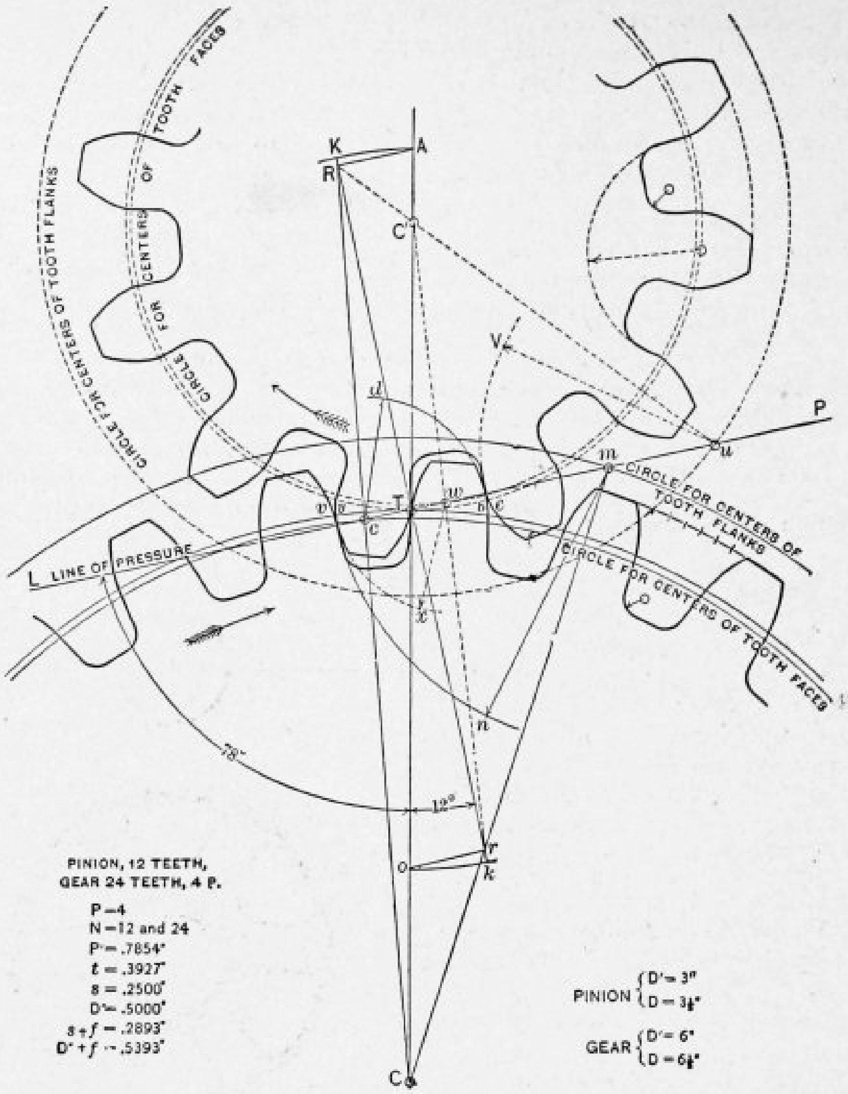


FIG. 4.

22. Distance Between Centers of Two Gears. The distance between the centers of two wheels is evidently equal to the radius of pitch-circle of one wheel added to that of the other. The radius of pitch-circle is equal to **s** multiplied by one-half the number of teeth in the wheel.

Hence, if we know the number of teeth in two wheels, in mesh, and the circular pitch, to obtain the distance between centers we first find **s**; and then multiply **s** by one-half the sum of number of teeth in both wheels. The product will be distance between centers.

Problem.—What is the distance between the centers of two wheels 35 and 60 teeth, 1¼-in. circular pitch? We first find s to be 1¼ X .3183 = .3979". Multiplying by 47.5 (one-half the sum of 35 and 60 teeth), we obtain 18.899" as the distance between centers.



DOUBLE CURVE GEARS IN MESH

23. Allowance for Shrinkage in Gear Castings. Pattern Gears should be made large enough to allow for shrinkage in casting. In cast iron the shrinkage is about ⅛ inch in one foot. For gears one to two feet in diameter, it is well enough to add simply 1/100 of diameter of finished gear to the pattern. In gears about six inches diameter or less, the moulder will general rap the pattern in the sand enough to make any allowance for shrinkage unnecessary. In pattern gears, the spaces between teeth should be cut wider than finished gear spaces to allow for rapping, and to avoid having too much cleaning to do in order to have gears run freely. In cut patterns of iron it is generally enough to make spaces .015 in. to .02 in. wider. This makes clearance .03 in. to .04 in. in the patterns. Some moulders might want .06 in. to .07 in. clearance.

24. Metal Pattern Gears. Metal patterns should be cut straight; they work better with no draft. It is well to leave about .005 in. to be finished from side of patterns after teeth are cut; this extra stock to be taken away from side where cutter comes through, so as to take out places where stock is broken out. The finishing should be done with file or emery wheel, as turning in a lathe is likely to break out stock as badly as a cutter might do.

If cutters are kept sharp and care is taken when coming through, the allowance for finishing is not necessary; and the blanks may be finished before they are cut.

25. Annular Gears. Annular Gears. Gears with teeth inside of a rim or ring are called Annular or Internal Gears. The construction of tooth outlines is similar to the foregoing, but the **spaces** of a spur external gear become the **teeth** of an annular gear.

Prof. MacCord has shown that in the system just described, the pinion meshing with an annular gear must differ from it by at **least** fifteen teeth. Thus. a gear of 24 teeth cannot work with an annular gear of 36 teeth, but it will work with annular gears of 39 teeth and more. The fillets at the roots of the teeth must be of less radius than in ordinary spur gears. An annular gear differing from its mate by less than 15 teeth can be made.

Annular gear patterns require more clearance for moulding than external or spur gears.

26. Pinions. In speaking of different-sized gears, the smallest ones are often called "pinions."

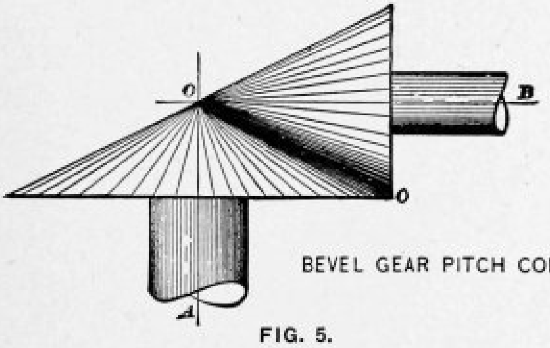
The angle of pressure in all gears except involute, constantly changes. Seventy-eight degrees is the pressure angle in double-curve or epicycloidal gears for an instant only. In our example, it is 78 degrees when one side of a tooth reaches the line of centers, and the pressure against teeth is applied in the direction of the arrows.

The pressure angle of involute gears does not change.

We obtain the forms for epicycloidal gear cutters by means of a machine called the Odontom Engine. This machine will cut original gears with theoretical accuracy.

27. Twenty-four Double Curve Gear Cutters for Each Pitch. It has been thought best to make 24 gear cutters for each pitch. This enables us to fill any requirement of gear-cutting very closely, as the range covered by any one cutter is so small that it is exceedingly near to the exact shape of all gears so covered.

Of course, a cutter can be **exactly** right for only one gear. Special cutters can be made, if desired.



BEVEL GEAR PITCH CONES.

FIG. 5.

BEVEL GEAR BLANKS.

28. Teeth of Bevel Gears Formed Upon Frustrums of Cones. Bevel Gears connect shafts whose axes meet when sufficiently prolonged. The teeth of bevel gears are formed about the frustrums of cones whose apexes are at the same point where the shafts meet. In Fig. 5 we have the axis A O and BO, meeting at O; and the apexes of the cones also at O. These cones are called the pitch cones, because thy roll upon each other, and because upon them the teeth are pitched. If, in any bevel gear, the teeth were sufficiently prolonged toward the apex, they would become infinitely small; that is, the teeth would all end in a point, or vanish at O. We can also consider a bevel gear as beginning at the apex and becoming larger and larger as we go away from the apex. Hence, as the bevel gear teeth are tapering from end to end, we may say that a bevel gear has a number of pitches and pitch circles, or diameters. In speaking of the pitch of a bevel gear, we mean always the pitch at the largest pitch circle, or at the largest pitch diameter, as at b d, Fig. 7.

29. Construction of Bevel Gear Blanks. Fig. 7 is a section of three bevel gears, the gear o B q being twice as large as the two others. The outer surface of a tooth, as m m', is called the length of the face of the tooth. The distance m m' is usually called the length of the face of the tooth, though the real length is the distance that it occupies upon the line O i. The outer part of a tooth at m n is called its large end, and the inner part m' n' the small end.

Almost all bevel gears connect shafts that are at right angles with each other; and unless stated otherwise we always understand they are so wanted.

The directions given in connection with Fig. 7 apply to gears with axis at right angles.

Having decided upon the pitch and the numbers of teeth:—

1. Draw center lines of shafts, A O B and C O D, at right angles.

2. Parallel to A O B, draw lines a b and c d, each distance from A O B, equal to half the largest pitch diameter of one gear. For 24 teeth, 4 pitch, this half largest pitch diameter is 3 in.

3. Parallel to C O D, draw lines e f and g h, the distance from C O D being equal to half the largest pitch diameter of the other gear. For a gear, 12 teeth, 4 pitch, this half largest pitch diameter is 1½ in.

4. At the intersection of these four lines, draw lines O i, O j, O k, and O l; these lines give the size and shape of pitch cones. We call them "Cone Pitch Lines."

5. Perpendicular to the cone-pitch lines and through the intersection of lines a b, c d, e f, and g h, draw lines m n, o p, q, r. We have drawn also u v to show that another gear can be drawn from the same diagram. Four gears, two of each size, can be drawn from this diagram.

6. Upon the lines m n, o p, q r, the addenda and depth of the teeth are laid off, these lines passing through the largest pitch circle of the gears. Lay off the addendum, it being in these gears ¼ in. This gives distance m n, o p, q r and u v equal to the working depth of teeth, which in these gears is ½ in. The addendum of course is measured perpendicularly from the cone pitch lines as at k r.

7. Draw lines O m, O n, O p, O o, O q, O r. These lines give the height of teeth above the cone-pitch lines as they approach O, and would vanish entirely at O. It is quite as well never to have the length of teeth or face, m m', longer than one-third the apex distance m O, nor more than two and one-half times the circular pitch.

8. Having decided upon the length of face, draw

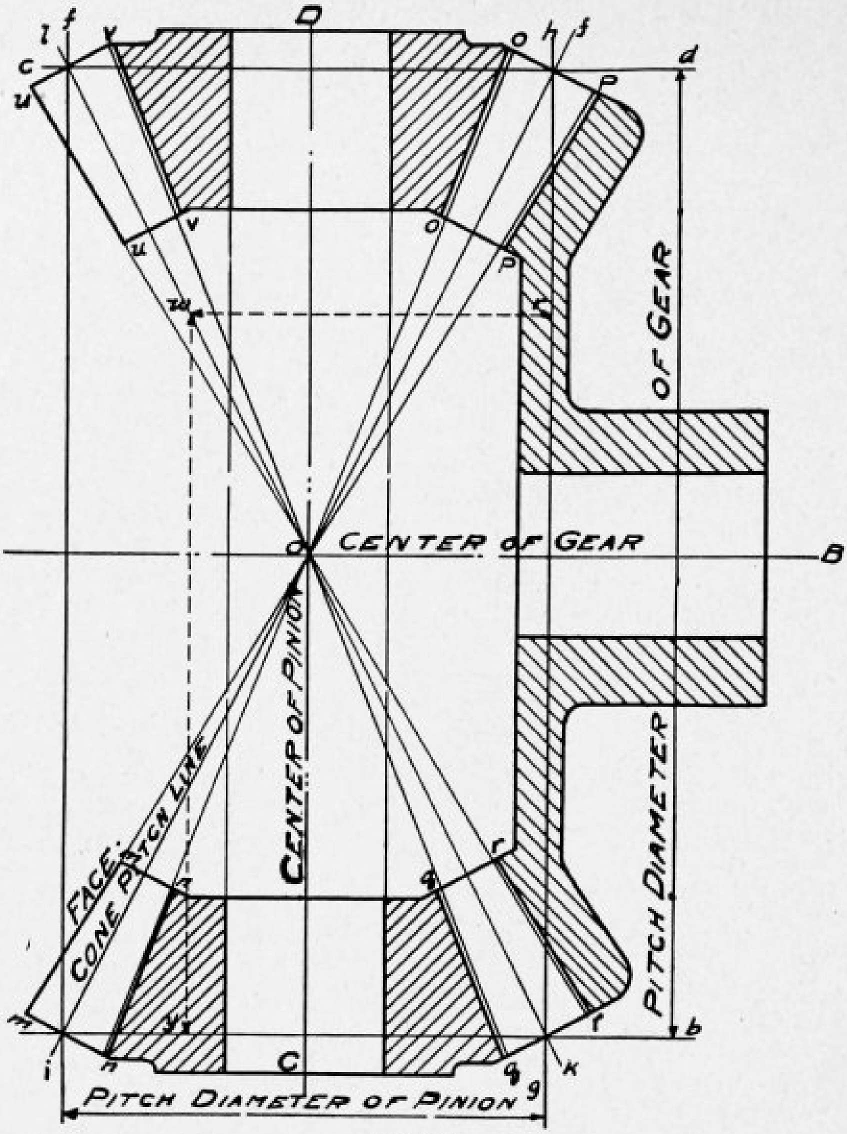


FIG. 6.

limiting lines m' n' perpendicular to i O, q' r' perpendicular to k O, and so on.

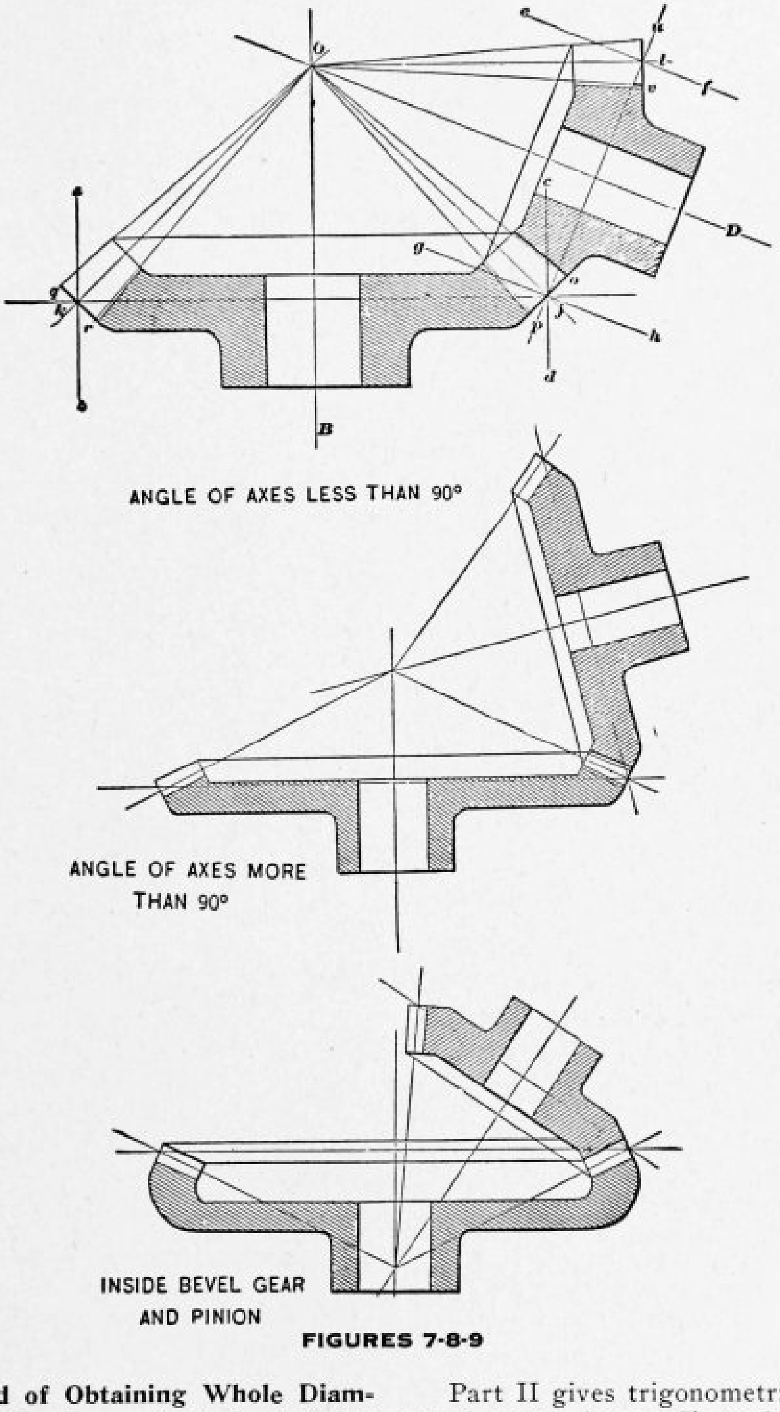
30. The Whole Diameter of Bevel Gear Blanks Can Be Obtained by Measuring Drawings. The distance between the cone-pitch lines at the inner ends of the teeth m' n' and q' r' is called the inner or smaller pitch diameter, and the circle at these points is called the smallest pitch circle. We now have the outline of a section of the gears through their axis. The distance m r is the whole diameter of the pinion. The distance q o is the whole diameter of the gear. In practice these diameters can be obtained by measuring the drawing. The diameter of pinion is 3.45 in. and of the gear 6.22 in. We can find the angles also by measuring the drawing with a protractor. In the absence of a protractor, templets can be cut to the drawing. The angle formed by line m m' with a b is the angle of face of pinion. In this pinion 59 degrees 11 min., or nearly 59½ degrees. The lines q q' and g h give us angle of face of gear, for this gear 22 degrees 19 min., or nearly 22 1/3 degrees. The angle formed by m n with a b is called the angle of edge of pinion, in our sketch 26 degrees 34 min., or about 26½ degrees. The angle of edge of gear, line q r with g h, is 638 26 min., or about 63½ degrees. In turning blanks to these angles we place one arm of the protractor or templet against the end of the hub, when trying angles of a blank. Some designers give the angles from the axis of gears, but it is not convenient to try blanks in this way. The method that we have given comes right also for angles as figured in compound rests.

When axis are at right angles, the sum of angles of edge in the two gears equals 90 degrees; and the sums of angle of edge and face in each gear are alike.

The angles of the axis remaining the same, all pairs of bevel gears of the same ratio have the same angle of edge; all pairs of same ratio and of same numbers of teeth have the same angles of both edges and faces independent of the pitch. Thus, in all pairs of bevel gears having one gear twice as large as the other, with axis at right angles, the angle of edge of large gear is 63 degrees 26 min., and the angle of edge of small gear in 26 degrees 34 min.

In all pairs of bevel gears with axis at right angles, one gear having 24 teeth; and the other gear having 12 teeth, the angle of face of small gear is 59 degrees 11 min.

From k lay off, upon the cone-pitch line, a distance K w, equal to ten times the working depth of the teeth = 10 D". Now add 1/10 of the shortest distance of w from the line g h, which is the perpendicular dotted line w x, to the outside pitch diameter of gear. The sum will be the whole diameter of gear. In the same manner 1/10 of w y, added to the outside pitch diameter of pinion, gives the whole diameter of pinion. The part added to the pitch diameter is called the **diameter increment.**



FIGURES 7-8-9

31. Another Method of Obtaining Whole Diameter of Blanks. The following method of obtaining the whole diameter of bevel gears is sometimes preferred:

Part II gives trigonometrical methods of figuring bevel gears; in our Formulas in Gearing there are trigonometrical formulas for bevel gears, and also tables for angles and sizes.

32. Construction of Bevel Gear Blanks Whose Axis are not at Right Angles. A somewhat similar construction will do for bevel gears whose axis are not at right angles.

In Fig. 7 the axis are shown at O B and O D, the angle B O D being less than a right angle.

1. Parallel to O B, and at a distance from it equal to the radius of the gear, we draw the lines a b and c d.

2. Parallel to O D, and at a distance from it equal to the radius of the pinion, we draw the lines e f and g h.

3. Now, through the point j at the intersection of c d and g h, draw a line perpendicular to O B. This line k j, limited by a b and c d, represents the largest pitch diameter of the gear.

Through j draw a line perpendicular to O D. This line j l, limited by e f and g h, represents the largest pitch diameter of the pinion.

4. Through the point k at the intersection of a b with k j, draw a line to O, a line from j to O, and another from l, at the intersection j l and e f to O. These lines O k, O j, and O l, represent the cone-pitch lines, as in Fig. 8.

5. Perpendicular to the cone-pitch lines we draw the lines u v, o p, and q r. Upon these lines we lay off the addenda and working depth as in the previous figure, and then draw lines to the point O as before.

By a similar construction Fig. 9 can be drawn.

33. Diametral Pitch Spur Gears. In recent years, the cut gears have become more prominent because the development of the automobile, truck and tractor has demanded improved methods in the transmission of power from one shaft to the other.

The desire to reduce the size of the gears and decrease the noise to a minimum, and to obtain a maximum efficiency, having increased the demand for cut gears. It became necessary to construct special machines on which these gears could be more rapidly and economically cut. To do this the standard circular pitch method then in vogue was found impracticable and the diametral pitch method of constructing the gear tooth was substituted.

In making gears it is necessary to know the circular pitch, both on account of spacing teeth and calculating their strength. It would be more convenient to express the circular pitch in whole inches, and the most natural divisions of an inch, as 1" P', ¾" P', ½" P', and so on. But as the circumference of the pitch circle must contain the circular pitch some whole number of times, corresponding to the number of teeth in the gear, the **diameter** of the pitch circle will often be of a size not readily measured with a common rule. This is because the circumference of a circle is equal to 3.1416 times the diameter, or the diameter is equal to the circumference multiplied by .3183.

In practice, it is better that the diameter should be of some size conveniently measured. The same applies to the distance between centers. Hence it is generally more convenient to assume the pitch in terms of the diameter, was given a definition of the module, and also how to obtain the module from the circular pitch.

We can also assume the module and pass to its equivalent circular pitch. If the circumference of the pitch circle is divided by the number of teeth in the gear, the quotient will be the circular pitch. In the same manner, if the **diameter** of the pitch circle is divided by the number of teeth, the quotient will be the module. Thus, if a gear is 12 inches pitch diameter and has 48 teeth, dividing 12 in. by 48, the quotient ¼-in. is the module of this gear. In practice, the module is taken in some convenient part of an inch, as ½ in. module and so on. It is convenient in calculation to designate one of these modules by **s.** Thus, for ½ in. module, **s** is equal to ½ in. Generally, in speaking of the module, the denominator of the fraction only is named. 1/3 in. module is then called 3 **diametral pitch.** That is, it has been found more convenient to take the **reciprocal** of the module in making calculation. The reciprocal of a number is 1 divided by that number. Thus the reciprocal of ¼ is 4, because ¼ goes into 1 four times.

Hence, we come to the common definition:

34. Diametral Pitch is the number of teeth to **one inch** of diameter of pitch circle. Let this be denoted by P. Thus, ¼ in. diameter pitch we would call 4 **diametral** pitch or 4 P, because there would be 4 teeth to every inch in the diameter of pitch circle. The circular pitch and the different parts of the teeth are derived from the diametral pitch as follows:

$\frac{3.1416}{P} = P'$, or 3.1416 divided by the diametral pitch is equal to the circular pitch. Thus to obtain the circular for 4 diametral pitch, we divide 3 1416 by 4 and obtain .7854 for the circular pitch, corresponding to 4 diametral pitch.

In this case we would write P = 4, P' = .7854", **s** = ¼". $\frac{1''}{P} = \mathbf{s}$, or one inch divided by the number of teeth to an inch, gives distance on diameter of pitch circle occupied by **one** tooth or the module. The addendum or face of tooth is the same distance as the module.

$\frac{1}{S} = P$, or one inch divided by the module equals number of teeth to one inch or the diametral pitch.

$\frac{1.57}{P} = t$, or 1.57 divided by the diametral pitch gives thickness of tooth at pitch line. Thus, thickness of teeth along the pitch line for 4 diametral pitch is .392 in.

$\frac{N}{P} = D'$, or number of teeth in a gear divided by the diametral pitch equals diameter of the pitch circle. Thus for a wheel, 60 teeth, 12 P, the diameter of pitch circle will be 5 inches.

$\frac{N+2}{P} = D$, or add 2 to the number of teeth in a wheel and divide the sum by the diametral pitch; and the quotient will be the **whole diameter** of the gear or the diameter of the addendum circle. Thus, for 60 teeth, 12 P, the diameter of gear blank will be 5 2/12 inches.

$\frac{N}{D} = P$, or number of teeth divided by diameter of pitch circle in inches, gives the diametral pitch or number of teeth to one inch. Thus, in a wheel, 24 teeth, 3 inches pitch diameter, the diametral pitch is 8.

$\frac{N+2}{D} = P$, or add 2 to the number of teeth; divide the sum by the whole diameter of gear, and the quotient will be the diametral pitch. Thus, for a wheel 3 2/10 in. diameter, 14 teeth, the diametral pitch is 5.

$D' P = N$, or diameter of pitch circle, multiplied by diametral pitch equals number of teeth in the gear. Thus, in a gear, 5 pitch, 8 in. pitch diameter, the number of teeth is 40.

$D P - 2 = N$ or multiply the whole diameter of the gear by the diametral pitch, subtract 2, and the remainder will be the number of teeth.

$\frac{D}{N+2} = s$, or divide the whole diameter of a spur gear by the number of teeth plus two, and the quotient will be the module.

When we say **the diametral pitch** we shall mean the number of teeth to one inch of diameter of pitch circle, or P, $(\frac{1''}{s} = P)$.

When the circular pitch is given, to find the corresponding diametral pitch, divide 3.1416 by the circular pitch. Thus 1.57 P is the diametral pitch corresponding to 2-inch circular pitch, $(\frac{3.1416}{P'} = P)$.

What diametral pitch corresponds to ½" circular pitch? Remembering that to divide by a fraction we multiply by the denominator and divide by the numerator, we obtain 6.28 as the quotient of 3.1416 divided by ½. 6.28 P, then, is the diametral pitch corresponding to ½ circular pitch. This means that in a gear of ½ inch circular pitch there are six and twenty-eight one hundredths teeth to every inch in the diameter of the pitch circle. In the table of tooth parts the diametral pitches corresponding to circular pitches are carried out to four places of decimals, but in practice three places of decimals are enough.

35. When two gears are in mesh, so that their pitch circles just touch, the distance between their axis or centers is equal to the sum of the radii of the two gears. The number of the modules between centers is equal to half the sum of number of teeth in both gears. This principle is the same as given as stated before, but when the diametral pitch and numbers of teeth in two gears are given, **add together the numbers of teeth in the two wheels and divide half the sum by the diametral pitch. The quotient is the center distance.**

A gear of 20 teeth, 4 P, meshes with a gear of 50 teeth; what is the distance between their axis or centers? Adding 50 to 20 and dividing half the sum by 4, we obtain 8¾ in. as the center distance.

The term **diametral pitch** is also applied to a rack. Thus, a rack 3 P, means a rack that will mesh with a gear of 3 diametral pitch.

It will be seen that if the expression for the module has any number except 1 for a numerator, we cannot express the diametral pitch by naming the denominator only. Thus, if the addendum or module is 4/10 in., the diametral pitch will be 2½, because 1 divided by 4/10 equals 2½.

The term **module** is much used where gears are made to metric sizes, for the reason that, the millimeter being so short, the module is conveniently expressed in millimeters. If we know the module of a gear we can figure the other parts as easily as we can if we know either the circular pitch or the diametral pitch. The module is, in a sense, an actual distance, while the diametral pitch, or the number of teeth to an inch, is a relation or merely a ratio. The meaning of the **module** is not easily mistaken.

36. Definition and Advantages of the Internal Gear. The internal gear might be described as an external gear, the teeth of which have been turned inside out. That part of the tooth which is known as the addendum on the external gear becomes the dedendum on the internal gear, and vice versa. This turning of the gear teeth inside out changes the action of the teeth somewhat in that for the same ratio of teeth, the length of the line of action is somewhat increased in the internal gear. Furthermore, the teeth come into and go out of action with less slippage and with a better rolling action.

The internal gear has several advantages over the external gear, and within the past few years its application has become much more general in tractor construction. It has been found to be especially suited to final drives for rear axles as applied to trucks, tractors and similar heavy-duty vehicles. It is also used quite extensively in connection with reduction gear mechanisms, and for this work has shown many advantages over the worm-type of gear reduction. Still another application is for clutches, both of the friction disk type and coupling type. In the following a brief description will be given of the various advantages of

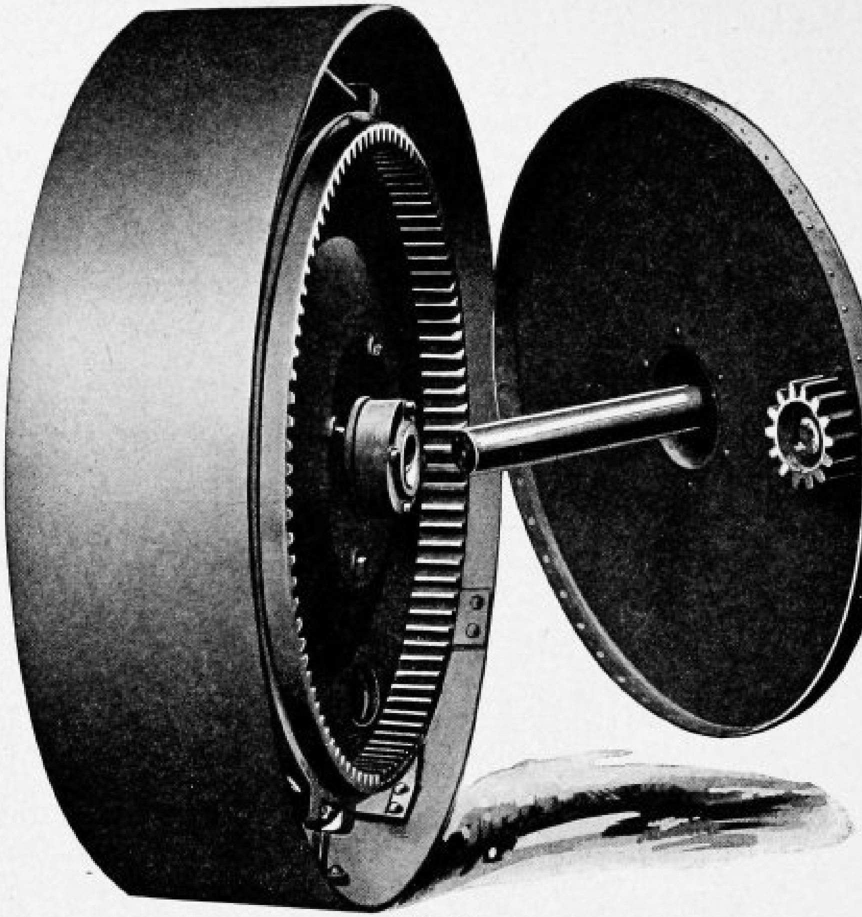


FIG. 10.

the internal gear, together with a simple analysis of the tooth action of an internal gear and pinion.

Guarding of gears is highly desirable in many mechanisms, and especially in final drives where every possible precaution should be taken to prevent dirt getting in the gear. An internal gear can be so designed, as illustrated in Fig. 3, that it forms its own gear guard, and in this way not only makes a much more attractive appearing gear, but also a much more compact drive. Owing to the fact that the Gear Shaper cutter as used on the Fellows Gear Shaper can be worked up close to a shoulder, or into a recess, a "housed" internal gear is just as easily cut as one made from a ring. The guarding of the internal gear is, therefore, entirely practical when the teeth are cut by the Fellows Gear Shaper prices.

37. Greater Length of Tooth Contact. As has been previously mentioned, the internal gear gives a greater length of tooth contact, owing to the fact that the pitch circle of the teeth of the internal gear follows the pitch circle of the pinion, instead of receding from it as is the case with two external gears in mesh. The external gear and pinion are indicated by means of the full black lines, the internal gear by red lines, whereas the rack is indicated by dotted black lines. Pinion, internal gear and rack teeth are, of course, all of the same length and pressure angle, and by reference to the illustration, it will be noticed that the length of tooth contact is greater between the internal gear and pinion than between the external gear and pinion or the rack and pinion. The length of tooth contact varies depending upon the ratio between the number of teeth in the gear and pinion. The ratio here is 1 to 5, the pinion having 16 and the gear 80 teeth. When the number of teeth in the pinion closely approaches the number of teeth in the external or internal gear, then the relative length of the tooth contact is much greater between the internal gear pinion.

38. Reduced Sliding Action. Owing to the fact that the length of tooth contact is greater between an internal gear and pinion, than between an external gear and pinion, the sliding action between the teeth is much less. This point presents one of the many good features that have been instrumental in bringing about a more universal application of the internal gear. As it is evident that the sliding action of one tooth over another causes friction, and friction results in wear, a reduction of the sliding action naturally tends to produce a better rolling action between the teeth as they come into and go out of action. This point will be fully dealt with in Chapter III.

39. Quieter Action. Not only does the increase in length of tooth contact and the reduction of sliding action give better efficiency, but it also produces a quieter action because of the reduction in friction. This action between an internal gear and pinion and an external gear and pinion rotating in mesh with each is quite different. The pinion and internal gear roll into action with practically no jar, reducing what might be called "hammer" blows between the teeth as they come into and go out of mesh. This results, of course, in quieter action and is one of the reasons why the internal gear, when properly cut and mounted, forms such a quiet and efficient means of transmitting power under heavy loads.

40. Longer Life. The questions that we have just mentioned, such as greater length of tooth contact, reduction of sliding action and quieter action, all tend to give us a gear tooth which has a longer life. If there is not interference present between the pinion and internal gear tooth, the amount of slippage between the opposing faces of the teeth more closely approaches a rolling action than is the case with two external gears in mesh. The resulting reduction in sliding action inevitably reduces the amount of wear that takes place, so that the teeth on the internal gear and pinion will stand up much longer under load.

41. Design of Internal Gears. The tooth of an internal gear are the same as those of an external gear, with the exception that a new element, the internal diameter, is introduced. The addendum and dedendum take the reverse positions from that which they occupy on an external gear, and the outside diameter is eliminated.

CHAPTER XIV

CLUTCHES

1. The Clutch. The internal combustion motor derives its power from a series of explosions or impulses. The power developed depends on the number of impulses per unit of time, and the energy generated is in direct proportion to the number of power impulses and the revolutions increase. Therefore it is not possible to start an internal combustion motor when under load because the power is generated by the combustion of the fuels directly within the cylinder, and must be put in motion before power is generated. Therefore it is necessary to revolve the motor through its cycle by either manual power or mechanical power, that is, by energy from some exterior force. As it has been demonstrated, a certain cycle of operation is necessary to secure power from an internal combustion motor; therefore it is essential that the motor revolve freely until it attains the proper speed to supply the energy necessary to overcome the resistance that tends to prevent motion of the tractor before it can be employed to drive same. Therefore a clutch becomes a very important factor in tractor construction. It is also very desirable that the tractor can be started or stopped independently of the motor.

A clutch is therefore a mechanical device which is used for transmitting motion and power either intermittently or continuously according to the will of the operator.

It is most important that a properly designed clutch be interposed between the motor and the transmission, which makes it possible to couple the motor to the transmission, or drive gearing, and disconnect it at will. The usual and most simple method of doing this is by means of some kind of a friction clutch, which when engaged, will propel the clutch shaft or first transmission shaft with the same speed and torque as the crank shaft of the motor. It is of utmost importance that the clutch be so constructed that the load can be picked up gradually.

2. Requirements of a Good Clutch. An important requirement in considering clutch forms is that such devices must be capable of transmitting the maximum power of the engine to which they are fitted, without any loss of power due to slipping. Such a clutch would be easy to operate, and but minimum exertion should be required of the operator. When the clutch takes hold, the motor power should be transmitted to the gear set in a gradual and uniform manner, or the resulting shock may seriously injure the mechanism. When it is released it is imperative that the two portions of the clutch disengage positively so there will be no continual rotation of the parts after the clutch has been disengaged.

The design should be carefully considered with a view of providing as much friction surface as possible to prevent excessive slipping and loss of power. The clutch parts should be located in an accessible manner where its parts may be easily removed for inspection, adjustment and repairs. There should be adjustments provided, so that a certain amount of wear can be compensated without expensive replacement.

3. When the Clutch Must be Used. In order to better understand the general requirements of clutching devices, it will be well to consider the condition which make their use imperative when a tractor must be propelled by a hydrocarbon motor. If a steam engine or an electric motor are installed as prime movers, it is not necessary to include devices of gear set between them and the driving wheels, as these members may be driven directly from the power plant if desired. With either of the forms mentioned the power is obtained from a separate source which may be uncoupled from the motor by the simple movement of a throttle valve or switch lever. When a gasoline motor is fitted, conditions are radically different from either steam or electric power plant. The power developed depends upon the number of explosions per unit time, and the energy is augmented directly as the number of explosions and revolutions of the crank shaft increases. It is not possible to start a gasoline motor while under a load because the power is obtained by the combustion of fuel directly in the cylinder, and as there is no external source of power to draw from, it is obvious that the energy derived depends upon the rapidity with which the explosions follow each other. It has been demonstrated that a certain cycle of operations are necessary to secure the gasoline motor action, and it is imperative that the motor revolves freely until it attains sufficient speed to supply the torque or power needed to overcome the resistance that prevents motion of the motor before it can be employed in driving the tractor.

4. How to Adjust the Friction Clutch. In order to have the clutch work smoothly it should be mechanically balanced to counteract the centrifugal force, either by counterweights or springs Heavy counterweights have a tendency to keep the shaft revolving as there is condsiderable momentum to the clutch when it is released, and makes it a little more difficult to shift the gears, until the motion of the shaft ceases.

5. Clutch Shoes. The clutch shoes are covered with maple block, soaked in linseed oil, or otherwise covered with friction fibre which can be easily replaced in case of wear. These clutch shoes are adjusted by clutch links with eye-bolts right and left threads, and sleeve nuts. To properly adjust these clutch shoes· loosen up the adjusting links so that the clutch shoes do not come in contact with the fly wheel when thrown in; then turn the clutch links out by turning the sleeve nut until the shoe just drags lightly in the surface of the fly wheel. Both shoes should be adjusted in this manner; and now having both shoes just coming into contact with the surface of the fly wheel or pulley, give each sleeve about one-third of a turn and hold the sleeve with a wrench, while you tighten up the lock nuts properly. It should be adjusted, providing that care has been taken to have each shoe the same clearance; otherwise it will give undue strain, and is liable to seriously affect other parts.

Clutches may be divided into the following distinct types:

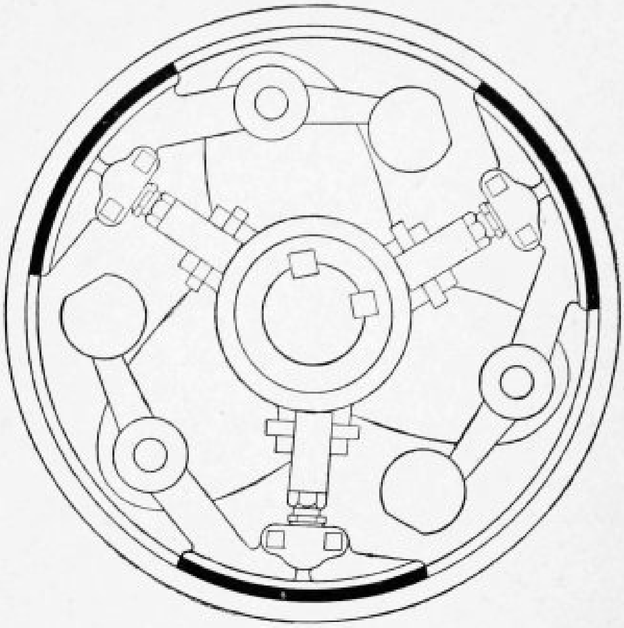
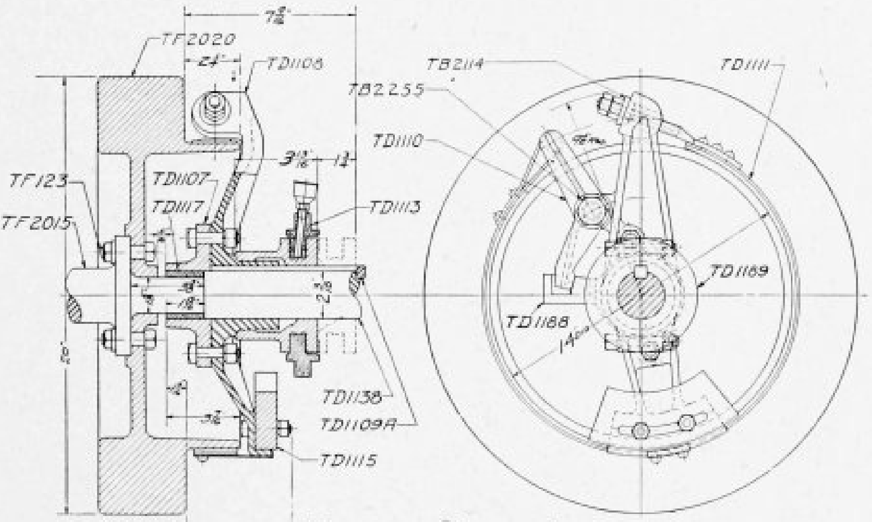


FIG. 1



TRACTOR DRIVE CLUTCH

FIG. 2.

(1) Internal Expanding:
(2) External Contracting Band:
(3) Dry Plate:
(4) Multiple Disk:
(5) Cone:

6. The Internal Expanding Clutch. The expanding shoe clutch is probably the most used for tractor purposes. It consists of a clutch spider keyed to the shaft, the clutch shoes, shifting trunnion and trunnion ring, adjusting screws and lock nuts. See Fig. I, which shows a typical three shoe internal expanding clutch.

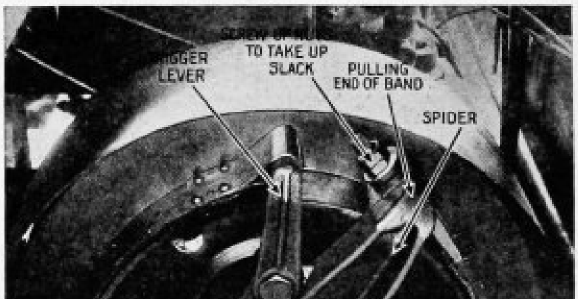


FIG. 2-A

The Clutch Shoes are counter weighted to counteract centrifugal force, and thus prevent them from grabbing when the clutch is being engaged. The friction surface is covered with asbestos fabric-facing which can be renewed when necessary. The three adjusting screws for adjusting the tension or pressure on the clutch shoes, when engaged in the flywheel of the clutch pulley, are plainly shown in Fig. I. In adjusting this clutch it is important that the adjusting screws are all of the proper length so that when the shoes are engaged the pressure on all of them will be uniform.

7. The External Contracting Band Clutch. The external contracting clutch is becoming quite popular in tractor construction, owing to its simplicity of construction and ease with which it can be adjusted. This clutch consists of a spider which is counterweighted, a clutch band, expanding and contracting bracket, a trunnion and trunnion ring. The clutch band is lined with an asbestos fabric-facing which can be removed when necessary. The adjusting screw as well as the clutch, is plainly shown in Fig. 2.

8. The Borg & Beck Three Plate Clutch. A very popular type of three-plate clutch, known as the Borg & Beck, is shown at Fig 3. The spring pressure is compounded by an ingenious combination of bell crank levers carrying rolls which slide on a wedge-shaped driving plate, the latter still further increasing the pressure upon the asbestos fabric-faced driven disk because of the wedging action due to the gradual angle of the incline plane on which the roller acts.

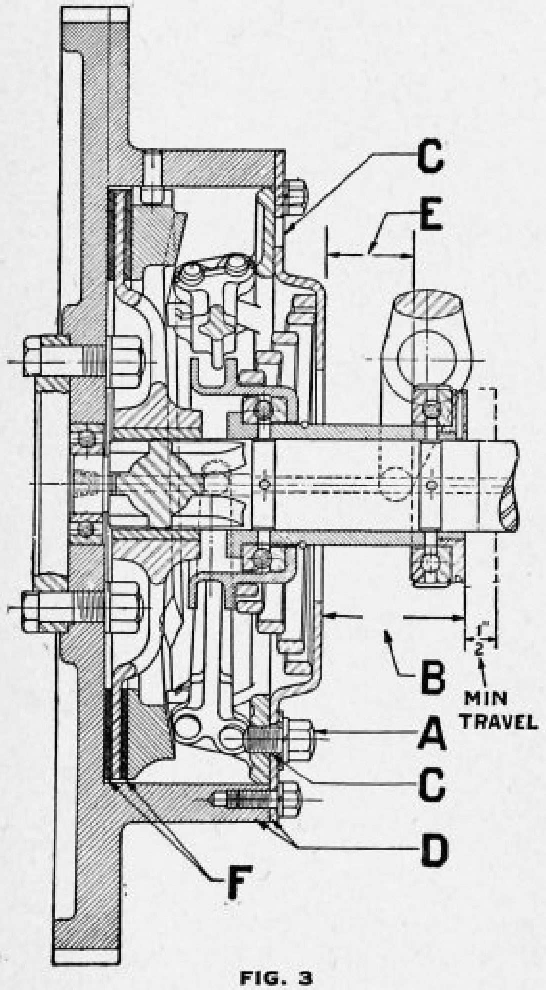


FIG. 3

The Clutch. Adjustment-renewing Rings and Care: To Adjust the Clutch: First release same with foot lever. Loosen both slot bolts, A, Fig. 33, and shift either of them to the right or clockwise about ½ inch. Let in the clutch, and if opening at B, Fig. 2, is less than 2 5/16 inches, throw out again and shift either slot A, Fig. 3, back (or anti-clockwise) far enough to open space at B to full 2 5/16 inches.

If this space at B is more than 2 5/16 inches the throw out movement will be too short for a clean release, and will make gear teeth clash when shifting gears. If the space at B is less than 2 5/16 inches the clutch will not hold.

When the bolts A, Fig. 3, reach last end of cover slots, due to repeated adjustments, screw them out of their mounting holes and set them back into repeat holes exposed near first end of slots, thus doubling the range of adjustment.

To Renew Asbestos Ring: When no more repeat holes show up at end of cover slots and the adjusting range is all used and clutch slips it is an indication the asbestos rings F, must he renewed. To do this be sure to mark an alignment mark on clutch cover and flywheel rim, at D, as clutch will not work properly if cover is shifted in assembling. Lock out the spring, by placing a space block, 1 13/16 inch high and 4 inches long between the cover and throw out yoke at E, Fig. 3. Now unscrew the cap screws around the edge of the clutch cover and slide same back. Now reach in and take out incline thrust ring and drive out the three drive pins in flywheel rim. Reach in and get asbestos ring and drive plate, and the other asbestos ring.

Clean out flywheel with a little gasoline on some waste, removing all the gummed oil, etc. Put a thin coat of oil on both sides of asbestos rings (use gas engine oil) and see that it lays flat against the flywheel, then the drive ring and see that it lays flat against asbestos ring. Slip in other asbestos ring. Put drive pins into flywheel rim so the heads are inside and be sure the incline thrust ring slides freely on the drive pins and that flat side goes against the asbestos ring. Slide clutch cover plate back to flywheel and turn same around until the alignment marks you made, line up, now screw cap screws into flywheel a short distance all around rim before you tighten any of them and adjust as before.

9. Multiple Disc Clutch. In order to obtain more driving surface some designers have used five plates instead of three. A five-plate clutch which operates on the same general principle as the three-plate type previously described is shown at Fig. 5. In this, two driving plates are carried by the fly-wheel and the three driven members are kept in engagement by means of bell cranks and toggle-link action. The reason that five disks are used instead of three is that the augmented surface makes it possible to reduce the spring pressure to some extent and makes for easier operation when it is desired to disengage the clutch. When the driving contact between the clutch plates is interrupted the member to which the clutch shaft is attached is kept stationary and fly-wheel hub and crank-shaft extension revolve freely because anti-friction bearings of the ball type are interposed between the members.

Features of Multiple-Disk Clutches. Power transmission by plates is sometimes accomplished by using a large number of small diameter disks instead of the smaller number of large plates. The multiple disk type offers several advantages not found in other forms, as it is the most compact form of clutch. The required contact area is obtained by using a multiplicity of comparatively small surfaces in preference to two large ones as is the case with the cone clutch or the greater number possible when three or five-plate clutches are employed.

The type of multiple-disk clutch that was most widely employed consisted of a number of soft steel disks which sometimes alternated with others of different material, such as phosphor bronze. One set of these disks is driven by the motor while the remaining plates are attached to a floating member to which the transmission shaft is joined. Pressure is usually obtained from a coil spring which acts against one of the disks, which in turn acts upon the neighboring one. It is common practice to house a clutch of this type in an oil-tight case, which insures that the members will always be kept in an oil bath. Oil performs the dual function of securing easy engagement by interposing a cushion between the metal elements and also to prevent wear because of its value as a lubricant.

10. The Hilliard Dry Plate and Oil Bath Multiple Disc Clutches. Shown in Figs. 4 and 5.

This Clutch is ideal for 3½ to 7 ton Trucks and Farm Tractors where amidship transmission mounting makes a dust proof type necessary.

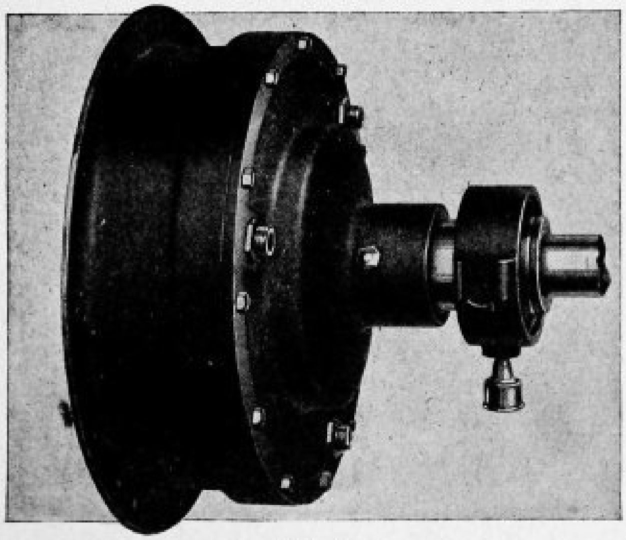


FIG. 4.

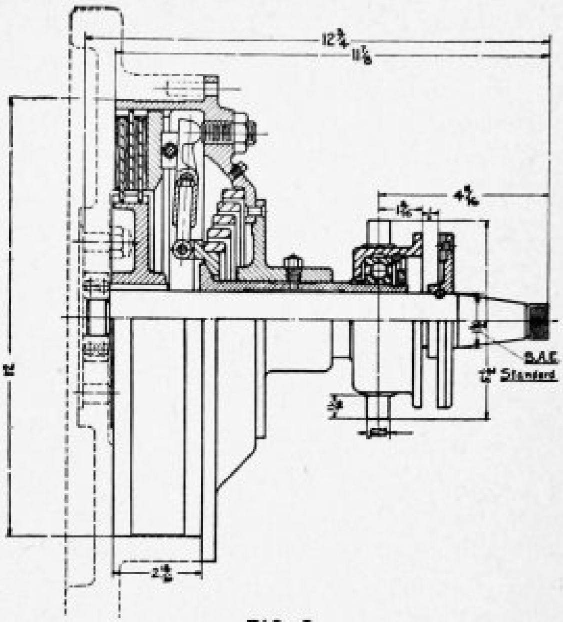


FIG. 5.

Special attention is called to the "Compensator" Ring to which the lever arms are attached.

Clearance is provided to permit any plane necessary to insure uniform pressure.

Failure to adjust uniformly or unequal wear at any point does not affect the perfect operation of the Clutch.

This is a very important and valuable feature found only in Hilliard Clutches.

These Clutches are made in several sizes known as S-4; S-6; S-8; S-10 and S-12, having from 4 to 12 linings for 50 to 200 H. P. at 1000 R. P. M.

They have independent housings which are bolted to the flywheel and horse-power considered they are unusually compact.

For every heavy service such as large Caterpillar Type Tractors, Gasoline Locomotives or heavy Truck-Trailer duty, these Clutches will stand up indefinitely.

When much slippage is required, we recommend running them in an oil bath to carry off the heat, to prevent damage to the friction plates.

11. The Cone Clutch. The cone clutch is a very simple and efficient form of clutch. This clutch consists of three main parts: the female member, which is machined either integral or bolted to the fly wheel, a corresponding male member, which fits into it, and a spring to maintain contact between the surfaces which is tapered 14 degrees 30 min. from the clutch shaft. This taper makes it easy to engage and disengage the clutch. Experience has demonstrated that plain metal-to-metal surfaces are not suitable with this form of clutch because they will grip too sudden and will soon slip if there is a thin film of oil between the surfaces. Therefore the friction surfaces are covered with leather or an asbestos fabric-facing, and in some cases cork inserts are used to prevent grabbing, the contact between the clutch cone and the fly-wheel rim is maintained by the use of a coil spring which is backed by a ball-thrust bearing in order to relieve the operating mechanism of any torque strain when the clutch is disengaged. In the cone clutch

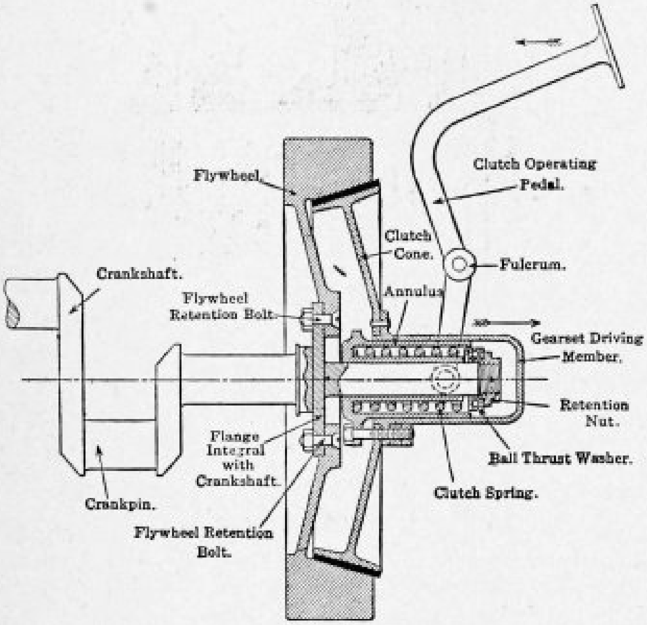


FIG. 6.

shown in Fig. 6 the male member is carried on a hub portion to which it is polted, and floats on the clutch spring housing which has a bearing on the crank-shaft extension. One end of the spring bears against the closed end of the spring housing while the other end is held by the ball-thrust washer and nut screwed on the end of the crank shaft extension. The spring pressure in this case keeps the cone seated by pushing it directly toward the flywheel. When it is desired to release the clutch the operating pedal is depressed in such a manner that it swings on the fulcrum point and moves the clutch cone and spring housing to which it is attached back so that the clutch cone is pulled away from the fly-wheel and the spring compressed. Some form of universal coupling or sliding joint is carried by the clutch shaft extending from the gear case. When the spring pressure forces the clutch cone into engagement with the fly wheel, the assembly turns as a unit and the gear set is driven by the crank shaft through the clutch and the clutch shaft which is attached to the clutch cone. When the cone is pulled away from the fly wheel the clutch shaft which carries the drive pinion in the transmission remains stationary and the crank shaft extension and fly wheel revolves freely. By the use of the foot pedal the clutch can be engaged and disengaged by the will of the operator.

12. The Avery Internal Expanding Clutch. Care of Clutch. Referring to cut No. 7, you will note we have a three-shoed clutch. Now to properly adjust this clutch it is necessary that the bearing be evenly

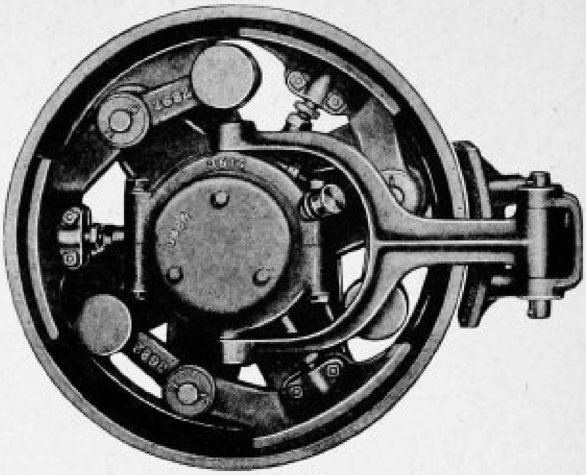


FIG. 7

distributed to each of these shoes, otherwise the efficiency of the clutch will be lowered, also it causes a strain upon the different parts, which is very hard for them to work under. These shoes hinge on a pin which should receive a drop of oil occasionally, and are forced out against the rim of the band wheel by the toggle bolt. This is a bolt with a hexagon shoulder and jam nut for holding tight. To adjust this clutch, force the collar in until it comes up against the side of the arms of the spider. If the bolts are too long to allow this collar to come clear over, loosen up the check nuts and screw them back until it will throw the clutch lever clear ahead. Now, then, tighten the clutch by turning the bolts to left until you cause a light strain to exist on the arm, due to the pressure of each bolt, get this just as near as you can, then tighten the jam nuts which hold the bolts from working loose and turning.

To Test Clutch. Now take the clutch lever and pull the clutch out. If you have the bolts too tight you will not be able to pull the clutch out. In this case, loosen slightly. In the other case, if the clutch does not hold to pull the tractor, the bolts are not quite tight enough and the adjustment should be made in the way stated above, screwing each bolt out a very little until the proper adjustment is obtained.

13. Caution—Never adjust the arms so that the collar will not go clear in against the arms of the clutch when the tractor is working, for if you do, you will have to hold the clutch in with the lever.

Never Slip Clutch for Any Length of Time, which causes enormous strain to bear upon the clutch collar and this will get so hot that it will burn up in a short time. Also never run slow by slipping your clutch, for this wears the shoes very rapidly and you can obtain the same result by throttling down the motor, unless it is in extreme cases like coupling up to a machine through ditches or in cases of that kind.

To Remove Clutch from Shaft. Clutch may be removed from shaft by removing pin which will allow clutch arm to be removed. Then by taking out the three small bolts in the cap this will expose the keys, which may be readily removed with the key puller, the clutch can be pulled out and lifted off very easily. Also the band wheel and crank shaft pinions. In case the rod running from the clutch lever to the clutch arm becomes so short that it does not push the clutch clear in when the lever is thrown clear ahead, it may be lengthened by disconnecting at the clutch arm end and turning the connection to the left, which will run it out on the threads and make the rod longer and can be shortened in the same manner should it be too long.

To Replace Keys in Clutch. In replacing keys in clutch, do not drive too tight. Drive both in evenly and just far enough to allow the cap to be replaced. Be sure that all dirt is wiped off the keys, also clean out the keyways, for a very little grit or dirt will cause these keys to stick and be very hard to take out the next time. These keys should be well oiled or white leaded when being replaced.

14. The J. I. Case Clutch. The Clutch used is the expanding shoe type. The construction is simple but it requires care and adjustment to keep in good order.

Clutch Adjustment.

The adjustment is made on the **turnbuckles** and should be made so the pressure on both **shoes** is even. To adjust place the clutch "in" and adjust turnbuckles until clutch engages properly. Work clutch lever back and forth a few times to see if clutch engages properly and evenly on both shoes before tightening **lock nuts.** Do not adjust shoes too tight or too loose. If too loose clutch will slip and wear out friction surfaces. See Fig. 8.

See that the clutch and brake connections are so adjusted that there is a point where the belt pulley is not engaged by the clutch or locked by pulley brake. If not so adjusted the gears will be held together which makes shifting of gears difficult.

Pulley Brake.

The pulley brake is applied by pushing forward on the clutch lever and can be used as a brake to hold tractor when the gears are engaged or for stopping the belt pulley in belt operations.

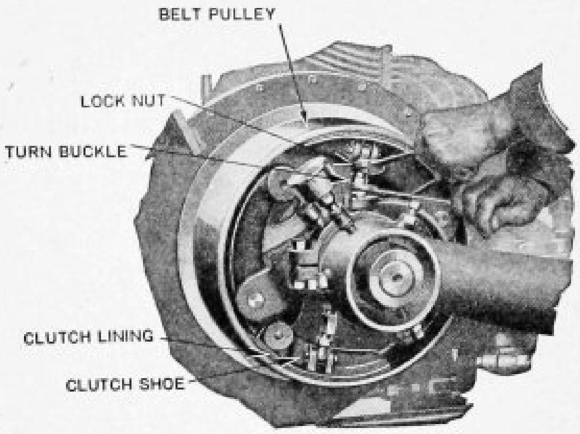


FIG. 8

Releasing Gears when Backing into Belt.

When tractor is backed into belt there is a strain placed on the transmission gears and sometimes with the clutch released the belt holds the pulley and keeps the load on the gears, making it hard or impossible to place gears in neutral. To relieve the strain on gears throw out clutch and pull back on the tight side of belt. This will make the shifting of gears easy.

To Operate Clutch.

Never throw clutch in with a jerk. This causes excessive strain on all parts and often results in serious breakage. Apply the clutch gradually, allowing it to slip while starting the load; then pull back to lock it.

Caution:

When work is being done around the tractor and the motor is allowed to run, always place gears in **neutral.** This will prevent accident should someone carelessly touch the clutch lever and engage the clutch.

Sometimes the clutch creeps in of its own accord if the counterweights on the clutch shoes should be too light. If this is the case add more weight, which may be fastened by rivets to the cast iron weights provided.

CHAPTER XV

THE TRANSMISSION

1. The Transmission. The power generated in the motor must be transmitted from the motor to the drive wheels or the belt pulley, through the mechanical arrangement known as the transmission mechanism.

The efficient operation of a gas tractor is largely determined by the method of transmission employed. It is well to remember that theoretically the power contact, and it is in this one particular that some tractor, because a certain amount of energy is absorbed by friction at the different bearings, and points of contact, and it is in this one partciular that some tractors lose a large per cent of their efficiency. The problem of power transmission in a gas tractor was one that was not easily solved and much experimenting was necessary before the perfected forms of the present day were evolved. The evolution from the crude form of a decade ago to the perfected type used in the modern Oil Tractor has been marvelous.

After the installation of the power plant the next important factor is the gear set of the transmission which should be combined with the clutch in such a way that it forms a unit construction. The unit construction has the advantage of retaining positive alignment of the gear set with the motor, indefinitely. In this construction the relation between the power plant and transmission is obtained when they are first assembled, and the alignment cannot be changed by any condition of operation after the unit has once been installed on a properly constructed frame.

On most tractors the gear set is a separate member installed back of the motor and directly over the rear axle or differential shaft, and the centers of the respective shafts are arranged to making the shortest possible distance to carry the power and the most compact and rigid construction. The distance between the clutch in the fly wheel to the rear axle is as short as possible. The result of this design has been well appreciated in the latest types. This adds much to the efficiency of a tractor, as a greater load can be pulled through this system of gearing because of its compactness, bringing the power close to the load, and thus eliminating the loss of power through intermediate gears and extra shafting.

2. Types of Transmission. There are several different fundamental types of transmission which may be classified as follows: It may be by belts, by friction drums rolling together, or friction face transmission, or by gear transmission. The last is employed in the most up-to-date tractors. Designers of Gas Tractors have found this type to be the most practicable for a tractor constructed for heavy duty.

Transmission for gas tractors should be of the unit construction type; cut steel gears should be used throughout, and high grade steel should be used in the shafting, and the very best grade of babbitt in the bearings. Roller bearings are rapidly replacing babbitted boxes in gas tractors; because they make lighter weights possible, cause less loss of power, less danger of hot boxes, and in case of accident where the bearings are damaged they can be easily replaced. The transmission gears should be enclosed and run in a bath of oil, as this decreases the friction very materially. Where bevel gears are used in transmissions, a ball thrust bearing should be placed back of same to take care of end thrust. One of the advantages in using roller bearings in transmission housings is, that when a bearing is replaced the shaft is in its original position whereas it often happens that when a bearing is re-babbitted, it is necessary to do the job two or three times before we get proper alignment. This often is a great deal of expense. While the construction mentioned above might be a little more costly, still it will effect a great saving in fuel.

3. Why a Transmission Is Necessary. The transmission employed on a gas tractor is a reducing transmission, reducing the high motion of the crank shaft, to the low motion of the drive wheel, at the same time increase the pressure applied or the torque on the rear axle. The torque increase is in direct proportion to the reduction in speed, less the power required to overcome friction at points of contact.

As said before the power developed by the internal combustion motor descends on the number of impulses per unit time, and the energy generated is in direct proportion to the number of power impulses, and the revolutions of the crank shaft increase. Therefore some form of transmission must be interposed between the motor and the driving wheels, in order that the speed of one relative to the other may be changed from high speed to low speed, and low torque to higher torque, making possible to utilized the high speed internal combustion motor for slow moving tractors.

More Than One Speed (varied conditions and uneven loads), as the tractor encounters it has been found advisable to interpose a change speed gearing which will give two or more ratios of speed between the motor and the drive wheels. As it is not possible to reverse the internal combustion motor utilized on modern tractors, it is necessary to add a set of gears to the gear-set to give the driving wheels a reverse motion when it is desired to back the tractor.

The Total Gear Reduction. In a tractor the total gear reduction varies between 30 to 1 and 100 to 1, so that several reductions have to be used, although in some entire transmission are built as a single unit. It is best to discuss each reduction separately.

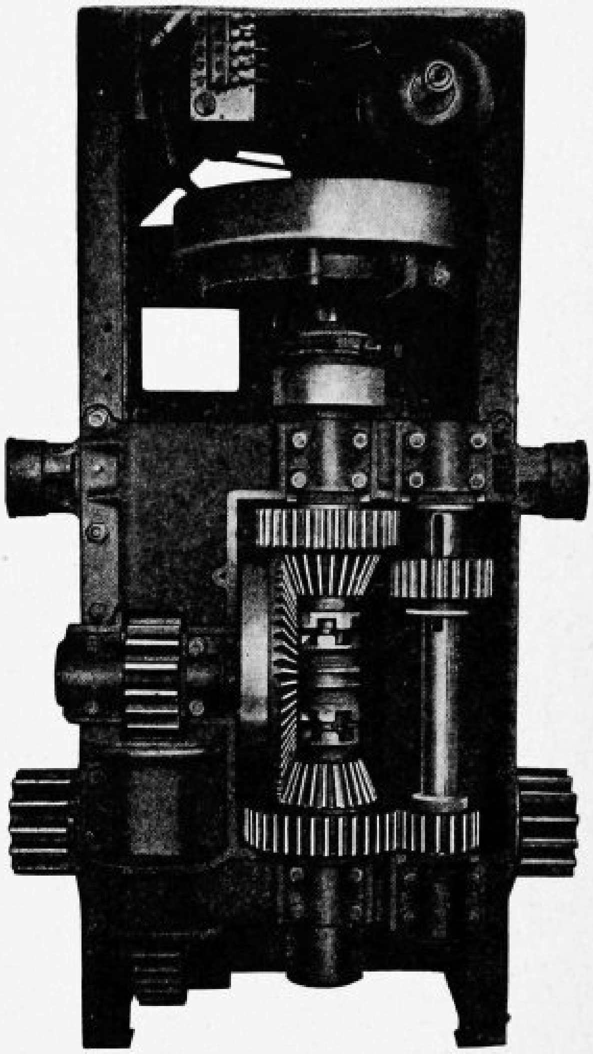
In general all tractor transmissions are driven from the motor through a friction clutch. No universal-joints are used, although clutches are designed to take care of any misalignment. Cone disk, shoe, band clutches, and friction drives are in use. The cone clutch and the internal expanding shoe clutch, and the contracting band clutch, are in most common use.

4. Tractor Transmissions Can Be Divided into Three Different Types.

A. The Spur Gear Type.
B. Combination Bevel and Spur Gear Type.
C. Combination Friction and Spur Gear Type.

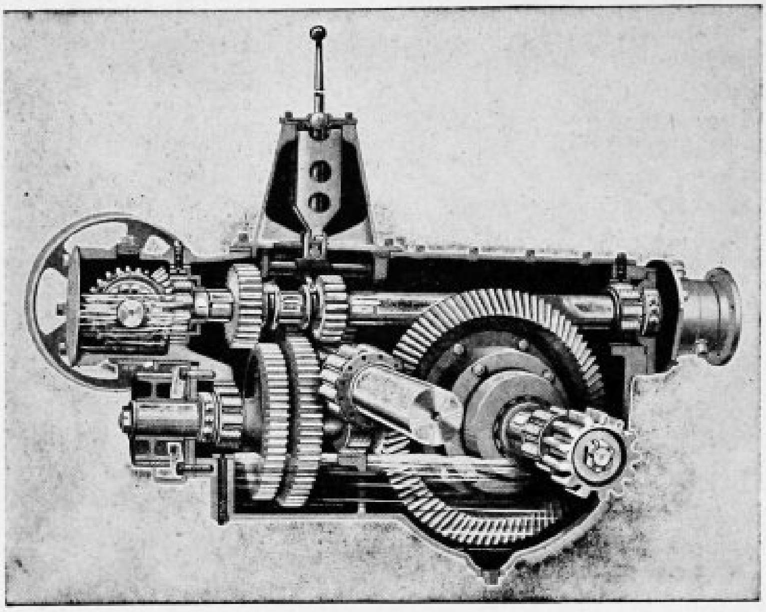
The Spur Gear Type. Is used where the motor is placed crosswise of the frame. The first reduction is taken off the crank-shaft extension or clutch shaft; and in this type of tractor the belt pulley is also taken off the extension shaft. This shaft is controlled by a friction clutch which can be operated at the will of the operator. The gears on this shaft are usually sliding gears, which can be engaged or disengaged with a second gear so as to permit the shaft to revolve, for belt work, without moving the tractor. In some cases where the tractor has two speeds, two sliding pinions are placed on the shaft of different diameters to obtain the required speeds. The bearings on this shaft consist of a self alignment ball pilot bearing usually located in the center of the fly wheel, and an outboard bearing usually of the ball or roller type. These pinions mesh with the gears mounted on the second transmission shaft so as to constitute the first gear reduction. These gears propell the shaft on which is mounted the main drive pinion meshing with the gear which comprises the spider of the differential gear. This constitutes the second gear reduction. The differential spider drives through the differential, the differential shaft on which is mounted the master pinions which usually drive either an external or internal master gear mounted in the drive wheels. This constitutes the third and final gear reduction. In some cases the differential is mounted on the rear axle driving the drive wheels through the axle. In this construction the rear axle constitutes both the rear axle and the differential shaft.

5. The Combination Bevel and Spur Gear Type. This type of transmission is used when the motor is placed lengthwise of the frame. The first gear reduction. The pinion is mounted on the crank-shaft extension or clutch shaft, which is supported by a self-alignment ball pilot bearing in the center of the fly wheel. On a bearing close to the bevel pinion, between the two bearings, is located a suitable friction clutch which can be controlled at the will of the operator. The bevel gear is mounted on the first transmission shaft constituting the first gear reduction. This shaft generally extends to one side to the belt pulley. On this shaft is placed the speed change pinions which mesh with the gear on the differential spider. This constitutes the second gear reduction. This second gear drives through the differential gear, the differential shaft on which is mounted the master pinions, which usually drive an external or internal master gear mounted in the drive wheels, which constitutes the third and final gear reduction. In some cases the differential is mounted on the rear axle, driving the drive wheels through the axle. In this case the rear axle constitutes both the rear axle and the differential shaft.



The Combination Bevel and Spur Gear Type Employed on the Twin City 25-45.

6. The Combination Friction and Gear Type Transmission. In this type of transmission the first reduction consist of two friction disks which are held together by sufficient pressure to cause one of these members to turn the other. This rolling traction, or friction transmission consists of two disks, one faced with an aluminum-copper alloy driven by the motor, and the wheel which is provided with a strawboard fiber driving ring mounted on a cross shaft at right angles to the crank shaft of the motor. The cross



The Combination Bevel and Spur Gear Type Employed on the E. B. 12-20

shaft is mounted on suitable bearings, and the driven disk or plate can be moved across the face of the driving disk. The driving member is mounted on a sliding shaft which can be moved toward the driven member and held in contact by a definite amount of pressure, or pulled away when it is desired to interrupt the drive. In this manner both the clutch and first gear reduction change of speeds and reverse is accomplished. One end of the cross shaft is extended to one side on which is mounted the belt pulley. On this shaft is also mounted the main drive pinion which meshes with the gear mounted on the differential spider. This concludes the second gear reduction. The differential-spider drives through the differential shaft on which is mounted the master pinions which usually drives either an external or internal master gear mounted in the drive wheels, constituting the third and final gear reduction. In some cases the differential is mounted on the rear axle driving the drive wheels through the axle. In this construction the rear axle constitutes both the rear axle and the differential shaft.

7. First Reduction Gearing. First reduction gearing may be of almost any kind spur pinion and gear, bevel pinion and gear, or friction and disk. The reduction varies from 1 to 1 to as much as 10 to 1. The change in speeds and the reverse are often worked in on the first reduction, but it is also common to use the second reduction. When the motor shaft is not parallel to the drive-wheel axle the first reduction gears are often of the level type. There is considerable advantage in having the bevel gears as the highest speed gears. The cost is reduced and also a chance provided to get a belt pulley on a fairly high-speed shaft without the necessity of using a separate set of gears and a clutch.

When spur gears are used for the first reduction, the change-speed gears and reverse are generally a part of it as they can be much smaller and cheaper in this position than in the next reduction. This arrangement is general on tractors, in which the motor sets crosswise; it is also used to some extent when the motor shafts are set lengthwise of the tractor, even though this arrangement necessitates a larger and more expensive set of bevel gears in the second reduction and also the use of a separate set of gears for the belt pulley. Change-speed gears are usually arranged so that the pinions slide on the drive-shaft and engage large gears on the driven shaft. No divided shafts or counter shafts, as are found in automobile transmissions, are used, except for reverse gears. Thus all gears are disengaged, except the ones actually in use, and no idle gears or extra reductions are necessary for different speeds.

Another advantage in this arrangement is that all change-speed gears are disengaged when the belt pulley is to be used. Tractors are used for belt work for long continuous runs and gears or shafting running idle are undesirable because they waste power and require special lubrication.

8. Second Reduction Gearing. The second reduction is sometimes the final drive, although this is not often the case. Usually it is the drive to the shaft that carries the differential. If the differential can be placed in this position ahead of the last reduction considerable expense can be saved because all the parts can be made much smaller.

Differentials have to be made strong and of ample size, because the traction members are always slipping, so that the differential parts are working all the time. Differential locks are considered good practice. Brakes for holding one side for short turning are often used, but brakes for stopping, while necessary, are not important.

9. Third Reduction Gearing. The third is usually the final reduction; it is the most important part of a tractor transmission. The load and vibration on the teeth and bearings generally cause wear of these parts first, and as they are large, expensive, and difficult to replace it is necessary they be made to give the best of service.

When there are more than three gear reductions, the extra one is used either to gain compactness or to provide for some special arrangement of parts.

Tractors are used for plowing a large part of the time and generally are operated at speeds of from 2 to 3 m. p. h. Many have only a single speed, but most of the late designs have two or three speeds. When there are three speeds one is lower and one higher than the plowing speed. When only two speeds are provided the second speed is usually slower than that for plowing. The range between speeds is nearly always between 30 and 40 per cent.

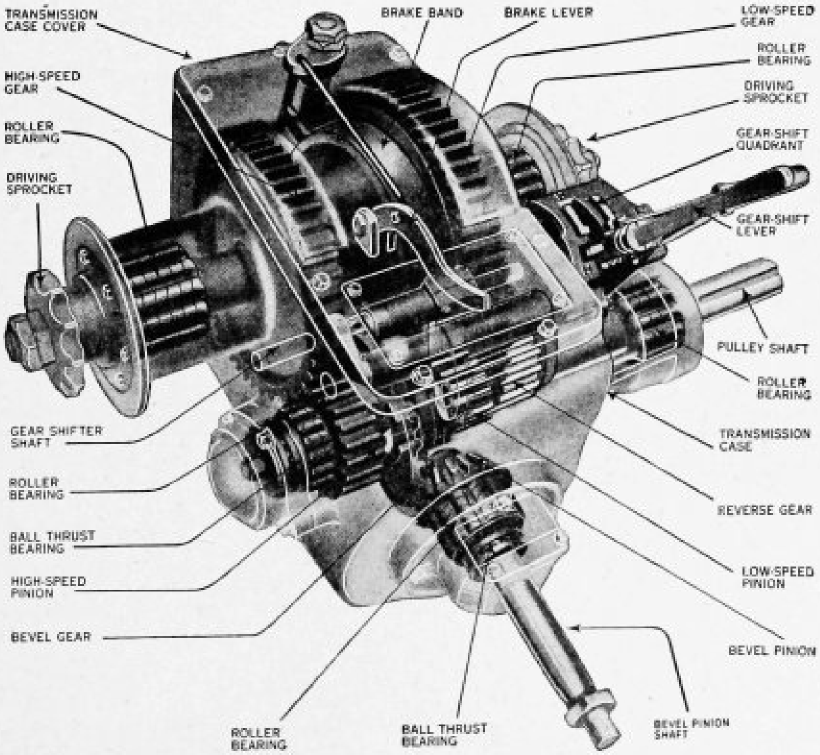
A tractor transmission is really a series of compromises, each part being affected by all of the others, so it is no wonder that there is such a difference in design. A different location of the belt pulley alone will materially affect the entire transmission arrangement. At present there is little chance of formulating valuable transmission standards. It will require more time and many tests to prove what is best.

10. Anti-friction Bearings. A notable advance in tractor transmission designates that anti-friction bearings are becoming universally used. It has been found that an ample non-adjustable, anti-friction bearing can last indefinitely in tractor service. Transmission-bearing trouble has been a common tractor fault in the past, and its elimination is a decided step ahead.

The shafting as a rule is made of ordinary mild steel, because gears and bearings generally have to be of such a size that the shaft sizes are ample when this material is used. It is important that splines be used instead of keys. The standard type of automobile or truck transmission does not meet tractor requirements at all. The gear reduction is too small, no belt pulley is provided for, the change-speed arrangement is wrong, the parts are not large enough, and it cannot be applied to a good tractor design.

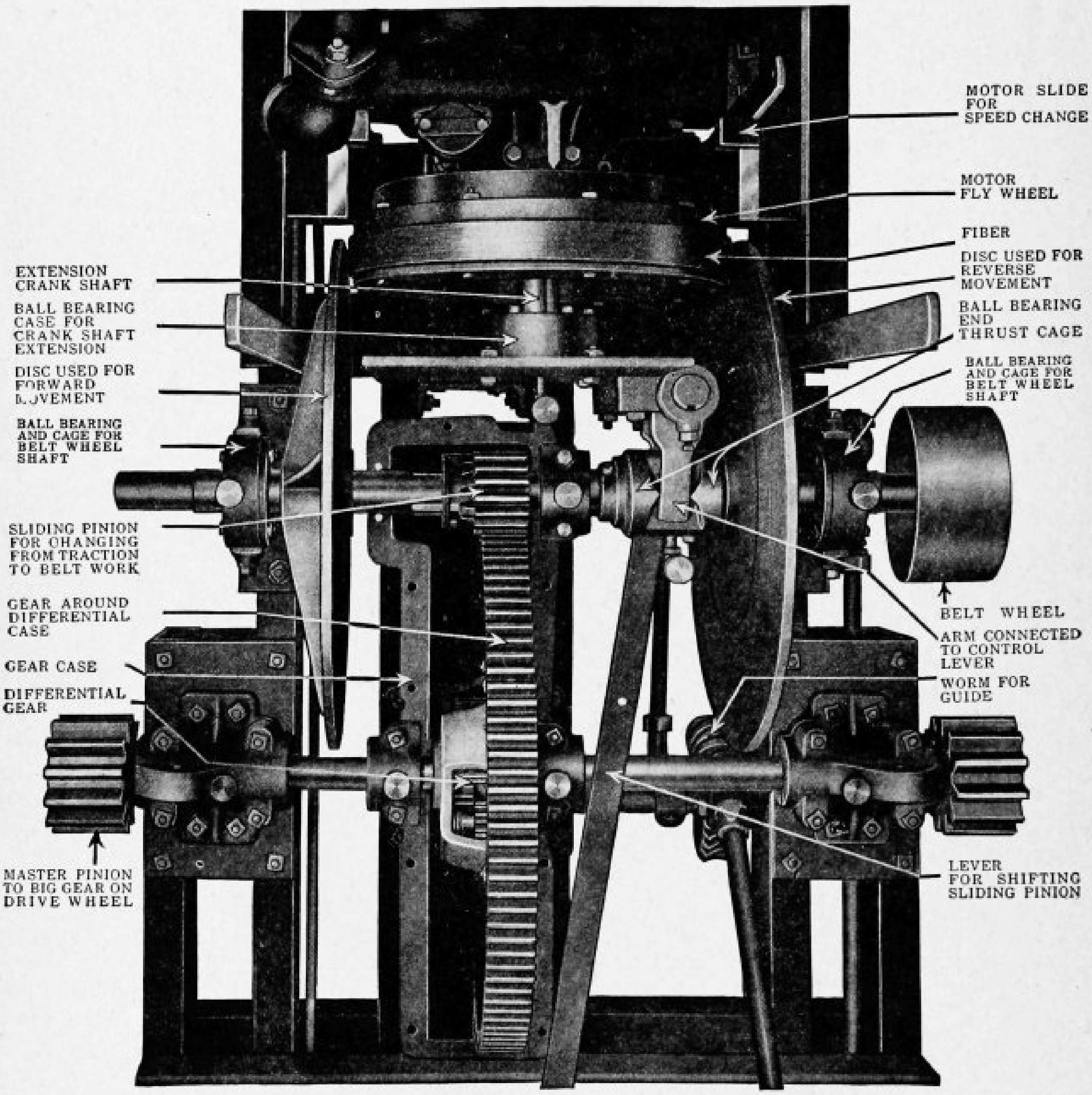
11. The Positive Jaw Clutch. Another type of clutch which is in use, is the positive jaw clutch. In this construction the positive type of clutch is used inside the gear case and is so arranged to be operated only while the main friction clutch connecting the engine with the drive shaft is disengaged and is only to be used when reversing the engine from forward to backward or vice versa. When the positive jaw clutch is in the neutral position the friction clutch can be engaged and the transmission shaft will revolve.

Operators are cautioned not to try throwing the positive jaw clutch from a neutral to forward or re-



The Combination Bevel and Spur Gear Type Employed on the Nilson Tractor

Interior View of Heider Tractor Showing Friction Transmission and Differential



NOTE—THE FORWARD, REVERSE AND STOPPING MOTION IS ACCOMPLISHED BY THE SLIDING MOVEMENT OF THE BELT WHEEL SHAFT. THE DIFFERENT FORWARD AND REVERSE SPEEDS ARE ACCOMPLISHED BY SLIDING THE MOTOR BACK AND FORTH WHICH IS DONE BY A LEVER IN THE CAB.

verse motion before bringing the drive shaft to rest by the foot brake. After a little practice the operator will become familiar with shifting the gears without any difficulty. After the positive clutch is once in play there should be no drag or slippage of the friction clutch.

12. Bevel Gears. The positive jaw clutch is engaged into the jaws of the two bevel pinions on the transmission shaft. These bevel pinions are mounted on phosphorous bronze bushings which fit very accurately on the transmission shaft. The positive jaw clutch is mounted on the transmission shaft; keyed to it with a feather key, and slides back and forth to engage with the bevel pinions. For forward speed place the lever that operates the positive jaw clutch in the backward notch on the quadrant, and the forward notch for backward speed.

The question of the efficiency of bevel gears in comparison to the spur gear is a problem which has caused much discussion and a wide range of opinions. However, the fact remains that through actual tests the efficiency remains the same, provided the design keep positive alignment of the gear set, with proper thrust bearings to take care of the end and side thrust. But if allowed to get out of alignment, there is a great decrease in efficiency. Therefore, the first essential in bevel gears calls for a construction which will keep the gears in alignment indefinitely. We have found in an earlier chapter that the gear teeth are formed exactly the same, except the lines of a bevel gear tooth must cross at a point where the center line of the two shafts intersect. This requires a special gear cutting or gear shaping machine to cut the bevel gear tooth, and as before stated if this construction is kept in perfect alignment the efficiency is very high.

The efficiency also depends largely on the surface of the gear tooth. The curve of the tooth must be such that there is a rolling friction instead of a sliding friction. The gear teeth should have smooth hard surface which adds much to the high efficiency of cut gears. Therefore, it will be readily apparent that cut gears running in a bath of oli are of greater efficiency than the ordinary cast gears.

13. Efficiency of Gears. As gears are employed to transmit the power from one shaft to the other as they make the most compact transmission and the most efficient.

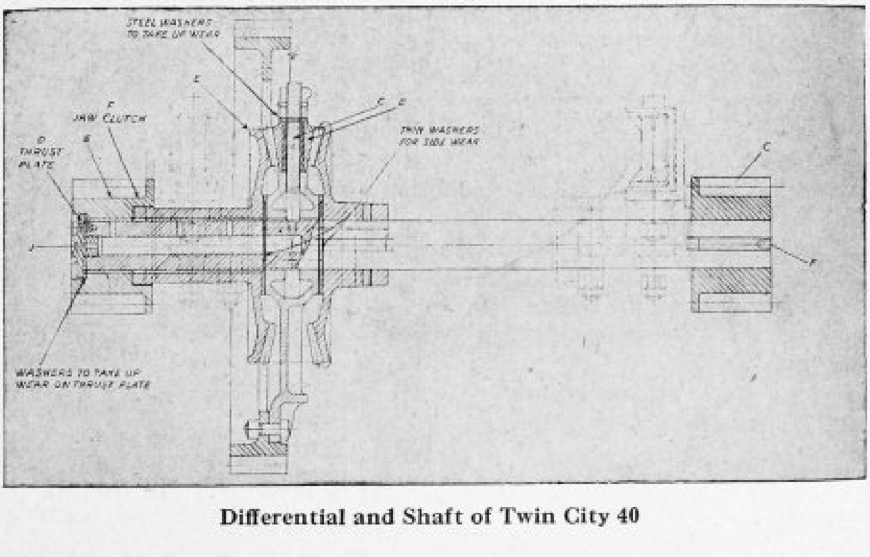
A properly constructed cut gear running in an oil bath should have the following efficiency.

Velocity at pitch line in feet per minute.					
3	10	40	100	200	
.90	.935	.97	.98	.985	etc.

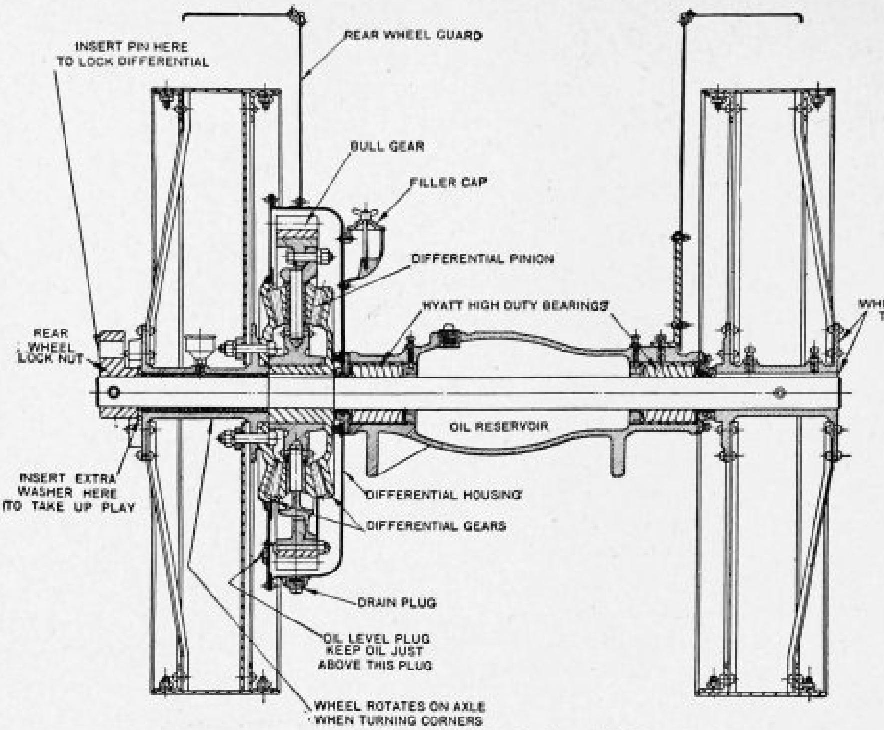
14. Example of Cut Gears. We will assume that we have a motor developing seventy-five horse-power on the crank shaft, and we wish to transmit the power to a belt pulley at an angle of 90 degrees to the crank shaft. In this case we would use a miter gear, the velocity at the pitch line would be about 1,500 ft., and the efficiency in this instance should be about .988. The power to be expected at the pulley would be .988 x 75, equals 74.1 horse-power belt pulley.

15. The Differential. One part of the transmission system which must be used on all tractors is the differential, which consists of gears or some equivalent, which is attached either to the rear axle, or to the differential countershaft. Without the differential it would be impossible to control the engine when turning a corner, so it performs an important function in the steering of the tractor, for when turning a corner with a four-wheel vehicle the outer wheels must turn at a higher rate of speed than the inner ones because they are describing a larger arc of the circle.

The differential is made up of a spur gear running loose on the differential countershaft, with two smaller bevel gears, and meshing with these two bevel gears are four bevel pinions, which are supported on



Differential and Shaft of Twin City 40



Axle Draw of the J. I. Case 10-20

radial stud shafts which project inwardly from the rim of and are mounted in the spider of the spur gear. The teeth of each pinion are at all times in mesh with the two bevel gears. So long as the tractors travel in a straight direction the pinions act as stationary driving members, and have no occasion to revolve, as the two wheels are running at equal speed. When, however, the tractor is steered in a curve and different velocities are required in the wheels and the bevel gears with which they are connected, the pinions no longer act as fixed driving members, but allow the necessary relative motion between the two bevel gears, and at the same time they continually transmit power to the two ends of the axles because they are always in mesh with each other. (See Figs. —.)

16. Brakes on Tractors. One of the important factors making for efficient engine operation is the brake controlling system. The braking members most commonly used are steel band brakes which are lined with material possessing considerable resistance to heat, such as asbestos wire fabric. The band of the foot brake is attached to a shaft in such a way that it will be brought into forcible engagement with the external surface of the drum which has been attached to the transmission shaft. This brake is very serviceable in various ways. It will resist the engine with its load under all conditions, which should be sufficient to lock the wheels. Its practicability displays itself when the engine is in use for belt work. All engineers are familiar with the inconvenience of blocking an engine in the belt.

17. Hyatt Bearings for Tractors.

Beginning twelve years or more ago, the matter of applying Hyatt Bearings to tractors was chiefly one of working out each design, and each position, individually without much reference to what sizes were being used in other tractors of a similar capacity. Tractor designs were so widely different that this was the only practical way to meet the situation. Within the last three or four years, however, it has become possible to correlate a great deal of our accumulated experience and the time has now come when we can, in laying down new designs, simplify our work by limiting our selection of bearings to a comparatively small number of different sizes.

While there is still considerable variation in engine sizes and total weight of tractors having a similar capacity, the fact remains that within reasonable limits any one bearing which is satisfactory in a given position in one tractor will also be satisfactory in a similar position in another tractor of equal rating, even though there is considerable difference in the general design of the two machines.

With a view to finding out which particular size of bearing would be best for each different bearing location, our engineering department has compiled a classified list showing load, speed and bearing size for each of the many hundreds of Hyatt applications. From this tabulation we have arranged load and size tables for all of the various bearing locations to cover four different sizes of tractors. The rating and other data which we have assumed as average values for these tractors is as follows in Table A.

Rating	Engine 4 Cyl.	R.P.M.	Torque	Gear Ratio	Drive Wheel Dia.	Tractor Weight	Draw Bar Pull
9–18	3¾ x 5	1000	2350	62	48″	3500	1500to2000
12–24	4¼ x 6	850	2100	59	54″	5000	2000to2800
15–30	5 x 6½	700	3100	54	60″	6500	2500to3600
20–40	6 x 7	600	4800	51	66″	9000	3500to5000

Table "A" Tractor data assumed for bearing recommendations n this bulletin.

For the sake of convenience we will limit the present discussion to the general type of tractor shown in the plan view Fig. 1. This layout does not represent any particular make of tractor, nor is it intended to represent our ideas of how a tractor should be designed; it is used simply as an illustration to indicate the relative location of the various bearing positions. We will at some future time discuss in detail bearing sizes and mountings for tractors of other general types.

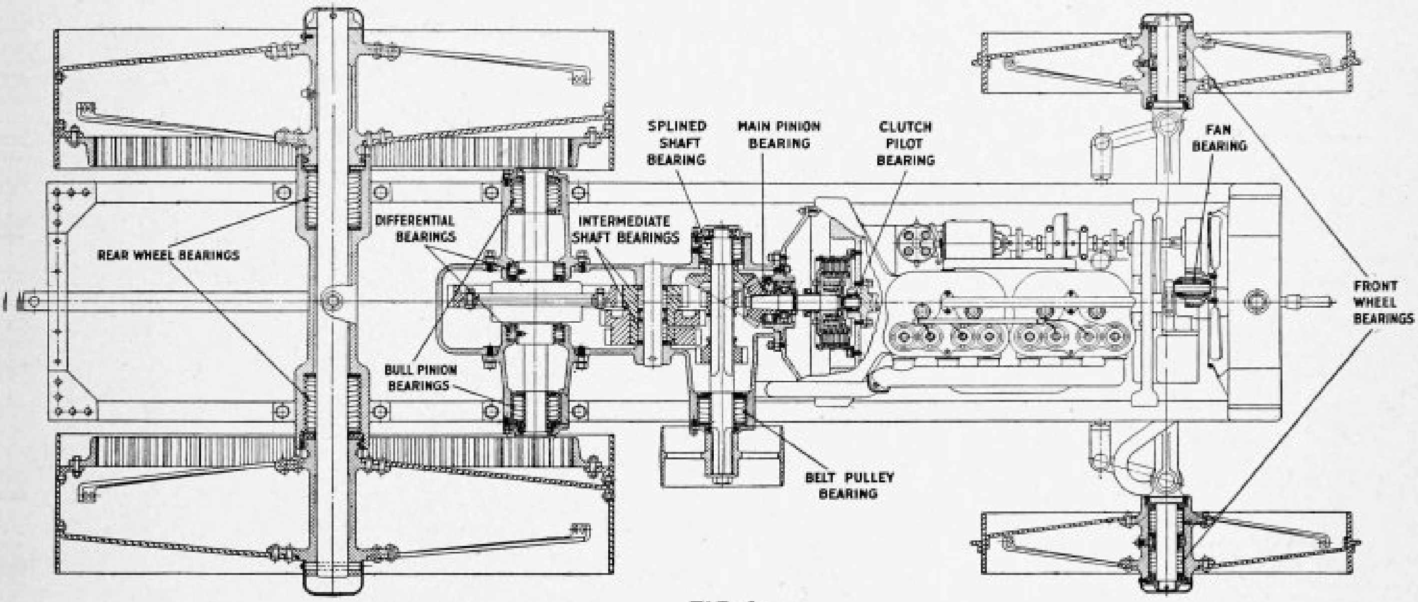


FIG. 1

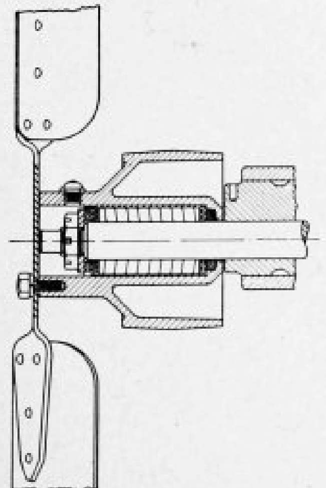


FIG. 2.

18. Fan. The belt driven fan (Fig. 2) is at present the usual construction for tractor work. Practically 95 per cent of the load on a fan bearing is caused by the belt tension. The end thrust is only a small amount caused by the reaction of the air against the blades.

Dia. Fan	Belt Width	Bearing Size				Hyatt No.
		Shaft	Length	Roller	Bore	
14″	1½″	⅝ x	2 —	¼ —	1 3/16	29085
18″	2 ″	¾ x	2½ —	5/16 —	1 7/16	29097
22″	2½″	1 x	3 —	½ —	2 3/16	19130
26″	3 ″	1¼ x	4 —	⅝ —	2 11/16	19205

Table "B" Bearings for Belt Drive Fans.

About the only rule necessary for selecting a proper size Hyatt Bearing for a fan is to have a shaft large enough in diameter so that it will not bend and to put a bearing on that shaft long enough to extend approximately a half inch ahead of the edge of the belt. For convenience in selecting the proper size bearing we have developed Table B for fans between 14 and 24 inches in diameter, having belts from 1½ to 3 inches wide. This table shows the Hyatt Bearing numbers and sizes that are ordinarily used.

It will be noted that the bearings listed are all of the planished outer race type, operating on a hardened and ground shaft. This type of race has proven entirely satisfactory due to the fact that with the race revolving the load is evenly distributed over its entire circumference.

Where the fan is gear driven (Fig. 3) the bearing sizes are determined by tooth load, fan weight and speed. This type of design is not as yet sufficiently standardized to permit presenting a table of bearing sizes. We may say, in general, that on account of the stationary housing it is best to use the high duty type of bearing having a solid outer race. The rollers can run directly on the fan shaft if same be hardened

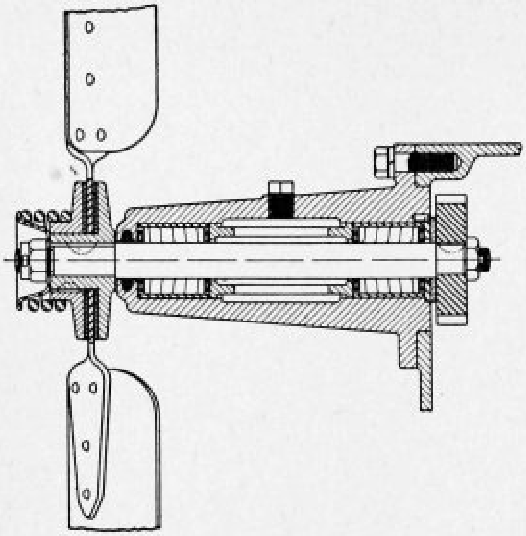


FIG. 3

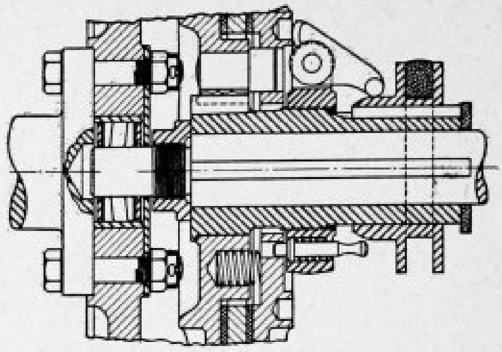


FIG. 4.

and ground, or be supplied with inner races if a soft shaft is used.

19. Clutch Pilot. The problem in connection with a bearing for the clutch pilot position is simply one of getting a bearing which will carry the weight of the clutch when disengaged, and which will not stick under any circumstances through lack of lubrication. The most favorable application, from the standpoint of cost, is to use a bearing without an inner race, providing the shaft is hardened to a minimum of 350 Brinnell. About 90 per cent of the clutches that are mounted on Hyatt Bearings use No. 17010 as shown in Fig. 4. This bearing will carry practically any size of multiple disc or plate clutch but where shoe clutches are used there is sometimes a possibility of throwing considerable overload on the pilot bearing due to faulty adjustment. In such cases it is advisable to use as large a bearing as can be accommodated.

20. Main Drive Pinion. When the transmission and motor are connected by a bell housing so that proper alignment is maintained a single bearing, next the bevel pinion, may be used. A construction in common use is shown in Fig. 5, same being a short series high duty bearing without an inner race. This construction is very desirable where saving room lengthwise is important, and provided the bevel pinion hub is properly hardened (minimum 500 Brinnell) makes a very satisfactory and economical application.

Where the matter of length is not vitally important, or where it is undesirable to use the hub of the bevel pinion, for an operating surface, the usual practice is to apply a long series high duty bearing with inner race mounted directly on the drive shaft. Fig.

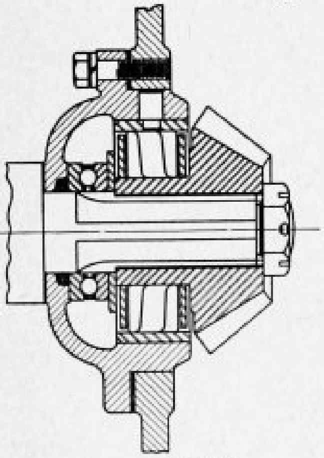


FIG. 5

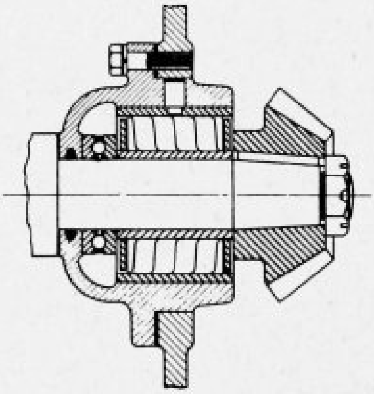


FIG. 6

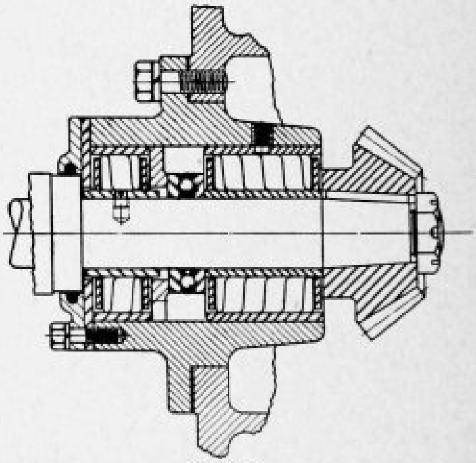


FIG. 7

Bearing Load	Bearing for Fig. 5		Bearing for Fig. 6 or 7		Forward Bearing for Fig. 7	
	Size: Shaft Length Roller Bore	Hyatt No.	Size: Shaft Length Roller Bore	Hyatt No.	Size: Shaft Length Roller Bore	Hyatt No.
750 to 1000 lbs.	2¼ x 1⅜ — ⅞ — 4⅜	27030	1½ x 2½ — ¾ — 3¾	27173	1½ x 1¼ — ¾ — 3¾	17124
1000 to 1500 lbs.	2½ x 1½ — 15/16 — 4¾	27032	1¾ x 2¾ — ⅞ — 4¼	27177	1¾ x 1⅜ — ⅞ — 4¼	17128
1500 to 2000 lbs.	2¾ x 1½ — 15/16 — 5	27034	2 x 3 — 15/16 — 4¾	27181	2 x 1½ — 15/16 — 4¾	17132
2000 to 2500 lbs.	3 x 1¾ — 1 — 5¾	27036	2¼ x 3 — 15/16 — 5	27183	2¼ x 1½ — 15/16 — 5	17134

Table "C" Bearings for Main Drive Pinions and Forward Main Shaft.

6 shows this construction and Table C a series of bearing sizes for same.

When the motor and transmission are not connected by a bell housing it is customary to introduce some sort of a universal joint between the engine clutch and the main drive shaft of the transmission. Where a universal joint or flexible coupling is used it is necessary to mount the pinion shaft on two bearings (see Fig. 7) mounting these as far apart as the space limitations will allow. Obviously the bearing next the bevel pinion may be either a short series, as shown in Fig. 5, or a long series bearing as shown in Figs. 6 and 7. The forward bearing, which takes the reaction of the pinion tooth load, plus the load of the universal joint, may ordinarily be a short series bearing. Table C shows a list of bearing sizes that may be used for the different types of mounting.

In the above illustrations of bevel pinion bearings we have shown a grooved type of ball thrust collar mounted so as to take the axial load from the bevel gears in one direction only. This is the simplest possible construction and has proven very satisfactory in thousands of tractors. Any thrust in a contrary direction to that created by the bevel gears can be taken by a plain collar on the pinion shaft, or by letting the hub of the clutch or universal joint bear against the forward face of the retaining cap.

21. Splined Shaft. The splined shaft bearing adjacent to the bevel driving gear has to carry both the bevel gear tooth load and the tooth load of the driving pinion on the splined shaft. As the shaft diameter is limited to the base diameter of spline, it is usually necessary to apply a long series bearing in order to get the necessary capacity. Where a long series bearing is used for the main driving pinion it is advisable, for the sake of reducing the number of different sizes, to make this bearing the same as the pinion bearing. Fig. 8 shows the simplest possible mounting for this position and the sizes shown in Table D will be satisfactory.

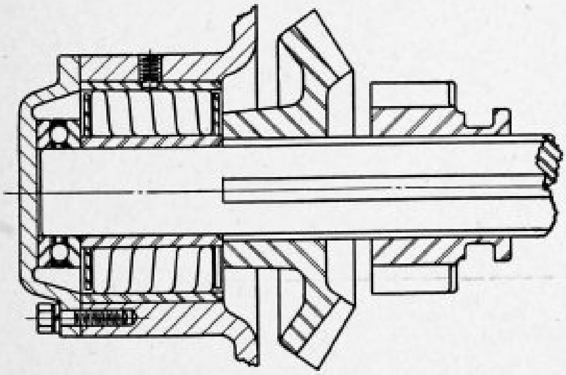


FIG. 8

End thrust due to the bevel gear may be taken by a ball thrust collar mounted as shown—provision for taking the occasional flotation of the shaft in an opposite direction is usually made in the mounting of the belt pulley bearing.

Bearing Load	Bearing Size				Hyatt No.
	Shaft	Length	Roller	Bore	
1500 to 2000	1½ x	2½ —	¾ —	3¾	27173
2000 to 3000	1¾ x	2¾ —	⅞ —	4¼	27177
3000 to 4000	2 x	3 —	15/16 —	4¾	27181
4000 to 5000	2¼ x	3 —	15/16 —	5	27183

Table "D" Bearings for Splined Shaft.

22. Belt Pulley. The belt pulley bearing has to carry a very heavy load due to the belt tension. The drive belts supplied with most separators, and other belt-driven machinery, are usually from one hundred to one hundred and fifty feet between pulley centers, and to swing a belt of this length entirely off the ground results in a very heavy load on the pulley shaft and bearing.

Selection of bearing size for this position is often governed by the advisability of limiting the number of different sizes in the layout. A great many tractors are in service with a belt pulley bearing of the same size as used at the other end of the splined shaft This makes a very satisfactory compromise, although the bearing is, theoretically at least, not large enough for constant belt service. The best practice is to leave the shaft at the belt pulley end as large as the top diameter over the spline applying a bearing at this point two sizes larger than the one on the opposite end. A short series bearing is sometimes used at the belt pulley and is satisfactory only if the tractor is used a small percent of the time for belt work.

Table E shows a list of sizes which cover our recommended practice, and the illustration (Fig. 9)

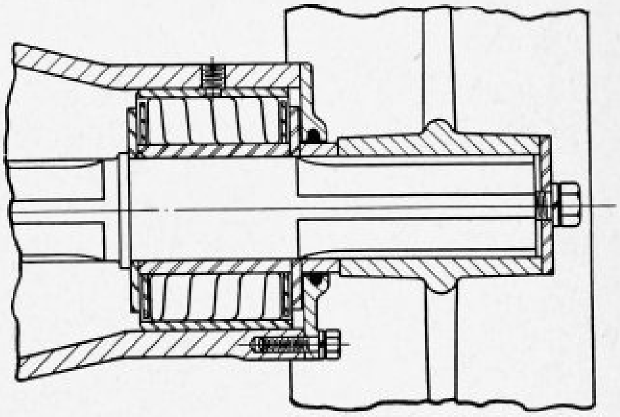


FIG. 9

Approx. Belt Width	Bearing Size				Hyatt No.
	Shaft	Length	Roller	Bore	
5"	1¾ x	2¾—	⅞ —	4¼	27177
6"	2 x	3 —	15/16 —	4¾	27181
7"	2¼ x	3 —	15/16 —	5	27183
8"	2½ x	3½—	1 —	5⅜	27185

Table "E" Bearings for Belt Pulley.

shows a type of mounting which provides for retainment of the shaft against end flotation in a direction opposite the bevel gear thrust.

23. Reverse Idler. A very important position, which is sometimes overlooked in tractor design, is the reverse idler bearing. Bronze bushings are reasonably satisfactory so long as positive lubrication is maintained. Owing to the possibility of lubrication being neglected it is advisable to use a bearing which will not give trouble due to lack of oil.

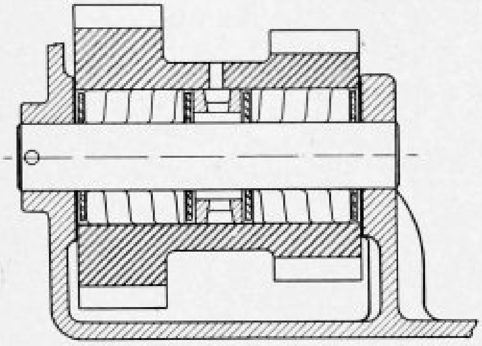


FIG. 10.

Bearing Load	Bearing Size				Hyatt No.
	Shaft	Length	Roller	Bore	
800 to 1200	7/8 x	1 1/2 —	5/16 —	1 1/2	26882
1200 to 1600	1 x	2 —	3/8 —	1 3/4	26962
1600 to 2000	1 1/8 x	2 —	7/16 —	2	26908
2000 to 2500	1 1/4 x	2 1/2 —	1/2 —	2 1/4	26909

Table "F" Bearings for Reverse Idler.

In most designs of this nature an hour glass type of pinion is used. This will require a short roller assembly in each end, as shown in Fig. 10. The size of a bearing for a reverse idler may be determined by the size of a shaft which will not deflect under the load. With a bronze bearing it is ordinarily necessary to figure sufficient bearing area to carry the load without seizing, and this results in using a shaft larger than is really necessary to stand the deflection. Using a Hyatt Bearing enables us to use a smaller shaft diameter than would be possible with the plain bearings. Table F shows a list of sizes which are available for this position. The shaft, and the bore of pinion, should be carbonized, hardened and ground to provide suitable operating surface for the rollers. On account of space limitations it is inadvisable to use inner or outer races.

24. Intermediate Gear. Mounting the intermediate gear set on a stationary shaft with the rollers operating directly in the bore of the pinion hub is the simplest and most economical mounting. The operating surfaces for the rollers must, of course, be carbonized, hardened and ground. The sizes commonly used are shown in Table G and a very simple and satisfactory mounting is illustrated in Fig. 11.

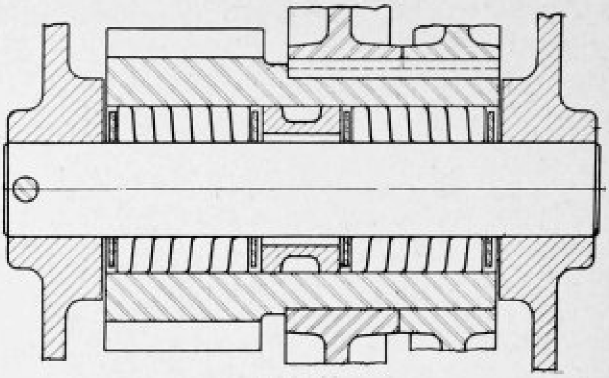


FIG. 11

Bearing Load	Bearing Size				Hyatt No.
	Shaft	Length	Roller	Bore	
2000 to 2500	1 3/8 x	2 —	1/2 —	2 3/8	27927
2500 to 3200	1 1/2 x	2 1/2 —	9/16 —	2 5/8	27926
3200 to 4000	1 3/4 x	2 1/2 —	3/4 —	3 1/4	26891
4000 to 5000	2 x	2 3/4 —	7/8 —	3 3/4	56907

Table "G" Bearings for Intermediate Idler.

25. Differential. The best practice for mounting the differential assembly is to mount the bearings on the hub of the equalizing gear housing. This construction calls for bearings of considerable inside diameter, but of comparatively limited capacity, and in order to meet this we have developed a series of special bearings having large inner races and relatively small roller diameter. Fig. 12 shows in detail a con-

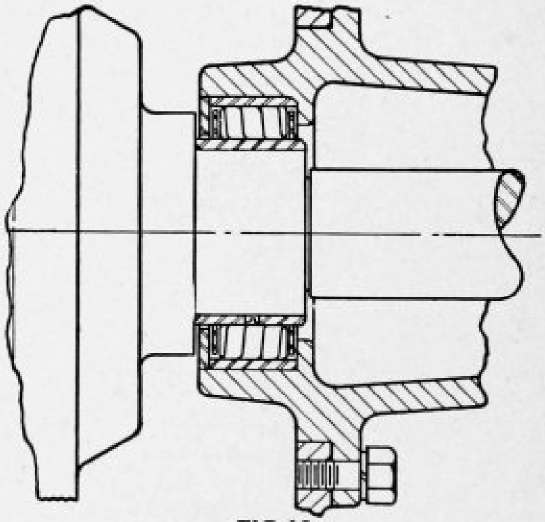


FIG 12

Bearing Load	Bearing Size				Hyatt No.
	Shaft	Length	Roller	Bore	
1500 to 2500	2 3/8 x	1 1/2 —	1/2 —	3 7/8	26628
2000 to 3200	2 7/8 x	1 1/2 —	9/16 —	4 3/4	26633
2500 to 4000	3 3/8 x	1 1/2 —	3/4 —	5 5/8	56605
3200 to 5000	3 7/8 x	2 —	3/4 —	6 1/8	56355

Table "H" Bearings for Differential.

struction of this sort and Table H lists the bearing sizes which are applicable to tractors having a bull gear type of final drive.

26. Bull Pinion. The bull pinion bearing must carry a heavier load than any other bearing in a tractor. It is a position requiring, above all things, a high radial load capacity bearing. It is common practice to use cast tooth bull gears, either internal or external, for the final drive and we have in addition to the high tooth load an additional load on the bull pinion bearing due to irregularities in the pitch circle of the bull gear. Furthermore a great many tractors have the rear axle mounted adjustably for aligning the pitch of the bull pinion and bull gear. These adjustments are quite liable to be improperly made in the field throwing a considerably increased load on the bearing. We have found by experience that it is necessary to apply bearings at the bull pinion position considerably larger than is theoretically necessary in order to meet these conditions.

From the bearing standpoint it is of considerable advantage to have both the bull gear and pinion machine cut and the mounting designed so that no adjustment of center distance between pinion shaft and rear axle is possible. With this construction a smaller bearing can be used than when the bull gear is cast. We have worked out a set of sizes, see Table I, showing bearings which are in use at the present time, both with the cast tooth and with the cut bull gears.

The bull pinion bearing may be mounted in several different ways. The arrangement shown in the general layout (Fig. 1) makes use of an inner race type bearing with washers clamped between the inner race and a shoulder on the shaft at the inner end and another similar washer between the race and a spacer at the outer end. Another arrangement is shown in Fig. 13. This makes use of an outer race type bearing with an overlength inner race corresponding to the numbers listed in Table I. This is sometimes considered preferable because it permits assembly or disassembly of the bull pinion shaft without removing the roller assembly. A washer clamped between the outer race and the end cap, and a somewhat smaller washer clamped between the end of inner race and the bull pinion, provides means for taking end flotation of the shaft in both directions at one point.

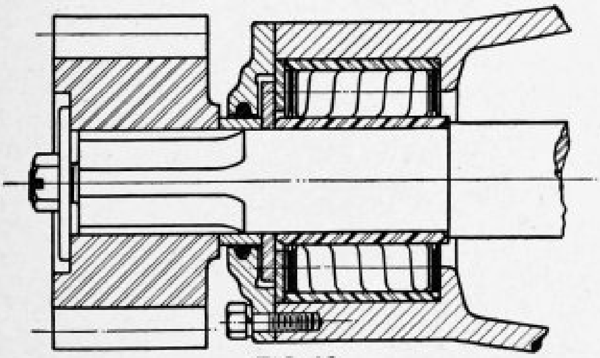


FIG. 13

Bearing Load	For use with cast Bull Gears		For use with cut Bull Gear	
	Bearing Size (S. L. R. B.)	Hyatt No.	Bearing Size (S. L. R. B.)	Hyatt No.
1800—3000	$1\frac{3}{4}$ x $2\frac{3}{4}$ — $\frac{7}{8}$ — $4\frac{1}{4}$	17178	$1\frac{1}{2}$ x $2\frac{1}{2}$ — $\frac{3}{4}$ — $3\frac{3}{4}$	17174
2400—4000	2 x 3 — $\frac{15}{16}$ — $4\frac{3}{4}$	17182	$1\frac{3}{4}$ x $2\frac{3}{4}$ — $\frac{7}{8}$ — $4\frac{1}{4}$	17178
3000—5000	$2\frac{1}{4}$ x 3 — $\frac{15}{16}$ — $4\frac{3}{4}$	17184	2 x 3 — $\frac{15}{16}$ — $4\frac{3}{4}$	17182
4200—7000	$2\frac{1}{2}$ x $3\frac{1}{2}$ — 1 — $5\frac{3}{8}$	17186	$2\frac{1}{4}$ x 3 — $\frac{15}{16}$ — 5	17184

Table "I" Bearings for Bull Pinion.

27. Rear Wheels. The drive wheels of a tractor, having a bull gear drive, may be mounted either with a revolving axle as shown in our main layout, also detailed in Fig. 14, or on a stationary axle having the bearings in the wheel hub, as shown in Fig. 15.

Both types of construction have their advantages, but the first mentioned is usually preferred from the standpoint of construction, and it is also perhaps the more economical of the two methods. On account of the large diameters required for rear axles, in order to prevent undue deflection, a planished race type bearing with the rollers operating directly on the shaft is a very satisfactory arrangement. The size of bearing to be used is largely determined by the quality of the steel in the axle. If an 18 point carbon, cold rolled shaft be used, the bearing will have to be longer than would be necessary with a 40-50 point carbon steel. Sizes shown in Table J are worked out on the basis of using cold drawn 40-50 point carbon steel unturned where the bearing operates. With a high quality of steel the bearings could be decreased in size

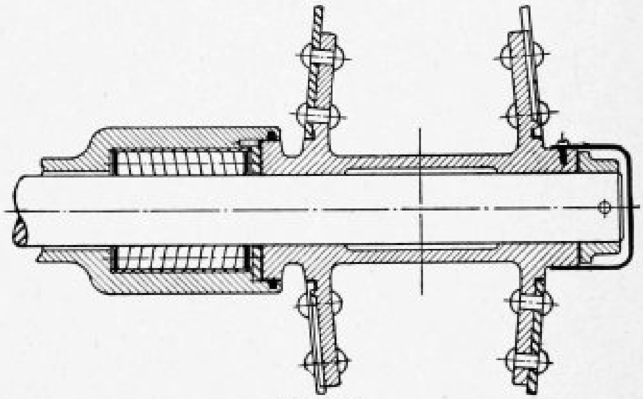


FIG. 14

Bearing Load	Bearing Size (Shaft Length Roller Bore)	Hyatt No.
1000 — 1500	$2\frac{1}{4}$ x 5 — $\frac{7}{8}$ — $4\frac{1}{4}$	49505
1500 — 2500	$2\frac{3}{4}$ x 5 — $\frac{15}{16}$ — $4\frac{7}{8}$	49655
2500 — 3500	3 x 6 — 1 — $5\frac{1}{4}$	49735
3500 — 4500	$3\frac{1}{4}$ x 6 — 1 — $5\frac{1}{2}$	46111

Table "J" Bearings for Live Axle.

in proportion to the increased surface hardness of the material.

With the dead axle type of mounting it is necessary

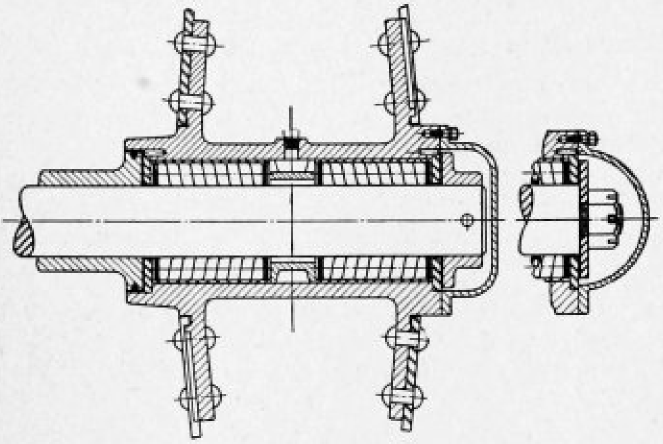


FIG 15

Axle Load	Bearing Size				Hyatt No.
	Shaft	Length	Roller	Bore	
1000 — 1500	2 x	4 —	⅞ —	4	49425
1500 — 2500	2¼ x	4 —	15/16 —	4⅝	49575
2500 — 3500	2¾ x	5 —	15/16 —	4⅞	49655
3500 — 4500	3 x	5 —	1 —	5¼	49730

Table "K" Bearings for Drive Wheel (Dead Axle).

to proportion the length of hub to the wheel diameter and rim width. It is advisable to so locate the bearings that they will extend at least one inch beyond the edge of rim. If the bull gear be set beyond the inner edge of the rim the inner bearing should be located so that the gear load will come directly in line with the bearing, and not outside of it. Due to the gear tooth load the inside bearing takes about two-thirds of the total load on the axle and, theoretically at least, this bearing should be larger than the outer bearing. For the sake of simplicity, however, we have found it advisable to make both bearings the same length, spacing them to equalize the load. Table K, referring to Fig. 15, gives a list of sizes that are in common use for this type of mounting.

28. Front Wheels. The automobile type of front axle is almost universally used on tractors at the present time. Steering knuckles have been made in a number of different ways—from cast steel, built up and of drop forging. The latter method is constantly gaining in favor and is, perhaps, the most economical. Drop forge knuckles may be very easily heat treated and ground, thus providing a very satisfactory operating surface for the bearing. Table L gives a list of bearing sizes suitable for use on a heat treated drop forge knuckle.

The length of a front wheel hub should not be less than one-fifth of the wheel diameter, and in any case the bearings should be located so as to project about one inch beyond the edge of tire. Where larger diameter wheels are used than indicated for the loads given the bearings should be increased in size, or set farther apart, to compensate for the increased leverage of the larger wheel.

The details of mounting may be worked out in a number of different ways. The mounting we have found to give the best all-round satisfaction is shown in detail in Fig. 16.

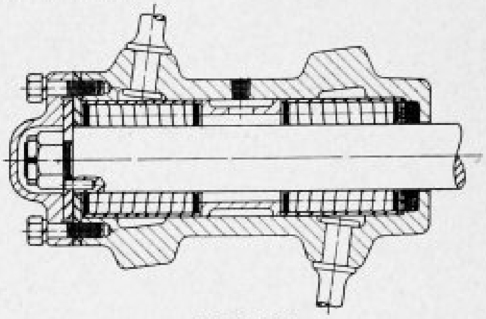


FIG. 16

Weight on Each Wheel	Max. Wheel Dia.	Min. Hub Length	Bearing Size				Hyatt No.
			S.	L.	R.	B.	
600	32"	6"	1⅜ x	2½ —	½ —	2 9/16	18222
900	36"	7"	1⅝ x	3 —	9/16 —	2 15/16	18300
1200	40"	7"	1⅞ x	3 —	9/16 —	3 3/16	18370
1800	44"	8"	2¼ x	3½ —	⅝ —	3¾	18497

Table "L" Bearings for Front Wheels.

29. Axle Drive Type Tractors. A modification of the type of tractor shown in Fig. 1, having an axle drive instead of a bull gear drive is shown in plan view Fig. 17. All of the data presented in connection with the tractor shown in Fig. 1, except the bearings for the intermediate gear, differential and axle drive, will apply to a tractor of this type. In other words bearings for the fan, clutch, main pinion, splined shaft, belt pulley, reverse idler and front wheels will be the same for axle drive type tractor as for a bull gear driven tractor of the same weight and engine size. The following illustrations and tables pertain only to the axle drive type of tractor.

Rating	Engine	R.P.M	Torque	Ratio	D. W. Dia.	Weight	Draw Bar Pull
9—18	3¾x5¼	1000	1350	55	42"	3200	1500—2000
12—24	4¾x6	900	2100	55	48"	4200	2000—2800
15—30	5 x6½	800	3100	55	54"	5500	2500—3600
20—40	6 x7	700	4800	55	60"	7500	3500—5000

Table "M" Tractor Data assumed for Axle Drive Type.

30. Intermediate Gear. With this type of tractor it is common practice to make the intermediate pinion the final drive. In order to get the desired gear ratio this pinion becomes comparatively small and it is, therefore, practically impossible to use a stationary shaft with the bearings mounted in the pinion hub. A very satisfactory construction is shown in Fig. 18.

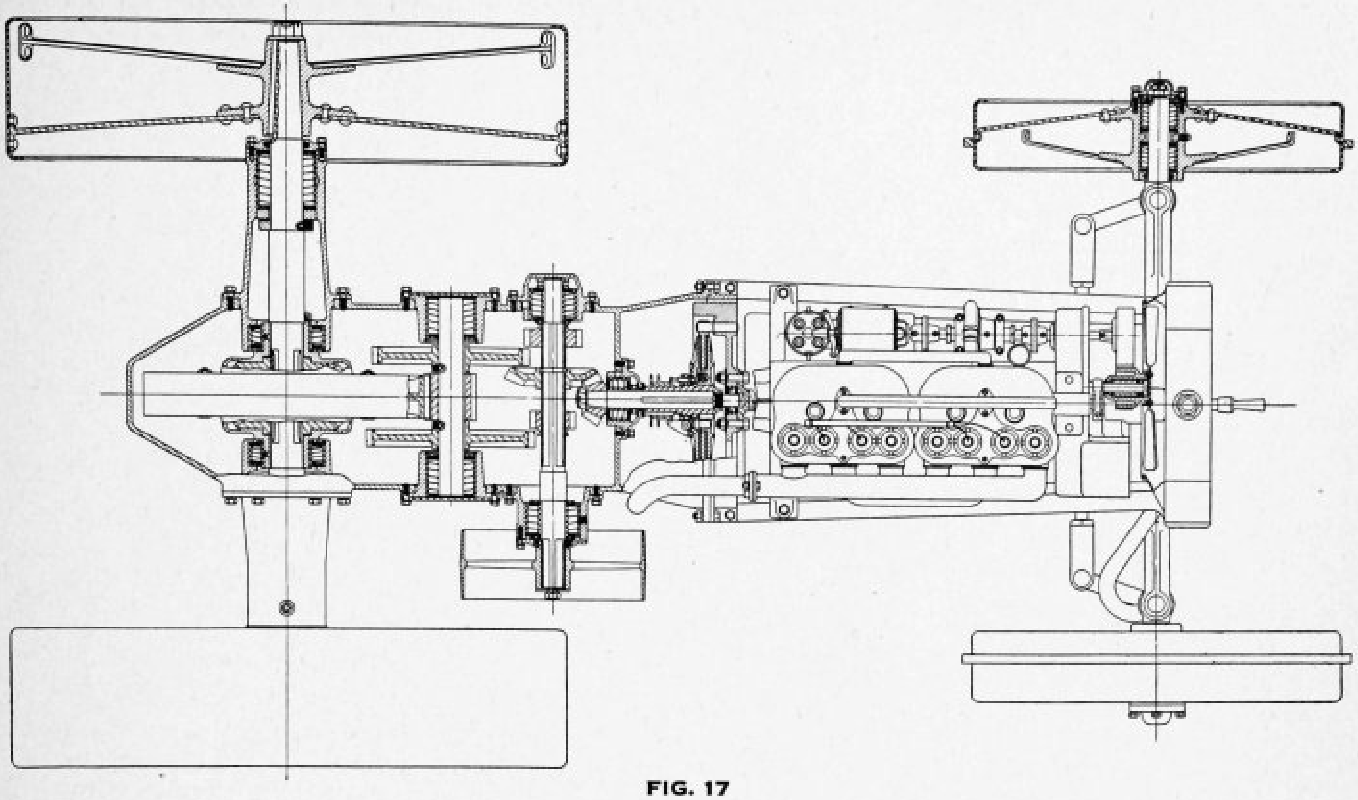


FIG. 17

In this design the shaft is carbonized, hardened and ground and bearings without inner races operate directly on the ends of this shaft. Table N gives a lise of sizes which have proven satisfactory for similar positions operating under the loads given in the table.

Bearing Load	Bearing Size				Hyatt No.
	Shaft	Length	Roller	Bore	
3000 — 4000	1¾ x	2½ —	¾ —	3⅝	17072
4000 — 5000	2 x	2¾ —	⅞ —	4⅛	17076
5000 — 6000	2½ x	3 —	15/16 —	4¾	17082
6500 — 9000	3 x	3½ —	1 —	5⅜	17086

Table "N" Bearings for Intermediate Shaft (Axle Drive Type).

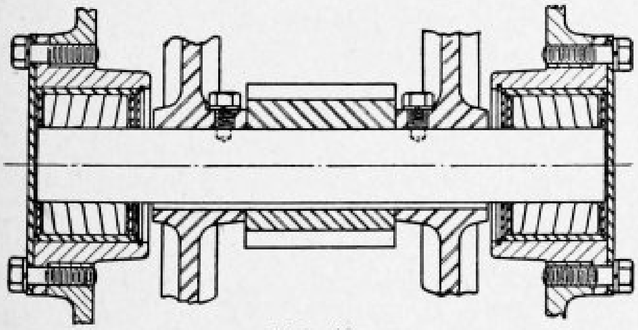


FIG. 18.

31. Differential Bearings. Since the differential in an axle drive type tractor is mounted on the rear axle it follows that the bearing load, and consequently the sizes, are considerably greater than if the differential were mounted on the jack shaft. The detail of mounting a differential on an axle is shown very clearly on our plan view (Fig. 17) and is essentially the same as the jack shaft mounting shown in Fig. 12. The bearing sizes, however, for a given size of tractor should be determined from Table O below.

Bearing Load	Bearing Size				Hyatt No.
	Shaft	Length	Roller	Bore	
2500 — 4000	3⅜ x	1½ —	¾ —	5⅛	56605
3200 — 5000	3⅞ x	2 —	¾ —	6⅛	56355
4500 — 6500	4¼ x	2 —	1¼ —	7⅛	40900
6000 — 9000	4½ x	3 —	1¼ —	8⅛	40930

Table "O" Differential Bearings (Axle Drive Type).

32. Rear Axle Bearings. Tractors having an axle drive require a shaft considerably larger than would be required on a bull gear driven tractor of similar weight and capacity. This, because the size is determined by the torsional strength rather than the deflection of the axle. It is advisable to use a high carbon alloy steel heat treated for the driving axle.

Bearing sizes in Table P have been determined on the basis of using heat treated alloy steel in the axle

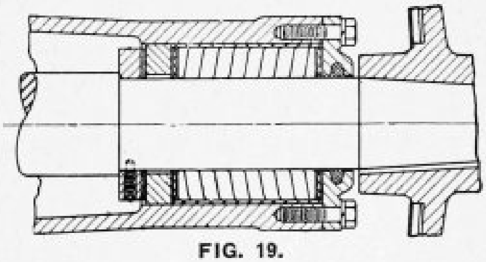


FIG. 19.

Bearing Load	Bearing Size				Hyatt No.
	Shaft	Length	Roller	Bore	
2500	$2\frac{1}{2}$	x 5	— $\frac{15}{16}$	— $4\frac{3}{4}$	49580
3750	3	x 5	— 1	— $5\frac{1}{4}$	49730
4800	$3\frac{1}{4}$	x 6	— 1	— $5\frac{1}{2}$	46111
6750	$3\frac{1}{2}$	x 6	— $1\frac{1}{8}$	— $6\frac{1}{8}$	40020

Table "P" Bearings for Rear Axle (Axle Drive Type).

with a minimum scleroscope reading of 60 points hard. Fig. 19 shows a typical layout for this type of construction. It will be noted that the axle is retained by means of a set collar and a washer held in the bore of the housing by the outer race.

TIMKEN ROLLER BEARINGS FOR FARM TRACTORS AND MOTOR TRUCKS.

33. What Timken Bearings Are. Timken Roller Bearings are constructed upon the basic design of the cone, the bearing surfaces of both inner and outer races being frustums of cones, and the rolls, too, being conical. The dimensions are so chosen that the apexes of the three parts coincide on the axis of the bearing, true rolling action resulting.

The bearing proper is composed of four component parts. These are the ribbed cone, with outside taper, the tapered roller, the tapered cage or roll retainer, and the cup, with inside taper.

The cone is built of Timken-made, electric steel, carbonized or pack-hardened to provide a hard tool-steel exterior which will permit of a polished surface and preserve the interior elasticity. It is turned out of tube stock by automatic machines of human-like capacities from Timken-made seamless tubes. Ribs on either end of the cone prevent the rollers from working out the large end. They are ground and finished to a fine degree of accuracy.

The roller is made of high-grade electric, alloy steel, heat-treated with the same delicacy of precision. It is manufactured by automatics from Timken-made rods, each roller being precisely checked for accuracy by magnetically operated automatic machines. Nibs on the end of the roller are guided by the ribs on the cone, thus assisting in the maintenance of alignment and constant line contact. The taper of the roller, the feature that gives Timken Roller Bearings their end-thrust carrying capacities and adjustability is constantly checked during production by gauges sensitive to one-hundredth the thickness of paper, such as is used for the page on which this is printed.

The one-piece cage is pressed from sheet steel, it requiring ten punching and drawing operations and four annealings to complete the process. Its function is to guide the rollers on the cone, maintaining correct alignment and constant line contact; and also the further purpose of holding and distributing the lubricating material. The assembly of the cone and rollers is completed by bringing the cage on to the group of

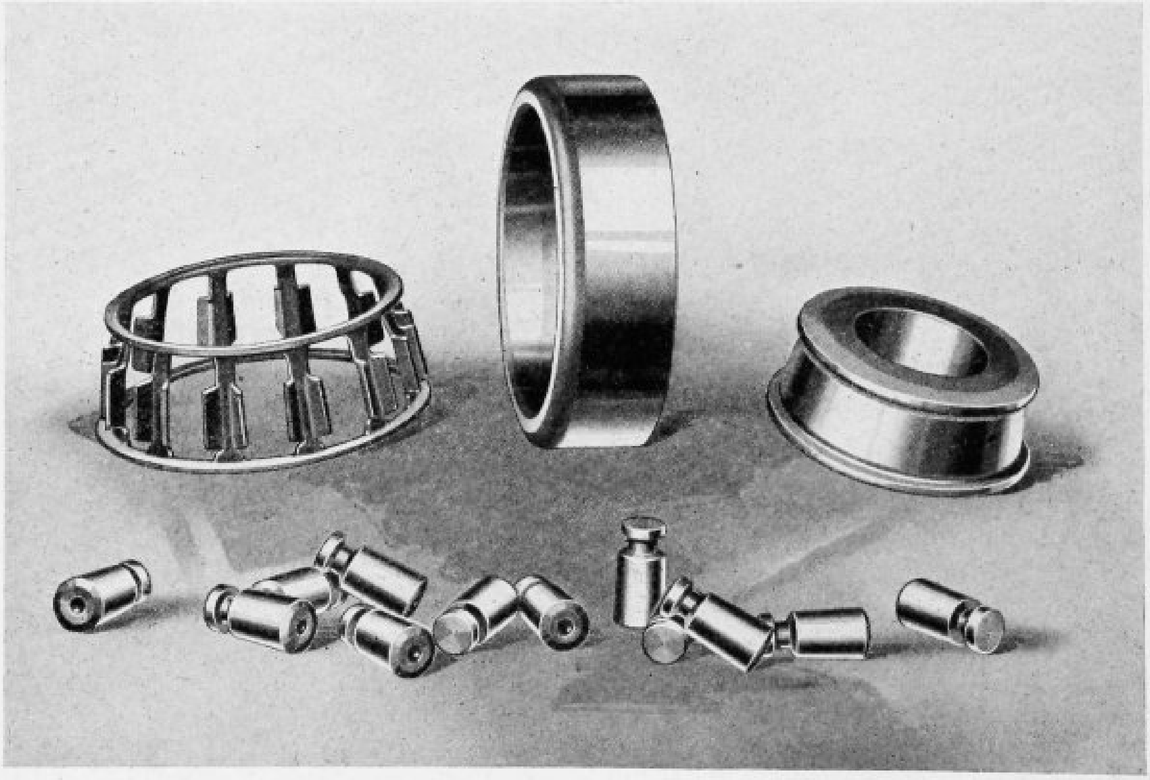


FIG. 20.

rollers around the cone. This operation makes a unit of the cage, cone and rollers, or inner race assembly.

The cup, or outer race, is virtually the container for the bearing proper. It is made of electric steel, tapered within with the same degree of accuracy employed in the manufacture of the cone. This taper permits of the bearing's adjustability. When wear finally takes place the cone assembly is brought closer into the cup, whose wear has been identical. The readjusted bearing is a new bearing, for the leeway of wear is ample, as repeated adjustments on at front wheel spindle, knuckle head, transmission, pinion shaft, differential, rear wheel, propeller shaft, steering gear, fan, sprocket shaft, clutch, and drive pinions.

The Timken principle of a roller bearing tapered to meet with equal resistance load and thrust and provide "take-up" for "wear-out" has combined with the Timken principle of quality and uninterrupted performance to establish Timken Roller Bearings as the standard anti-friction bearings both in America and Europe, where they are manufactured, and throughout the world that utilizes motor service. (See Fig. 20.)

34. In the Tractor Front Wheel. The Timken Roller Bearing at the base of the knucklehead of this tractor front wheel makes steering easier by taking up the shock and thrust on the steering pivot and by reducing the friction in the pivot to a minimum.

On the spindle the Timken Bearings allow the wheels to revolve without power loss due to friction. They also constantly take up the end thrust which develops from driving on rough and uneven ground, or on a slant, as with one wheel in the furrow and when making turns.

Because of the compactness of Timken Bearings, with their mountings and enclosures, it is possible to reduce the distance between the center of the spindle and the center of the pivot to the lowest possible degree. This is a particular advantage in the case of heavy, wide tractor wheels where space can be eliminated with an increase rather than a loss of strength.

Statistical investigation has shown that in one rotation of the tractor wheel not less than five side thrusts are delivered, due to bumps, furrows, and general uneveness of the ground. With the average sized wheel, then, not less than 3,200 side shocks are produced each mile. It is obvious that a bearing incapable of taking up side thrust has no place in the front hub.

For that reason more and more tractor builders and designers are each day installing Timken Bearings in their front wheels, and indeed it may truthfully be said that the further the refinement of the farm tractor and farm implement, the more complete the Timkenization.

The cups in each of these instances are press fitted with an allowance of from .002 in. to .003 in. The cones have a floating fit with a .0005 in. allowance. Adjustment in either case is made at the castellated nut at the bottom of the pivot and on the spindle extreme. (See Fig. 21.)

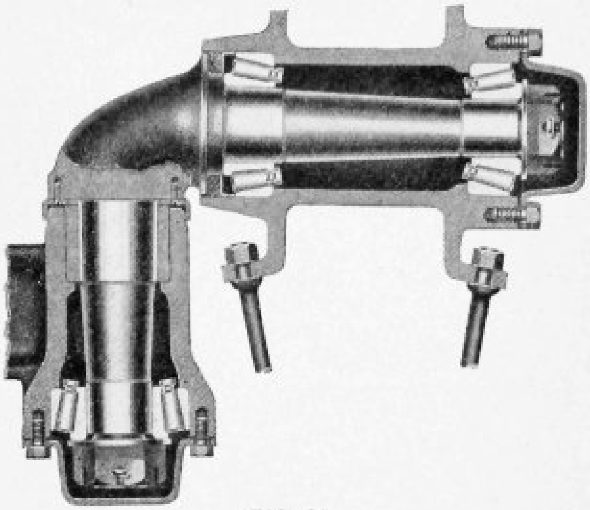


FIG. 21.

35. In the Tractor Transmission. In the tractor transmission here illustrated are shown twelve Timken Bearings; two each on the belt pulley, main drive pinion, counter, and differential shafts; and four on the live axles. In each case the installation of Timken Tapered Bearings facilitates the assembling of the parts, because the taper of the cones permits of their insertion into their cups even though not exactly centered during the operation.

There is also provided an ease of adjustment in every case, adjustment being made externally. Thrust developed at the bevel gear on the main drive pinion shaft is taken up by the rear bearing; thrust on the belt pulley shaft from the bevel gear is taken up by the inner bearing. With the bearings on the opposite ends they take up the heavy loads and thrusts, keeping the gears in perfect mesh and the shafts in absolute alignment.

The heavy radial and axial loads on the axles are taken up by the Timken Bearings so that all available power is transmitted to the drive wheels with a minimum of frictional loss.

While quietness for quietness' sake is not especially sought after in farm tractors, noise is a sign of lost energy and power. Timken Bearings at the counter and differential shafts, as well as at the main drive pinion and belt pulley shafts and axles, allow the assembly to operate with a remarkable freedom from noise and friction.

Farm tractors never coast. Constantly they work at a maximum. Timken Bearings, designed and manufactured for just such severe service—and being renewable by adjustment, when the unavoidable wear occurs—are the logical anti-friction applications at these points.

Each of the twelve cups has a press fit; the allowance on the smaller cups, at the belt pulley and pinion shafts, is from .002 in. to .003 in.; on the larger

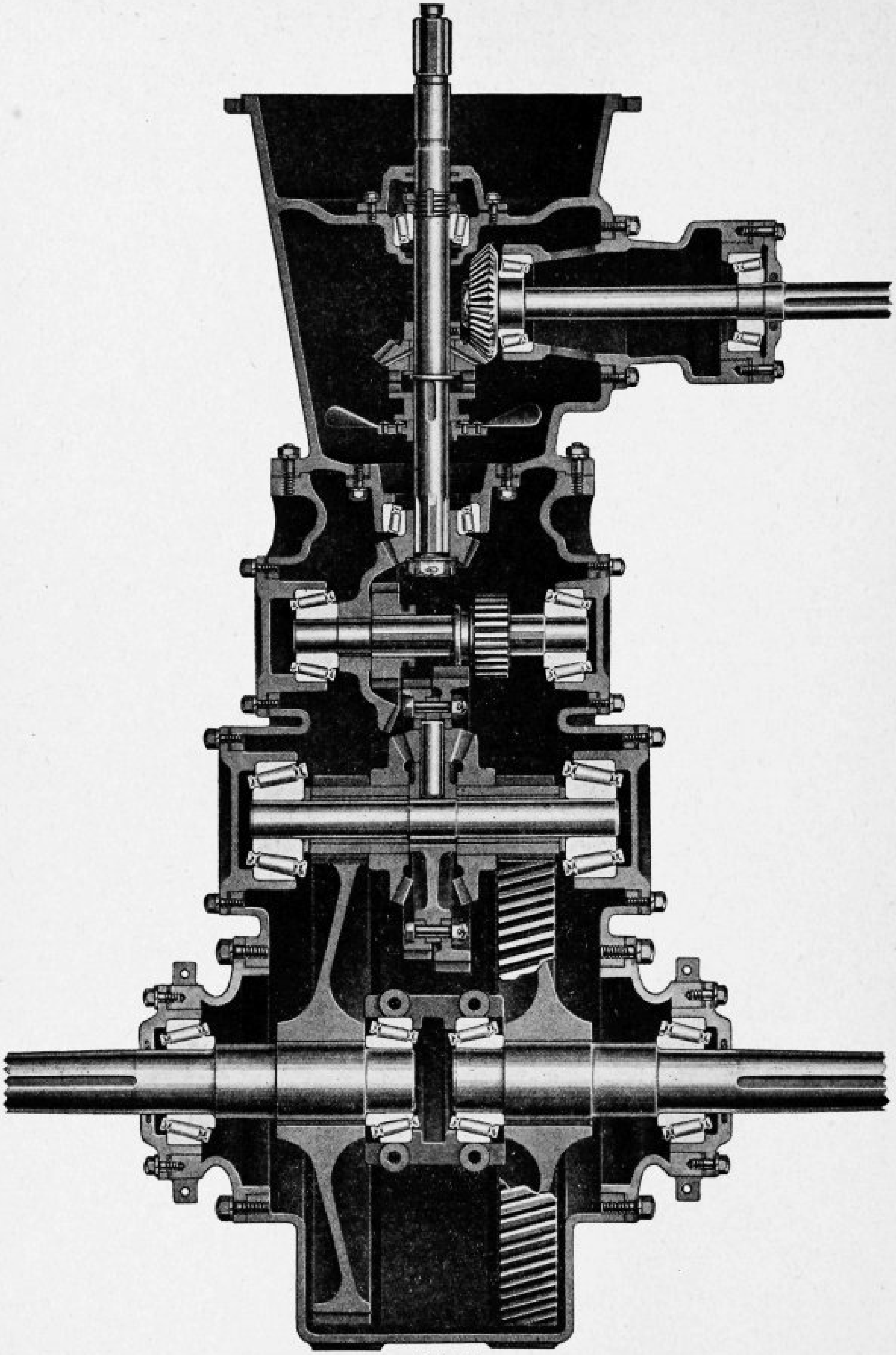


FIG. 22.

cups a safe allowance is from .003 in. to 005 in. The cones have press fits of the same allowances, except the forward cone on the main drive pinion shaft which has a light press fit with an allowance of about .0005 in. Adjustment is made by shims from the outside in each case, except at the main drive pinion shaft where an adjusting nut is applied at the forward end. (See Fig. 22.)

36. What Timken Bearings Do. Performance is the test by which the builders of Timken Roller Bearings prefer them to be judged. Not what anti-friction bearings should do, but what Timken Tapered Bearings actually have done, is but one of the proofs of a principle basically correct, perfected, and engineered to the highest possible degree of serviceability.

Timken Bearings perform equally well under severe or easy conditions. They are as much at home in units constantly racked and strained as they are in smoothly running, moderate speed assemblies. They stand the gaff under conditions of most stiff and rigid operation.

At the points of most racking service in automotive vehicles, the front wheel spindles, differential pinions, and transmissions, they have proven themselves to be unparalleled for service, wear, and dependability. Bearings that bear several vicious shocks each wheel rotation for hundreds of thousands of miles—and it is not unusual for Timkens in front wheels to be delivering one hundred per cent service at 500,000 miles—must have more than good fortune built into them.

It is the duty of anti-friction bearings constantly and successfully to combat friction. It is this distribution of the load over a line contact that gives roller bearings their super-efficient radial, thrust, and radial-thrust load supporting qualities. Carrying the radial load is but half the job. The end thrust, or axial load, is as ever-present and ruinous to the assembly unless provision is made for its take-up.

To this job of minimizing wear from radial and side loads the Timken Roller Bearing, tapered throughout, is without competition best adapted. Each time the tapered rollers, guided by their tapered cage, roll over the tapered cone, two duties are performed. Both the radial and end loads are given over to tapered lines of contact—the greatest possible distribution of support.

Timken Tapered Roller Bearings, because first of their infallibility of principle and excellence of craftsmanship, and second because of their adjustability to wear, are not only by far the longest lived bearings it is possible to construct, but usually outlast all other parts of the installation. Holding up without wear as long as the best possible materials masterfully produced can hold up, Timken Roller Bearings, when the inevitable wear does occur, can be adjusted quickly and certainly. And so slight is this wear, although enough to cause trouble if not corrected, that the readjustment can be repeated indefinitely—or to hundreds of thousands of miles, or hundreds of millions of revolutions.

Timken does not **happen** to build the best bearing. Nothing simply **happens** in the production of the Uninterrupted Performance Bearing. Even at the modern Heroult electric furnaces where the manufacture starts, the ever-present rigidity of inspection and completeness of manufacture begin; they mark the initial step in a Pursuit of Permanence, chaperoned by the Spirit of Conscientiousness. Through the soaking pits, rolling mill, tube mill, carbonizing furnaces, and into the roll and cone automatics, it is ever attendant. It sees that the bearing with the minutest flaw—although it might deliver—is scrapped. It knows that even a single Timken Bearing cannot afford not to produce.

That is why most car and truck drivers never see their Timken Bearings.

CHAPTER XVI

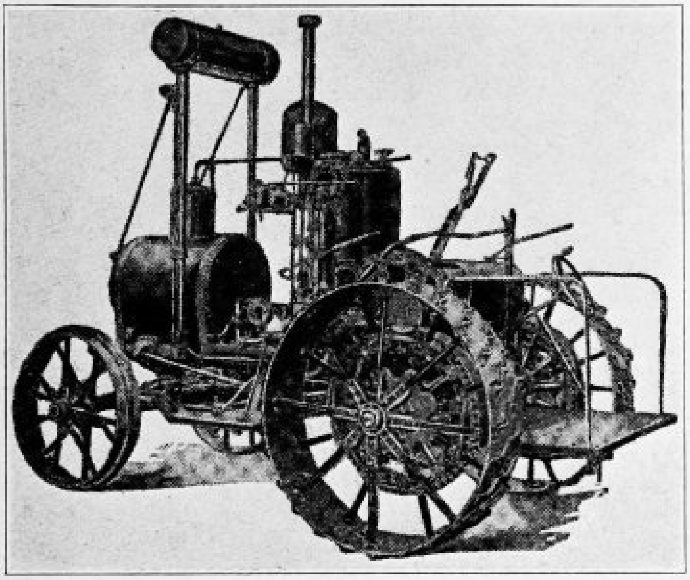
THE MODERN GAS TRACTOR

1. The Modern Gas Tractor. In the previous chapters we have taken up the fundamental principles, construction, care and operation, of the internal combustion motor, and the accessories necessary to its successful operation. This motor with its accessories constitute the power-plant. We have also explained the distribution of the power generated by the power-plant, through the transmission. During the past few years great progress has been made in all branches of engineering and science. This is especially true in the internal combustion motor and its application to the selfpropelling automobile, truck and tractor. From crude and unsatisfactory construction of but a few years ago to one of great refinement and practicability of today, there has been no achievement in mechanical engineering that has been of greater importance to man kind than the gas tractor, owing to the important bearing it has upon the production of foodstuffs. And no invention since the reaper and the modern self-binder, has been of more vital importance to the farmer than the present gas tractor. It has decreased his burdens, it has encreased his profits, it has made better farming possible and increased crop production. the gas tractor is far superior to animal power for the farm, because it will do more work in a given time than is possible with animal power. A greater portion of the farm work must be done during hot weather. The tractor works in any kind of weather without fatigue, while the horse, the mule, or the ox, is affected by extreme temperatures, either hot or cold. The farm animal is subject to all ills that flesh is heir to. If the animal brakes down, nature is the only possible repairman. Any one of average intelligence can replace broken parts with but slight delay. As the tractor feels neither heat or cold, it will work equally well in the heat of summer or the cold of winter. It knows neither light or darkness; and its day's work is limited by the number of hours in the day, and the indurance of the operator. It does not grow weary and require work by hours with frequent stops for rest. It knows no fatigue, and often when the day's work is finished it has just reached its most efficient operating point. The horse may be considered a hay motor in the sense that it eats hay for food. Edison says he is the poorest motor ever built and his thermal efficiency is only two per cent, while the thermal efficiency of the gas tractor is twelve per cent.

The horse eats 12,000 pounds of food stuff per year. He consumes the out put of five acres, and his food must be produced on the surface of the earth in fertile soil well cultivated and consumes time and labor to produce it. The soil upon which his food is produced must be exposed to the sun and produced during the summer months, then lay idle at least six months out of the year. The same land would produce enough food stuff for five human lives. While the food for the gas tractor is produced from materials procured from beneath the surface of the earth, where the food for man can not be produced and cannot be used to better advantage. It can be produced twelve months out of the year, does not decrease the suitability of the land for crop production. The gas tractor does not require the expensive housing of the horse. It demands some attention to be sure, but only hours as compaired to days with the horse.

The gas tractor has had to pass through an evolution just as every other mechanical device. History tells us the steam boat was barred from the canals and rivers because it made large waves which washed the banks. The people of the New England States years ago petitioned congress to enact a law to prohibit the rail road trains to travel not to exceed seven miles per hour. The bicyclist was compelled by law to remove his bicycle from the highway when a horse approached. The steam tractor was forced to use horses to guide it so as not to frighten other horses, all these mechanical devices have out lived the critic that made it so hard for its progress. The same is true of the gas tractor, it has come to stay, it has had its weaknesses to be sure, but the farmer must understand the tractor as he did the horse if he is to have success, the users of tractor must be educated so as not to abuse the machine, the tractor schools have there part in this education, the tractor of today with its wonderfully constructed power plant, its inclosed transmissions with cut gears and anti-friction bearings, its simplicity of construction, and assessability is paving the way of progress, education in this line is increasing the demand for well made, efficient tractors. The tractor user must realize the slow progress made has not been wholly due to the tractor, but partly to his not understanding it.

2. The First Gas Tractors, was a nameless machine. "Will it go?" "It" did not even have a name, for the word "tractor" had not been coined. It had none of the "accessories" which are now considered tractor necessities. It had no magneto—they were unknown in those days. It had no electric wiring, no timer, no coils. The dry cell battery had not demonstrated its ability to ignite the vapor. Will it go? It alone can answer. Then turn it on and while awaiting its reply, a few interesting operations must be performed. The gas was generated in the "burner" after the manner of the old-fashioned gasoline stove. A platinum tube which extends into the combuston chamber is heated to a white heat. The vapor is now admitted into the cylinder. A tank of compressed air is released, "turning over" the massive fly-wheel. When the piston comes up on the compression stroke, a cam releases a trip which explodes a parlor match in the combustion chamber and—bang! It has started. Subsequent charges were ignited by the hot tube and—Bang! Bang! Will it go? In no uncertain tone, it answered—Bang! Bang! Bang!



One of the First Tractors

Gasoline Troubles.

Inventive genius ever looks for more worlds to conquer. It is always gratified with each achievement but never satisfied. The inventive spirit was gratified with the tractor placed on the market in 1898 because "it would go". True, it made as much noise as an old-fashioned Fourth of July celebration but—"it would go". It took a barrel of water a day to cool the motor but "it would go"—Sometimes! On that hangs a tale of woe but that is another story. The pioneer tractor as well as the pioneer automobiles had their troubles —no doubt about that. Most of the motor troubles were undoubtedly caused by impurities in the gasoline and no one knew anything about straining gasoline in those early days. After the importance of clean fuel was realized, the second step in the development of the tractor and the automobile had been taken and the pioneer manufacturers were no longer satisfied with a machine that would go—Sometimes. Then began the quest for "more worlds to conquer".

Magneto Introduces New Epoch.

The evolution of the tractor presents one of the most fascinating pages in the history of agriculture. The makers of heavy farm machinery followed the massive construction of the farm engine in the early tractors just as the early type of automobile developed by the carriage maker followed the general lines of the carriage with its high wheels and dashboard. The development of both the tractor and the automobile proceeded very slowly till the dry cell battery demonstrated its ability to serve the ignition system. The magneto was introduced a few years later, insuring a dependable ignition system and the future of the two great industries was assured. The early pioneers in both industries struggled with the same problems until a reasonably dependable motor had been developed, after which the trend of automobile improvement was in the direction of speed and comfort while the development of the tractor was in the direction of transforming the brute strength of the motor into an economical and dependable beast of burden for the farm.

The First Model of the Huber Gas Tractor at work on the farm of Laude's Bros., York, Pa. in 1899

3. The Gas Tractor. The Gas Tractor, a mechanical device to conver heat energy into traction. One of nature's natural laws is known as traction. Traction is the force required to pull a load on a street, pavment, railroad, or field; usually measured in pounds per ton. On a macadam road, about 50 lbs. is required to pull one ton. The force of traction is larger at the moment of starting than at slow velocities, but at high velocities it rapidly increases. It is greater for small wheels than large ones. On a level railroad track at slow velocities a locomotive must pull 4 to 8 lbs. for each ton of train load. This traction becomes greater for high speeds, cold or wet weather.

Traction Required for Hauling. A tractor used for hauling on the level must have a draw-bar pull in pounds equal to the following table.

On Rails or Plates	4 to	20 lbs. traction
On Macadam Roads	30 to	60 lbs. traction
On Hard Asphalt	10 to	25 lbs. traction
On Hard Wood	15 to	30 lbs. traction

On Newly Graveled Roads...	150 to 200 lbs. traction
On Sand	200 to 400 lbs. traction
On Stuble Fields	100 to 250 lbs. traction
On Plowed Fields	150 to 300 lbs. traction

It will be seen from the table that the better the road surface, the less power is required to move the load. If a train of wagons weighing fifteen tons are hauled over a good macadam road, the traction required equal 15x30, 450 lbs. To move the same load over a dry stubble field the traction required would equal 15x150, 2,250. Number of lbs.

4. Advantages of Power Traction. There is no place about the farm where power is more necessary than in the fields, and it is said that more energy is spent in plowing annually than in the combined factories of the world during the same period. The earliest plow was a crotched stick and served to till the ground for the first of our primitive ancestors, who conceived the idea that breaking the ground was the first step and one of the most important that had bearing upon the growth of the seed sowed therein. Plowing has always demanded more expenditure of energy and time than all other lines of farm work combined.

The call came for power to pull a plow which would make many furrows in the time usually taken to make one. The earth must be plowed at a certain time, and under sharply defined conditions. To violate any of the rules, either of time or thoroughness of tillage, makes material difference in the quality and quantity of the crops. The amount of land tilled has depended upon the equipment of the farmer and the endurance of his employees and horses. At best, the area plowed has usually been but a small percentage of the ground available for cultivation. The crop has been limited and the productive ability of the farm has been relatively low in comparison to what power makes possible.

The first gasoline tractor was placed on the market in 1893 but could not compare with the steam tractor because of the crudeness of the gasoline engine of that period. It was not until 1903 that the gas tractor became a commercial success. The development of the practical internal combustion tractor was even more important than the invention of the mechanical reaper and binder or the threshing machine. It gave the agricultural industry the power that was needed, and its advent marks the greatest jump of progress in the history of agriculture. From its advent, barely a decade ago, the story has been one of steady progress. Difficulties have been gradually eliminated, and today one may say that many of the tractors sold have reached a high efficiency, while all made by reputable manufacturers are practical and capable of wide application. It is estimated that over seventy-five firms are offering gas tractors of all varieties, and the sales at the present time run well up into the thousands yearly. They have been shipped to all parts of the civilized world, yet the industry is but in its infancy.

Power traction is superior to animal energy because it will do more work in a given time at less expense than possible with any other traction means. It can be adapted to tasks that cannot be accomplished by any other power, and it is always ready for work. When intelligently managed its operating cost is much less than that of horses necessary to do the same work; or the amount of work done in a given time is so much greater than possible with any other form of power of the same cost, that its merits are apparent to any one able to analyze its performance.

5. Tractor Furnishes Power for Various Farm Machines. We have seen that the horse can do its best work only when pulling a load. If used for power through the medium of a tread-mill for operating various forms of machines, the efficiency is still lower and the ratio between useful work obtained, and amount of food consumed, is such that it is not economical to utilize the animal in this way. The usefulness of a tractor is more varied than that of any other farm machine. It is not only the most economical power for plowing, but it operates with equal economy all the machines and appliances necessary for raising and harvesting crops. These include disc harrows, seeders, drills, packers, binders, etc.

It can be used for hauling grain to the elevator, pulling stumps and hauling all kinds of lumber and supplies to the farm. Most tractors can be used for stationary power, and a belt may be run from the pulley provided for the purpose to operate threshers, shellers, shredders, pumps, sawing outfits and any other form of machine needing power. It has sufficient power to run a large number of machines at a time, if the main drive is connected to a line shaft which will turn a number of machines in unison.

The internal combustion engine is assuming increased importance in contracting and road construction work. Operating expenses of a tractor are materially less than when animals are employed because the amount of help needed is reduced to a minimum. One man easily does the work of three or four. The fact that it requires no attention and consumes no fuel when not in use is an advantage not possessed by animal power.

The tractor knows no seasons; and on any farm, work can be found for it at all times. It will pull the plows and drills in the spring; in the summer it can be used for making roads and hauling supplies; in the fall it can operate a binder or thresher; in the winter it may be used as power for a sawing outfit, or for running a husker, shredder, or sheller. Between seasons it will do heavy hauling, pump water, cut ensilage, operate grinding mills, haul manure, bale hay and dig ditches. The large range of use to which the average tractor can be adapted, and the relatively slight cost for its maintenance, cannot fail to impress the economical owners of farms who are conducting them on a business basis and to whom great efficiency and lower cost of production means vastly increased profits.

6. Economical Aspect of Power Traction. One of the great difficulties of farming on a large scale by old methods exists in the fact that certain work must be accomplished at a definite time. The plowing, the seeding, harvesting and threshing must all be done during definite periods. This work must be in progress while climatic and weather conditions are right. It is at this time that the capacity and endurance of mechanical power is emphasized, and the wonderful superiority of the tractor ofer horses and farm hands made evident.

The value of early fall plowing is generally accepted, as under this treatment the weeds are turned under the sod while still green, and the decaying vegetable matter forms an invaluable fertilizer. The weeds all bear seed which would sprout in the spring under ordinary circumstances. Plowing brings these near fore winter comes the frosts soon put an end to this objectionable vegetable growth. The result is a field the surface, and as they commence their growth before from weeds for the next grain crop.

The agriculturist who uses a tractor for threshing is able to do it as soon as the grain is ready. If this is interrupted by rain the tractor can be utilized for plowing; and under these circumstances many farmers have finished their fall plowing almost as soon as they have completed their threshing operation.

Another work that must be done promptly is harvesting. This is usually done in very hot weather, and both horses and men suffer from working in the excessive heat. If one has a large area under cultivation and no men are available for the harvesting, it will not take much hot weather to destroy grain of a value greater than that of a tractor and might have harvested the entire crop at the proper time.

7. Why Gas Tractors Are Most Popular. When one considers the many advantages, ease of operation and economical maintenance of the gas tractor, it is not difficult to understand why this form has attained so great a popularity. The mechanism is relatively simple and can be started at any time without unnecessary delays. Its radius of action is greater than that of a steam tractor because it is more independent as regards a base of supplies. A man can easily carry the amount of water consumed by the cooling system of the average gas engine in an ordinary pail, while five gallons of fuel will operate it for some time. The steam tractor must have two tenders. These comprise a tank wagon for water and another conveyance for wood or coal. Even if liquid fuel is burned under the boiler, the water tank will be necessary; and twice as much liquid fuel will be needed than for a gas engine of the same power.

Considerable time is needed to steam up, and great care is necessary if the steam tractor is to be operated in cold weather. It is not profitable or desirable to use the anti-freezing solutions in the boiler that can be so conveniently carried in the cooling system of the gas tractor. The larger and heavier steam tractors need two men to operate them just as a steam locomotive does. The engineer is occupied in driving and controlling the machine, and a fireman is needed to keep fuel under the boiler. The heaviest gas tractor can be controlled by one man.

A steam tractor must be relatively heavier than a gas-operated machine of the same power. While this may be considered an advantage from some points of view, it is a decided disadvantage in others. It is reasonable to assume that it takes more power to move a heavy machine than than to move light one. The more massive construction will pack the ground more than the light weight ones because there is a certain limit to the size of the driving wheels beyond which it is not desirable to go. When a heavy machine becomes mired, it is more difficult to pull it out of the hole by other forms of power, or by its own energy then to pull a light one.

8.. Selection of Power Plant. The type and size of engine needed depends on many varying conditions. The weight of the tractor and its capacity are the first things to be considered. The purpose for which the tractor is intended, and the nature of the country in which it is to be operated, are also factors of some moment. Another important point is the proposed selling price. One would not expect to find a highly refined and expensively built motor on a light or cheap tractor. Then again there would be nothing gained by installing a motor of large capacity in a machine built only for relatively light work. If the tractor is a type that is likely to be used by the farmer of comparatively small means, the motor should be a simple one that will be easily understood and cared for, without too much trouble or expense. Single-cylinder motors are invariably used on low powered machines. The two-cylinder motors are used on machines of moderate capacity, while the four-cylinder power plant is installed in the highest types of construction.

9. Power Delivery Under Belt. Most traction engines are provided with a pulley by which the motor may be coupled to any form of machinery that can be driven by a belt. In this work practically the entire brake horse-power of the motor is available, as there is but little loss in transmission. When it is used for traction purposes, part of the power is being used in moving the machine over the ground and part is being lost in friction in change speed and drive gearing. An engine that may deliver 30 horse-power under belt would not diliver more than 15 horse-power at the drawbar, under ordinary conditions.

10. Why Proper Distribution of Weight is Essential. To get the largest proportion of power at the drawbar, the gas tractor designer is forced to consider a number of important conditions.

First, the engine must be strong and durable, and the friction losses through gears and shafting must be rduced to a minimum.

Second, the design of the machine and the distribution of weight must allow the engine to travel over a great variety of soils.

The weight must be so distributed and carried that it will consume the least possible amount of power to drive the engine. The successful traction engine must be capable of running over wet, and sometimes muddy ground, over soft-plowed ground, or over rough field surfaces. Every horse-power that is used to move the engine is lost, and only that available at the drawbar can be counted in traction work. The engine designer should consider concentrating the weight of the egine where it can be carried to best advantage.

The front wheels should carry a load that will hold them in contact with the ground with sufficient pressure to insure positive steering. Also to insure proper equilibrium, when ascending reasonable grades. The smaller the front wheels are in diameter, and the more weight carried by them, the greater the amount of power it requires to force them ahead, and the more difficult it is to control the tractor.

In order to secure the greatest tractive efficiency, the greater part of the weight should be carried over the rear axle. The motor should be placed at such a point that the front end will not be overloaded or the frame stressed unduly. When the motor is placed parallel with the frame, and when the bulk of the gearing is carried by the rear axle, the greater portion of the strain due to weight and vibration will pass directly to the ground. The degree of adhesion between the rear-driving members and the road or field surface depends upon the amount of weight that keeps them in contact with the ground. It should not be inferred that tractors having the motor placed in front or in the middle of the frame are not practical, as many of these have given exceptionally good results in practice.

11. Influence of Weight on Traction. When a motor-propelled vehicle travels on a level course, its tendency to forward motion is resisted by three main items. The most important of these is the rolling resistance at the point of contact of the wheels with the ground. Of the other two—the friction in the rear axle and driving mechanism, and the air resistance—the influence of the latter may be neglected in such slow-moving vehicles as tractors. If the vehicle is traveling up a grade the power required to lift the weight up the incline should also be considered. The road resistance, as we have seen, depends to some extent on the character of the road surface, but another factor is the diameter of the wheels and the speed at which the vehicle travels. In the table previously given, we find that on a good macadam road a pull of 30 pounds would move a ton, therefore, the heavier the tractor, the greater the amount of power needed to overcome the resistance of the road. The horizontal effort required to pull a tractor up a grade is equal to about one per cent of its weight for each per cent of the grade. If we have a tractor weighing 10,000 pounds, and we wish to pull it up a 10 per cent grade, it will require a pull equal to 10 per cent of the weight or 1,000 pounds. This, added to the traction resistance of 30 pounds per ton, means that an added pull of 200 pounds must be considered in connection with the amount of force needed to climb the grade. Obviously a lighter tractor would not require so much power on grades, and could be operated by a motor of less power. At the same time, as the amount of adhesion between the wheels and the ground would be less in case of the light machine, its traction capacity would be reduced in direct proportion.

It will be apparent that there are extremes which the careful designer will avoid. A heavy machine with an inadequate power plant or with, an inefficient system of transmission, will not be practical because it could not surmount grades and would not have the range of work that its size would indicate. On the other hand, the mistake can be made of using too large a power plant in a light machine. This would mean that while it would prove to be a good hill climber or have a capacity for hauling, it would not have weight enough to insure the delivery of its full drawbar horse-power on account of the limits in traction imposed by the light weight on the rear wheels.

12. Types of Tractors. The various constructions that can be termed "gas tractors" vary from the small self-propelling lawn mowers to the heaviest machines equipped with motor of over 100 horse-power. Of the many types of tractors offered the public, the most common, and that which has the widest sale, is the medium capacity outfit that will handle about two to six plows as well as any of the other farm machines generally used on medium sized farms. The field for the very light tractor is not a large one inasmuch as these are suitable only for hauling and for work under the belt. Their capacity is not large enough to make them profitable in anything except the lightest forms of work. While traction engines are on the market with power plants as low as 10 horse-power they are not as practical for general service as those which have twice the power and cost but little more. In some special classes of work the light tractor has a field, but in general the practical type is seldom equipped with less than a 25 horse-power motor.

Tractors have been designed for use in orchards that are moderately light, if compared to the large machines used on the prairie farms of the Middle West. They are entirely suited for the work they are to do and give good results in practical use. A man owning a small farm, such as one that would find work for about four horses, can use the higher tractor to advantage. It will do all the plowing that the horses will and when not employed in the field the engine can be utilized in all of the various duties which require stationary power where horseflesh could not be used. Tractors having 60 horse-power motors are quite common and are generally used in road work as well as on medium sized farms.

Tractors vary in type at present just as widely as did automobiles of a decade ago. Owing to the infancy of the gas tractor industry, there has been an attempt at standardization as is now the case in automobile construction. Some tractors on the market are very rough in construction, and appear to have been evolved by a cut-and-dry method, rather than by an attempt to follow any definite plan or design. Others show evidence of careful thought and study of engineering principles. The machines that are carefully designed use steel castings instead of cast iron; utilize power plants of the automobile type; and employ the best cut steel gearing, thoroughly encased, to protect it from the dirt and well lubricated to insure long life and efficient operation. The mechanism is thoroughly protected from the elements and the control members are conveniently placed so that they may be easily handled by the operator.

As can be expected, the machines using the best construction and materials, and based on correct engineering principles, are more costly than the hastily designed and crudely constructed machines. This is a case where first cost is of less importance than after cost or maintenance expense. The well-designed machine will be serviceable under conditions that will quickly consign the cheap mechanism to the scrap heap. The farmer who intends to purchase a tractor should look into the construction and engineering features of the various types very carefully before purchasing. Many who condemn gas tractors as impractical pieces of machinery do so because they purchase poorly designed machines, eighter through ignorance of mechanical principles, or because the low selling price proved attractive. A farmer would not expect the amount of work out of a cheap horse, or in fact, any farm machine that he would get out of the more expensive one. As a rule one gets no more than one pays for, and this applies just as well to the purchase of a gas tractor as to a mowing machine, cultivator, or any other farm implement.

13. Traction Engines for Small and Medium Sized Farms.. Many farmers are of the opinion that traction engines are only suitable for large farms where extensive areas must be cultivated. This is a misconception that is not borne out by the actual facts. Even if the area under cultivation is not a large one, power traction would permit of more thorough soil tilling than is possible with horses. On every farm forage plants must be chopped, corn shredded and shelled, wood sawing must be done during the winter months, and water must be supplied in abundance at all times in the year. Engine power is the only practical energy for this work.

In many districts, a great advantage can be gained from deep plowing, which is necessary to liberate the fertility of new soil. Deep plowing is not possible with horse-power because the average farmer who has humane instincts hesitates to plow as deep as may be desirable through fear of cruelly abusing his animal.s It will be seen that even the small or medium sized farm can use a tractor to advantage in plowing work, providing that it can be adapted to other labors at periods when plowing over. Discing and thorough harrowing are necessary to prepare a good seed bed, and proper pulverization of the soil is necessary to retain moisture. The advantage of an engine on a small farm is that it can do this work as well as plowing, and in many cases the same power plant to which plows are attached will do the discing and harrowing at the same time.

Many of the smaller farmers are just beginning to recognize that animal power is slow; and that the increased number of horses made necessary by the modern methods of farming are not only expensive in first cost, but necessitate setting aside some of the most valuable land for raising hay and grain to feed the animals. A number of tractor manufacturers are furnishing medium weight machines equipped with 30 horse-power motors that will do the work of fifteen horses at the drawbar. These have been designed especially to meet the general demands of the smaller corn belt farms of the Middle West. Such a machine will pull a four-bottom gang in breaking, and six in plowing. From ten to fourteen acres a day can be plowed and harrowed in one operation. These machines are easily handled as they will turn short and work closely into the corners of the field. It is claimed that two good sized boys with a machine of this character will easily do the same amount of work that twelve horses and four men will do in a day. Such a tractor will run up to a 32-inch spearator and will operate corn huskers, shellers, shredders or any similar machinery. Any farmer working 160 acres can use such an outfit with profit.

14. Effect of Grades on Traction. The traction required to over-come grades is one per cent of the load, including tractor and wagons, for each per cent of grade, added to the power required on the level, providing the road conditions are the same as on the level roads.

Problem: If it requires 450 lbs. traction to move a load of fiteen tons on the level, what traction is required to move the same load up a 10 per cent grade with the same road conditions, the tractor weighing 8,000 lbs.

RULE: 15X2000=30000
30000+8000=38000
38000÷10=3800 lbs. traction required
3800+450=4250.

15. How to Determine the Percentage of a Grade. To determine the percentage of grade of a road or field without any special instruments, take a ten foot stick, and rest one end on the ground, being careful to keep the stick level. This can be done by using a spirit level or a bottle filled with water, allowing a bubble to form on the top which would answer as a level. Measure from the end of the stick to the ground, and multiply the distance in feet, or fraction there of, by ten, which will give the per cent of the grade. The average of several such measurements would give fairly accurate results. See Fig. No. 3, which is a convienent table for determining the percentage of grade.

Problem: What is the percentage of a grade where the slope is 3 inches in ten feet.

Rule: 3 inches= ¼ of a foot or .25
.25X10=2 .50=2½% grade.

Grades

Rise in feet	% Grade	Angle
1' in 1'	100%	45°
1' in 2'	50%	26° 34'
1' in 4'	25%	14° 2'
1' in 5'	20%	11° 19'
1' in 6⅔'	15%	8° 37'
1' in 10'	10%	5° 43'
1' in 20'	5%	2° 52'

FIG. 3

Below you will see an illustration of what grades cost in horse-power.

ground conditions. The average traction required to pull a 14-inch plow 5 inches deep in different soils is about as follows:

Loamy sand	350 pounds
Sandy loam	390 pounds
Moory soil	435 pounds
Gumbo loam	683 pounds
Blue clay	1029 pounds

The above table shows an extreme wide range of traction required to pull a 14-inch plow which varies from 300 to 1,000 pounds. From records made at the National ractor Demonstrations, gave the average traction required to pull a 14 inch plow 6 inches deep in stubble land at 450 pounds which equals 5.35 pounds per square inch cross sectional area of furrow turned. The traction required per square inch cross sectional area in vergin sod varies from 12 to 20 pounds. There is so many factors that enter into the amount of traction required to pull plows, it would be difficult to give any fixed rule. he conditions of the soil, the conditions, adjustments, the shape of the plow bottom, and grades. The traction which a horse can exert in pulling a load, depends on his weight, and the speed he is traveling. If a horse exerts about 250 pounds at one mile per hour, he will exert about 125 lbs. at two, and 50 lbs. at five miles, and so on.

Statistics state that a horse will exert one-half of his weight on the tugs for a very short time, one fourth of his weight for a longer time, and one-seventh of his weight pratically all of the time, or from morning until noon the average working hour day, by using the traction exerted by the horse we should be able to make a very close estimate, of the traction required of a tractor to perform the same work.

We will consider as an illustration, that a team of horses is hitched to a load. These horses we will say weigh 1,400 pounds each. The average weight

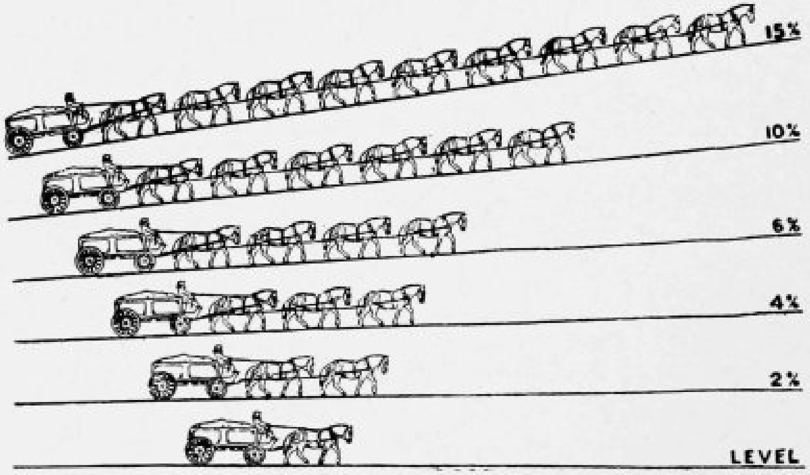


FIG. 4

It requires nine times the traction to assend a 15 per cent grade over that required on the level.

16. Traction Required for Plowing. Traction required for plowing varies with different soils, and

they would pull is estimated to be two hundred (200) lbs. each.

The traction required for breaking and plowing varies with different soils and ground conditions. The traction required to pull a 14 inch plow, 6 inches deep, ranges from 250 to 1000 lbs. or draft varing from 3 to 12 lbs. per square inch cross section area of furrow slice turned. This extreme wide range of ground condition is responsible for a great many disappointments in tractor purchases.

I should recommend that the prospective purchaser of a gas tractor study the grades and ground conditions of his farm before making such a purchase.

The amount of traction required to pull his plows may be obtained in the following manner:

Place a spring scale in one tug. The product of the number of lbs. registered on the scale, multiplied by the number of tugs, equals the traction required to pull one plow. The product of this result multiplied by the number of plows desired equals the traction required of the tractor or drawbar pull, to pull the plows on the level.

The traction required to ascend grades will be taken up later.

Problem: 1. If it requires 86 lbs. pull on each tug of a three horse team to pull one 14 inch plow, what traction is required of a tractor to pull eight plows under the same conditions?

RULE:

86X2=172 number of lbs. pull by each horse.

172X3=516 number of lbs. required to pull one plow.

516X8=4128 number of lbs. traction required to pull eight plows.

Problem: 2. If it requires 86 lbs. pull on each tug of a three horse team to pull one 14 inch plow 5 inches deep, what traction is required of a tractor to pull eight plows 7 inches deep in the same ground?

RULE:

86X2=172 number of pounds pull by each horse.

172X3=516 number of lbs. required to pull one plow five inches deep.

14X5=70 number of inches cross section area of furrow turned.

516÷70=7.37 number of lbs. pressure per square inch cross section area of furrow turned.

14X7=96 number of inches cross sectional area of a 14-inch plow 7 inches deep.

98X7.37=722.26 number of lbs. traction required to pull one 14-inch plow 7 inches deep.

8X722.26=5778.08 number of lbs. traction required to pull eight 14-inch plows 7 inches deep. Ans.

Problem 3. If it requires 5778.08 lbs. traction to pull eight 14-inch plows, 7 inches deep, on a level field, what traction is required to draw the same plows up a 6 per cent grade, the tractor and plows weighing 2100 lbs?

RULE:

1% of 21000=210 lbs. 210X6=1260 number of lbs. traction required to over-come the 6% grade in excess to the traction required on the level.

5778.08+1260=7038.08 number of lbs. drawbar pull required. Ans.

17. To Estimate the Traction Required. An estimate of the traction required to pull a plow can be obtained quite accurately by assertaining the number of horses, and their weight, required to pull a plow. The horse is supposed to pull one-seventh of his weight and keep going.

Problem 1. If it requires three 1400 pound horses to pull one 14 inch breaking plow, what traction must a gas tractor have to pull ten breakers under the same conditions?

RULE:

1400÷7=200.

200X3=600 number of lbs. required to pull one breaker.

600X10=6000 number of lbs. traction required to pull ten plows.

Problem 2. If it requires three 1400 lb. horses to pull one 14-inch breaking plow 4 inches deep, what traction must a tractor have to pull ten 14-inch breakers 5 inches deep?

RULE:

1400÷7=200.

200X3=600 number of lbs. traction required to pull one 14-inch breaking plow 4 inches deep.

14X4=56 number of square inches cross sectional area of furrow turned.

600÷56=10.7 number of lbs. pressure per square inch cross sectional area of furrow turned.

14X5=70 number of square inches cross sectional area of furrow turned 14 inches wide, 5 inches deep.

70X10.7=749 number of lbs. traction required to pull one 14-inch breaker 5 inches deep.

749X10=7490 number of lbs. traction required to pull ten 14-inch breaker 5 inches deep.

Problem 3. If it requires 7490 lbs. traction to pull ten breakers on the level, what traction is required to pull the mup a 4% grade with the same ground conditions, the tractor and plows weighing 26000 lbs.

RULE:

1% of 26000=260.

260X4=1040 number of lbs. required to over come 4 grade.

1040+7490=8550 number of lbs. required to pull the ten breakers up a 4% grade.

18. Horse Power of Tractors. There has been a great deal of discussion as to the proper method of rating Gas Tractors. The present practice is to rate the tractor with the brake horse power at the belt pulley, and one half the brake horse power at the drawbar. Another method that seems to be gaining favor is to give the B. H. P. at the belt pulley, and the lbs. pull at the draw-bar. If a tractor has three speeds of say 1, 1½, 2½, 3.3 3 1/2 miles per hour, what is now rated at 2 P. B. H. P. would have a traction or drawbar pull of 20 D. B. H. P.

5000 lbs. at 1.5 miles per hour
3000 lbs. at 2.5 miles per hour
2142 lbs. at 3.5 miles per hour

With this method the purchaser, by first obtaining the lbs. pull required to pull his plows, can select the draw-bar pull required of a tractor to do his work. This method of rating would be just as easy for the manufacturer, and much easier for the farmer, as very few understand horse power ratings. With the present wheel construction it has been found impractical to rate a tractor with a draw-bar pull of more than one-half the total weight of the tractor.

19. Brake Horse-Power. The unit of power—horse-power—is defined as the amount of power necessary to raise 33,000 pounds one foot in one minute.

Brake horse-power derives its name from the fact that a device known as the Prony brake is used in determining it. It is actually the amount of power delivered at the fly wheel. A Prony brake consists essentially of a band which can be tightened so as to apply friction to a revolving shaft in such a manner as to resist the tendency of the band to revolve with the shaft. The amount of force necessary to do this is measured by weighing scales. Thus, the amount of pull is determined.

Since we know the distance in feet that the point at which the scales are applied would travel, and the time it would take—one minute being taken as the unit—and since we know the scale reading or the pull required to keep the band from moving, we have the three elements of horse-power described above, namely: the distance in feet, the time taken in minutes and the force in pounds.

Therefore, since one horse-power is the amount required to raise 33,000 pounds one foot in one minute, if we take the number of pounds recorded on our scales, multiply it by the distance in feet, and this product by the speed in minutes, and divide the result by 33,000, the final result will give the brake horse-power of the motor. (See Fig. 5.)

Calculating the Brake Horse-Power by a Prony Brake.—When the brake is arranged as indicated in Fig. 5 we may obtain the power transmitted by the motor by the formula.

$$\text{B. H. P.} = \frac{L\ 2\ \text{"pi"}\ P\ N}{33{,}000}$$

in which B. H. P. = actual horsepower transmitted; L = length of lever, from center of shaft to point of contact on scale; "pi" = 3,1416; p = pressure on scale; n = number of revolutions per minute.

By adopting a length of lever equal to 63 inches, the formula may be reduced to the simple form:

$$\text{B. H. P.} = \frac{n\ p}{1000}$$

If a length of lever equal to $31\frac{1}{2}$ inches is used the formula is as follows:

$$\text{B. H. P.} = \frac{n\ p}{2000}$$

Problem: If the weight on the scales equals 75 lbs. and the number of revolutions equals 800 and the length of the arm is 63 inches, what is the B. H. P?

Rule:

$$75 \times 800 = 60000 \qquad \frac{60000}{1000} = 60 \text{ B. H. P. Ans.}$$

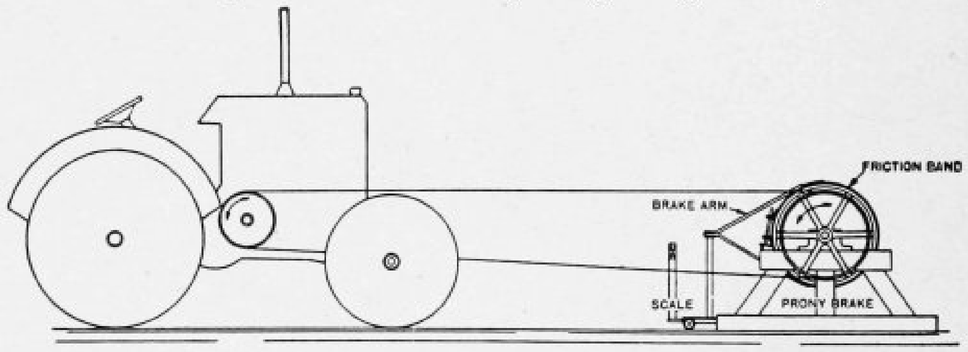
20. Draw-Bar Horse-Power. We often hear draw-bar horse-power referred to, and therefore, shall include an explanation of its calculation. Being the power delivered at the draw-bar, it is the traction which the operator has at his disposal in pulling loads.

Definition of Draw-Bar Horse-Power. To designate the power of a motor, steam engine or gas tractor the term Horse-Power is used. Horse-power is a unit of power and represents the measure or rate of doing work. One horse power represents the amount of power required in lifting 33,000 pounds one foot in one minute, or the equivalent.

The unit of work is the foot pound, and is the amount of work required to lift one pound through a distance of one foot. Horse power, therefore, is the amount of power required in doing 33,000 foot pounds of work in one minute. This may be accomplished by lifting a weight of one pound through a distance of 33,000 feet in one minute; or 550 lbs. one foot per second or 165 pounds through a distance of 200 feet in one minute,

since 200 x 165 = 33,000.

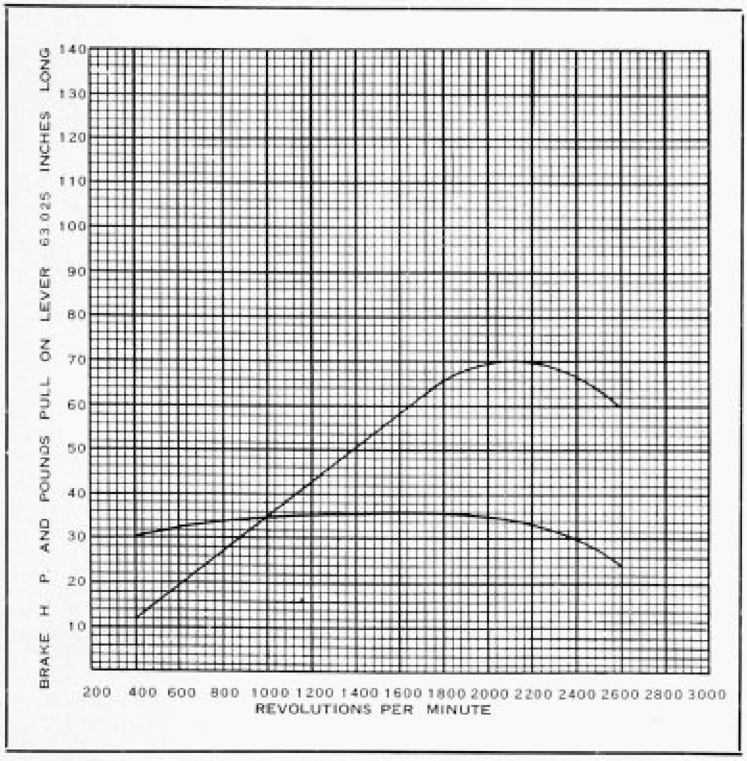
It makes no difference how the power is applied or how the work is accomplished as long as the force,



Use of Prony Brake in Determining Brake Horse Power

FIG. 5

The Horsepower Chart of an Eight Cylinder Motor $3\frac{1}{4}$x5



The figures along the left-hand edge of the chart, reading from the bottom up, show the horsepower developed. The Horizontal figures at the bottom, reading from left to right, show the number of revolutions per minute or the speed of the motor.

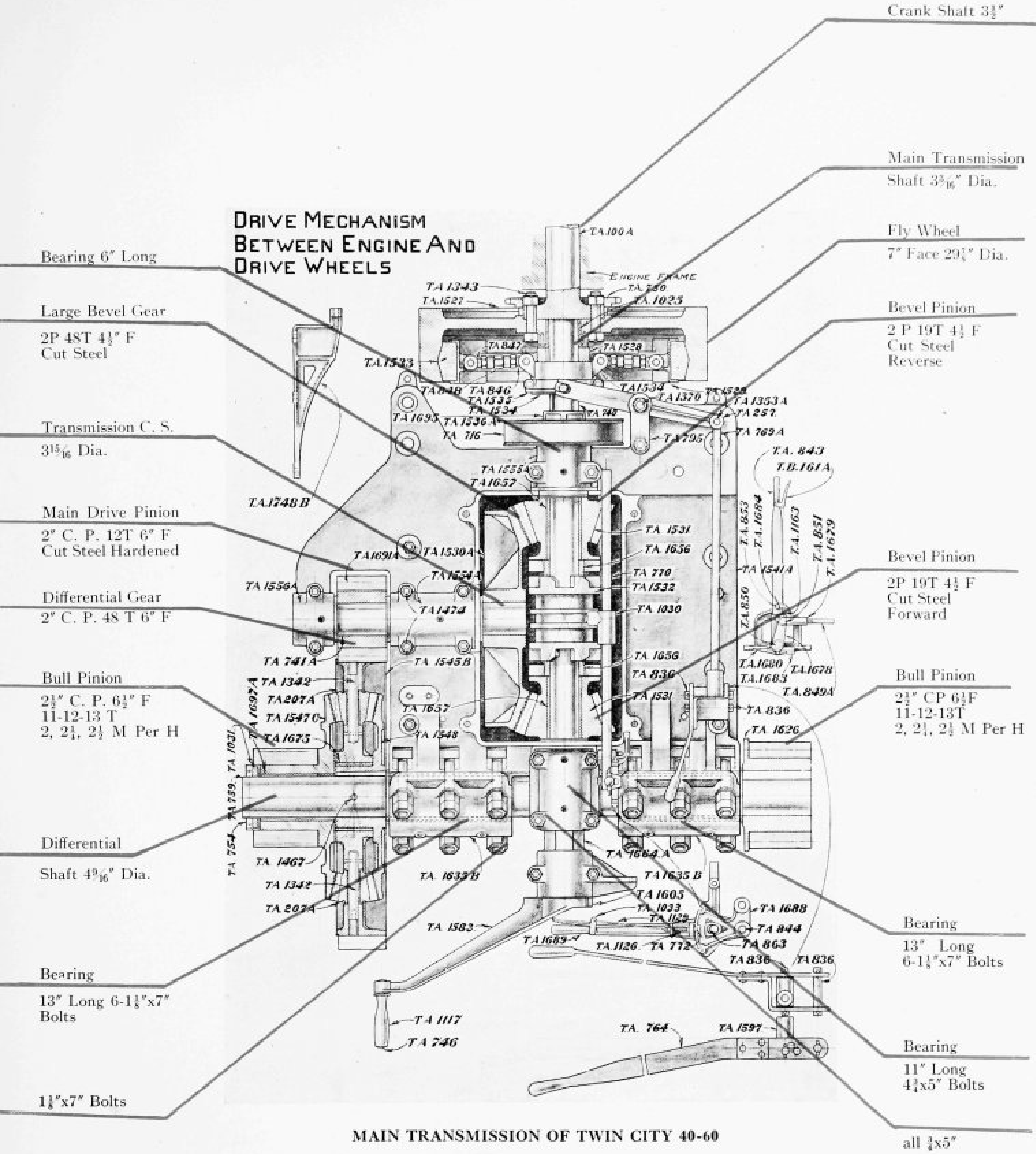
The line starting near the lower left hand corner and running diagonally up to the right with a curve at the top, is the "power curve" starting with 12 horsepower at 400 R. P. M. (revolutions per miunte), it increases to 70 horsepower at 2200 R. P. M., and then drops back to 60 horsepower at 2600 R P. M., by starting at a point on the Horizontal column corresponding to the number of R. P. M. desired and drawing a line up until it intersects the power curve, from the point where the vertical line intersects the power curve draw a line to the left column of figures at the point where this Horizontal line intersects the left-hand Vertical column of figures indicates the B. H. P. to be expected.

The line running Horizontally across the diagram, represent the torque curve, and shows the pull on the level at 63.025 inches, shown by the left-hand column of figures equals 35 lbs., from the curve it will be noticed that the torque remains practically constant from 400 to 2400 R .P. M., that is with wide open throttle at all speeds, by mutiplying the pressure shown on the left-hand column of figures by 63.025=2205.875 equals the number of lbs. one inch torque on the crank shaft.

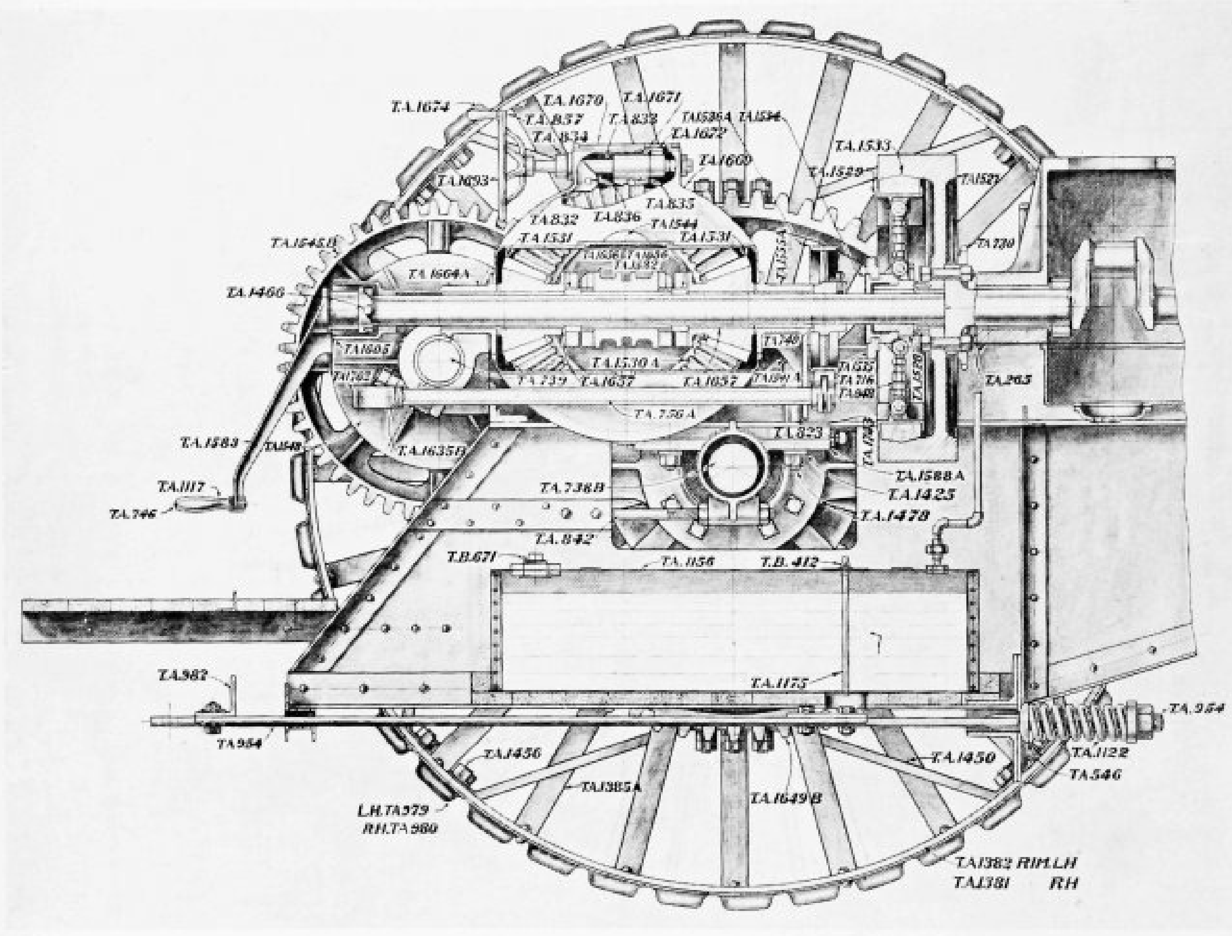
By dividing this number by the desired number of inch the torque can be found.

Problem: with 2205.875 lbs. one inch. torque what is the 15 inch torque.

Example: 2205.875÷15=147.0583 equals the number of lbs., 15 in. torque or the pressure at the rim of a 30 inch pully.



MAIN TRANSMISSION OF TWIN CITY 40-60



DRIVING GEAR, TWIN CITY 40-60

the distance it acts through, and the time can be determined.

FIG. 6

In Fig. 6 a horse is shown lifting a weight of 150 pounds. If this weight were lifted through a height of 22 feet ten times in one minute (220 feet) the work accomplished would be equal to one horse power,

since 150 x 220 = 33,000.

A work horse is capable of exerting a continuous pull equal to about one-seventh of its weight. At most field work the horse is required to maintain a pull of about 160 pounds on the traces, although the pull of an implement or a load always varies. For a short period of time, however, a horse is capable of exerting a pull of much more than this, but such over-exertion cannot be maintained without injury to the horse.

The weight and the draft of a load should not be confused. The draft of a load of one ton on a wagon on a hard road may be less than 100 pounds, while in a field a pull of probably 300 pounds would be required to move that same load. It is the actual pull in pounds that determines the horsepower required to pull a load or an implement.

There is no connection between the term horse power used in indicating the power of an engine and the power developed by a horse. A good horse is, however, capable of developing approximately one horse power continually while at work.

The same formula for its determination is used as in B. H. P., namely, the pounds exerted times the feet traveled per minute, divided by 33,000.

Example.

Supposing the engine is exerting a pull at the draw-bar of 3,750 pounds, at the rate of two miles per hour. Two miles per hour is the same as 176 feet per minute, hence the D. B. H. P. of the tractor is

$$\frac{176 \times 3{,}750}{33{,}000} = 20.$$

From the above we find that a tractor traveling at the rate of two miles an hour will have to exert a pull of 187½ pounds for each D. B. H. P. developed. Below we give a diagram showing the pounds pull exerted per draw-bar H. P. at different rates of travel of the engine.

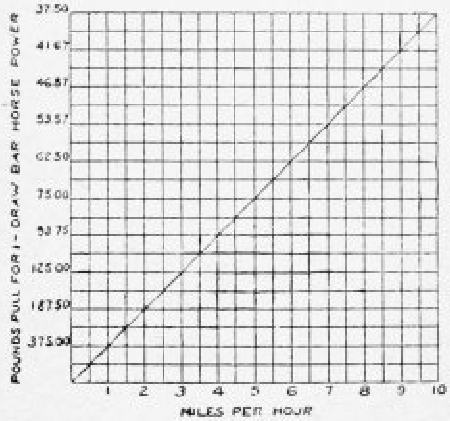


FIG. 7

Explanation: Of Fig. 7. The figures at the bottom of the diagram represents miles per hour. The column to the left represents pounds pull per D. B. H. P.

Problem: What is the pounds pull per D. B. H. P. for a tractor traveling three miles per hour?

Rule: From a point on the horizontal column of figures representing three miles per hour, draw a vertical line intersecting the line running diagonally across the diagram, now draw a horizontal line to the vertical column at the left. We find it requires 125 pounds per D. B. H. P. By multiplying the number of pounds thus determined by the number of D. B. H. P. required we obtain the total D. B. H. P.

Problem: What is the draw bar pull of a 25 D. B. H. P. at three miles per hour.

Rule: If it requires 125 pounds per D. B. H. P. at three miles per hour 125 X 25 = 3,125 the number of pounds required

The drawbar pull of a tractor is determined by means of some form of traction dynamometer, such

Draw Bar Dynamometer

FIG. 8

as shown at Fig. 8. This instrument is placed between the movable body, or load. The tractor is started and the maximum amount of pull is indicated in pounds upon the gauge. This dynamometer may also be used to indicate the tension in tow-line or draft gear. As will be apparent, an instrument of this nature may be used very easily in making comparative tests between the tractive power or drawbar pull of various forms of engine and will also indicate the amount of draft needed to haul a wagon, pull a plough or do any other work.

The most easily understood rating, and one generally used in describing a tractor to the average farmer is the horse equivalent horse power. This enables one who wishes to know how the work of a tractor will compare with the actual work of farm horses to make an intelligent approximation. It is difficult to make exact comparisons inasmuch as no two horses can do exactly the same amount of work, and furthermore the average animal is more flexible in its exertions than any tractor. We have seen that the horse is able to exert two or three times its average power for a short distance in the field, while a tractor has no such great overload capacity.

The horse equivalent power of a tractor is considerably less than its drawbar horse power and represents the number of actual average farm horse that a tractor can replace in every-day work. It may be approximated by dividing the drawbar pull, exerted by a tractor traveling at two miles an hour by 200. If the tractor shows a drawbar pull of 3,000 pounds at that speed its drawbar horse power or horse equivalent power will be equal to that produced by 15 animals of 1400 lbs. weight.

Hyatt Dynamometer. The Hyatt Dynamometer is one of the hydrostatic type consisting of two units: A Pressure Gauge, which is used as a hitch between the plow and the tractor, and the Recording Instrument, which records the draw-bar pull, the distance traveled and the elapsed time.

Pressure Unit. The Pressure Unit is always hitched between the tractor and the load to be pulled. It consists of a rubber bag, filled with a liquid, to which the pressure is applied by a piston having an area of 10 square inches. The draw-bar pull is transmitted to the piston by a lever having three hitch points giving three different ratios of draw-bar pull to pressure on the piston. The three hitches permit the Dynamometer to be used in testing tractors of widely differing powers; the direct or 1-1 hitch having a maximum capacity of 3,000 pounds, the 2-1 hitch, 6,000 pounds, and the 4-1 hitch, 12,000 pounds draw-bar pull.

Recording Instrument. The Recording Instrument is of special design, consisting principally of a Bristol recording pressure gauge. It is connected to the Pressure Unit by a flexible brass tube, which conveys the liquid under pressure from the rubber bag to the Bourdon spring which actuates the pen arm, thus recording the draw-bar pull. A needle valve, inserted in the pressure line, may be adjusted to control the flow of liquid and dampen excessive vibration of the pen.

The chart shown in Fig. 9 is divided into spaces by a series of concentric circles, over which the pen travels, recording the draw-bar pull. With the 1-1 hitch each space represents a pull of 250 pounds, with the 2-1 hitch, 500 pounds, and with the 4-1 hitch, 1000 pounds.

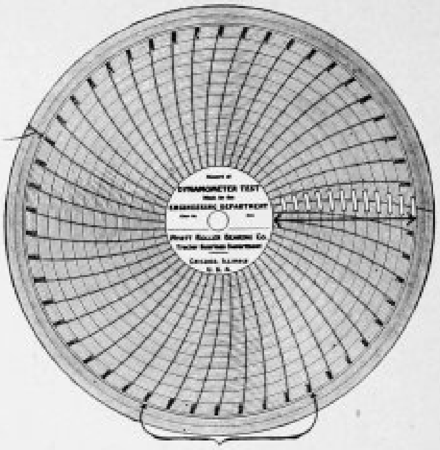


FIG. 9

The chart is caused to revolve by an odometer wheel which rolls on the ground and is connected to the Recording Instrument by a flexible shaft and suitable gearing. The chart is divided about its circumference into 50 equal parts, each representing a distance traveled of 100 feet, the full chart representing a run of 5,000 feet.

Another pen records the elapsed time on the annular space at the margin of the chart. This space is subdivided into ten smaller spaces, each representing six seconds of time. A clock in the Recorder case, fitted with a special cam, trips the time pen at one minute intervals, and the fractions of a minute may be estimated by counting the number of smaller spaces over which the pen has traveled.

Method of Computing Draw-bar Horse Power. The Dynamometer chart tells the entire story of the test. From it is obtained all data for computing the final results.

The heavy line "B" on the chart shown in Fig. 10 represents the actual draw-bar pull, and an average of this is obtained by tracing the line with a radii averaging instrument. The average draw-bar pull may be divided by the number of plow bottoms, if the load was a plow, giving the pounds of draft per bottom. From the red line at the margin of the chart the distance traveled and time consumed is determined.

Each full diagonal line represents one minute of travel and the space between any two of the radial lines indicates the distance traveled in the corresponding minute, unless the diagonal line is broken. If the diagonal line is complete, the space between the corresponding radial lines represents the distance traveled for a fraction of a minute, which may be determined by counting the number of small spaces over which the pen has moved in that time.

Having the average draw-bar pull, time and dis-

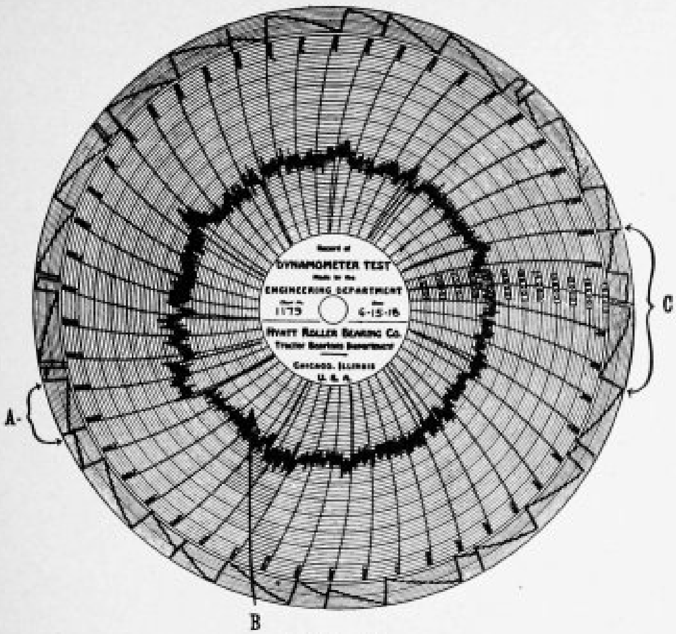


FIG. 10

tance, the average draw-bar horse power may be determined by the formula:

$$\text{Av. D-B-H-P} = \frac{\text{Average draw-bar pull in lbs. x dist. traveled in ft.}}{\text{Elapsed time in minutes x 33,000}}$$

21. Torque. Torque is the amount of twisting stain on a shaft, one inch from the center, and is termed by engines as one inch torque. The torque on a shaft may be calculated by multiplying the pressure applied by the distance from the center of the shaft.

Problem: If the pull on a belt is 200 pounds and the pulley on which it is running is 40 inches in diameter, what is the torque on the shaft?

Rule: 200 X 20 = 4000, the number of pounds one inch torque. Ans.

In the above problem 200 is the pressure applied, 20 is the distance from the point of application to the center of the shaft, or the radius of the pulley.

While 4000 is the number of pounds in a one inch torque, 200 is number of pounds in a 20 inch torque.

If a break is used for determining the power transmitted on a shaft, the torque on the shaft may be obtained by multiplying the pressure on the scale by the length of the lever in inches equals one inch torque on the shaft.

22. Torque on the Crank Shaft. The torque on the crank shaft may be obtained by the following formula:

M. E. P. X Area X crank throw in inches X .6366 X the mechanical efficiency equals the one inch torque.

Problem 1: What is the torque on the crank shaft of a four cylinder four stroke cycle internal combustion motor, 5 x 6 with 84 pounds M. E. P.

Rule:

5 X 5 X .7854 = 19.6350 equals area of piston.

19.6350 X 84 = 1649.34 the average pressure applied.

1649.34 X 3 X .6366 X .90 = 2,834.91, the number of pounds one inch torque on the crank shaft. Ans.

Having obtained the torque on the crank shaft, the pressure at the rim of the belt pulley may be obtained by dividing the torque by the radius of the pulley. Or the radius of the pitch circle of a gear equals the pressure at the pitch line.

Problem 2: With 2,835 pounds torque on the crank-shaft what is the pressure at the rim of a 20 inch pulley on the crank shaft extension or clutch shaft?

Rule: 2,835 ÷ 10 = 283.5 equals the number of pounds pressure at the rim of the drive pulley.

Problem 3: With 2,835 pounds torque on the crank shaft, what is the pressure at the pitch line of a five inch pinion on the clutch shaft?

Rule: 2,835 ÷ 2.5 = 1,134 the number of pounds pressure at the pitch line of the first gear reduction.

Problem 4: With 1,134 pounds at the pitch line of a 20 inch gear what is the torque on the first transmission shaft?

Rule: 1,134 ÷ 10 = 11,340 equals the number of pounds one inch torque on the shaft. Less the loss by friction at the pitch line of the gears, also at the bearings, while we find in a previous chapter that a well designed cut gear is about 98 per cent efficient and a well designed bearing the same. However in practice it is customary to deduct five per cent for loss at the pitch line of the gears and 2.5 per cent for each bearing making a 10 per cent loss for each gear reduction.

Applying the same to the above we have.

Rule: 11,340 X 90 = 10,206, the number of pounds torque after deducting for the loss by friction.

Problem 5: With 10,206 pounds torque on the first transmission shaft what is the pressure at the pitch line of the second drive pinion? The pinion is 6 inches pitch diameter.

Rule: 10,206 ÷ 3 = 3,402 equals the number of pounds at the pitch line of the differential gear, or the second gear reduction.

Problem 6: With 3,402 pounds at the pitch line of a 24 inch pitch diameter differential gear, what is the torque on the differential shaft?

Rule: 3,402 X 12 = 40,824 X 90 = 36,741.6 equals the torque.

Problem 7: With 36,741.6 pounds on the differential shaft what is the pressure at the pitch line of the 7 inch master pinions?

Rule: 36,741 ÷ 3.5 = 10,497.6 equals the number of pounds at the pitch line of the master pinions.

Problem 8: With 10,497.6 pounds pressure at the pitch line of the master gear, with a 30 inch pitch diameter what is the torque on the rear axle or rear wheel hub, where it is applied to the driving wheels?

Rule: 10,497.6 X 15 = 157,464 X .90 = 14,717.6 equals the number of pounds torque on the rear axle.

Problem 9: With 141,717.6 pounds torque on the rear axle, what pressure will be applied at the rim of the 62 inch drive wheels?

Rule: 141,717.6 ÷ 31 = 4,571.4 equals the number of pounds pressure applied at the rim of the drive wheels, which have a tendency to drive the tractor forward (or traction) as it requires about 350 pounds per ton to move a tractor over a stubble field, from practical experience (it must get the highest traction efficiency), a tractor should weigh twice the draw-bar pull. This tractor should weigh 9,000 pounds or 4½ tons.

4.5 X 350 = 1,575 equals the number of pounds traction required to move the tractor over the field, 4,571.4 + 1,575 = 2,996 equals the number of pounds at the draw bar.

Problem 10: If a tractor has 2,996 pounds pull at the draw bar and travels at 2½ miles per hour, what is the D. B. H. P?

Rule: 2½ miles per hour equals 220 feet per minute.

2,996 X 220 = 659,120 ft. lbs.

659,120 ÷ 33,000 = 19.9733 equals the D. B. H. P. Ans.

23. The Pressure on the Bearings. The pressure on the bearings may be obtained by finding the torque on the shaft and dividing the torque by the number of bearings.

Problem: If the differential shaft is four inches in diameter, has two bearings eight inches long, and there is 36,741.6 pounds torque on the shaft, what is the pressure per square inch on the bearings?

Rule: 4 x 8 = 32, the number of square inches area of each bearing.

32 x 2 = 64, the area of both bearings.

36,741.6 ÷ 64 = 574 equals the number of pounds pressure per square inch projected area. Ans.

The pressure allowable on bearings depend on the speed of the shaft, i e., the speed at which the circumference of the shaft is traveling this speed in tractor motors which give the best service in the field is about 500 feet per minute with an average bearing pressure of about 45 pounds per square inch projected area of crank shaft bearings. There is a wide range of bearing sizes in tractor motors. To give good service the bearings should be ample, with low working pressure, so that a film of oil exists between the revolving and stationary members. In the later motors the bearings i. e. the crank shaft and crank pin bearings are each equal to one-half the piston area. This makes it necessary that the crank pin and crank shaft diameters equal one-half the cylinder bore, and the journal length equal one and one-half their diameter. This would give a bearing pressure of 500 pounds per square inch of bearing surface at the beginning of the power stroke, 170 pounds average pressure per square inch during the power stroke, and about 45 pounds pressure per square inch of bearing area during the complete cycle. The piston pin should be .33 the cylinder bore and the bearing length .5 the cylinder bore. The cam shaft diameter .25 the cylinder bore and the length of the journal twice the diameter. These dimensions have been found to give good service in the field, and insure a long life motor with a minimum of upkeep and with a high mechanical efficiency.

24. Tractor Construction. In the smaller tractors the unit construction is being used extensively, i. e. The motor base, transmission and tractor frame are cast in one unit. In some cases two or more units are bolted together. In this construction it is impossible for the different members to become out of alignment, and makes it possible to inclose all working parts, which may then operate in an oil bath. While the larger tractors have substantial frames made of structural shapes upon which the different units are mounted. In the later construction it is advisable to have each unit three point suspended to prevent strains and breakage, if the frame should spring while traveling over uneven ground.

While the four stroke cycle motor is universally adopted, there is a wide range in design, and construction, of tractor parts, i. e., the motor may be single cylinder, horizontal, single cylinder vertical, two cylinder opposed, two cylinder paired vertical, two cylinder paired horizontal, four-cylinder opposed, four-cylinder vertical, four-cylinders paired horizontal, six-cylinder vertical, eight-cylinder V type. The cylinders may be cast singly, in pairs, what is known as twin mounting or **en bloc,** i. e., where all four cylinders are in one casting. In some tractors the motor is mounted cross-wise of the frame while others are mounted lengthwise of the frame, similar to that of an automobile. In either case the motor may be of separate construction and bolted to the frame, or integral with the frame and transmission case. The latter seems to be gaining popularity, as it prevents the working parts from getting out of alignment. The method of mounting the motor lengthwise of the frame makes a narrow tractor design possible and emphasises the accessability, two very important points in tractor construction.

25. The Width of the Tractor. The width of the tractor should be no wider than its load, i. e. The draft should always be in the center of the draw bar, if not in the center a side draft is certain and the drive wheel nearest to the hitch is forced to pull the greater percentage of the load, which is usually the wheel running in the furrow or on the edge of the furrow. To get the best service from a tractor the driving wheels should be so located as to pull the same percentage of the load and to work under exactly the same conditions. In later constructions there is a tendency toward having both wheels travel on the land to be ploughed. To give both drivers equal footing, the driver should be some distance from the furrow. If too close the ground will give way under the driver and lose its footing. The other driver has a tendency to throw the front end toward the furrow and sometimes over on the ploughed land, making it impossible to do an even job of plowing or to keep a straight furrow, and to leave no unploughed land. The four wheel tractor having two drive wheels and two guiding wheels is most popular among tractor users. Where two driving wheels are used a differential gear is necessary.

Therefore to obtain the best service in ploughing the drive wheels should be as close together as practical and as far from the furrow as possible, making the rear of the tractor very narrow. With this construction the drivers are working under the same conditions and if one driver should have better footing than the other the tendency towards slueing the front end would be reduced to a minimum and by constructing the tractor with a very low center of gravity it is practical to keep the tractor quite narrow without danger of tipping over on side hills. It is understood that in traveling over stubble or ploughed fields the ground conditions are continually changing, and the footing of the drivers change, i. e. We may have good footing on both drivers. Then after traveling a few feet we have a good footing first on one driver and then on the other. The farther the drivers are apart the greater the tendency to throw the front end first one way, then the other, making it difficult to steer and to do a good clean job of ploughing. In some tractors this important point has been overlooked. The rear is made too wide and the front too light, so that it was almost impossible to keep the tractor near the furrow, and in many cases the burden of ploughing is taken off the horse and placed upon the tractor operator.

26. Multiple Cylinder Tractor Motors: The tendency is towards increasing the number of cylinders on tractor motors. There are several reasons for this.

1st. We understand the internal combustion motor derives its power from a series of impulses or shocks. Therefore the more severe the shock the more rapidly the parts become crystallized, and the shorter the life of the motor.

2nd. The greater the number of cylinders, the more numerous the impulses, and the lighter the shock. The shocks are also more evenly distributed over the teeth in the gear train which comprises the transmission, and gives a steadier motion, thus insuring longer life to the entire machine.

3rd: The greater the number of cylinders the smaller the cylinder bore per horse power, and the smaller the intake and exhause valves, making it possible for all parts to be closer to water, keeping them cool, thus allowing higher speed and higher compression. All this is conducive to higher efficiency and longer life.

4th. Increasing the number of cylinders and increasing the speed of the piston, also increases the air velocity in the intake manifold, by opening one intake valve before the other closes, tending to keep the velocity of the ingoing charge constant, thus keeping the heavy particles of fuels in suspension and broken up. It is important, in order to get high efficiency in a gas tractor, that the fuels be broken up into fine molecules and not only broken up at the carburetor, but delivered in the same state to the combustion chamber. Therefore it is conducive to higher efficiency to have higher speed and constant velocity of the in-going charge. So we see that the number of cylinders, and the speed is sure to increase as the user becomes better acquainted with the real advantages obtained by the increased number of cylinders.

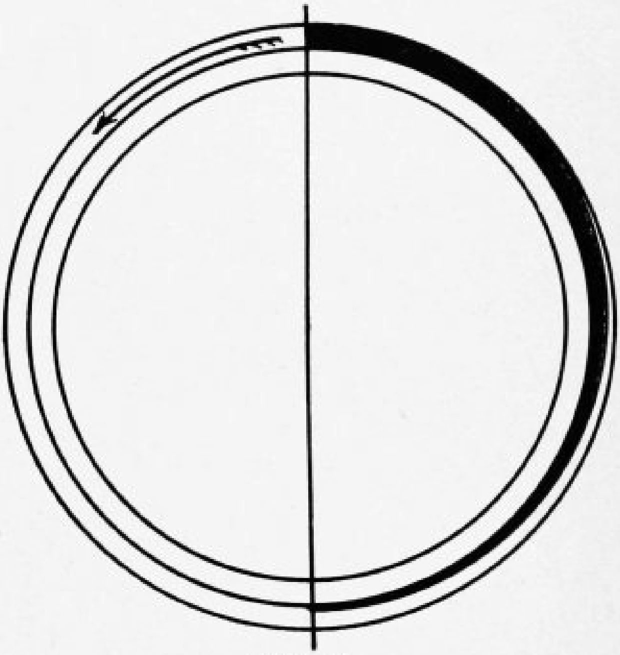


FIG. 11

Fig. 11 is a power diagram for a one cylinder motor. The heavy black portion shows the part of the cycle through which a pressure is exerted on the piston. The width of the black portion represents the pressure in pounds per square inch exerted on the piston. The heavier portion represents a pressure of 248 pounds pressure per square inch, applied to the piston at the beginning of the power stroke, and which diminishes as the piston travels outward with an average pressure of 84 pounds per square inch piston area. The outer circle represents the first revolution, the inner circle the second revolution.

The diagram shows that pressure is applied to the piston only 180 degrees of the 720 degrees of the cycle, and shows a lapse of 540 degrees between impulses.

Fig. 12 is a power diagram of a two cylinder op-

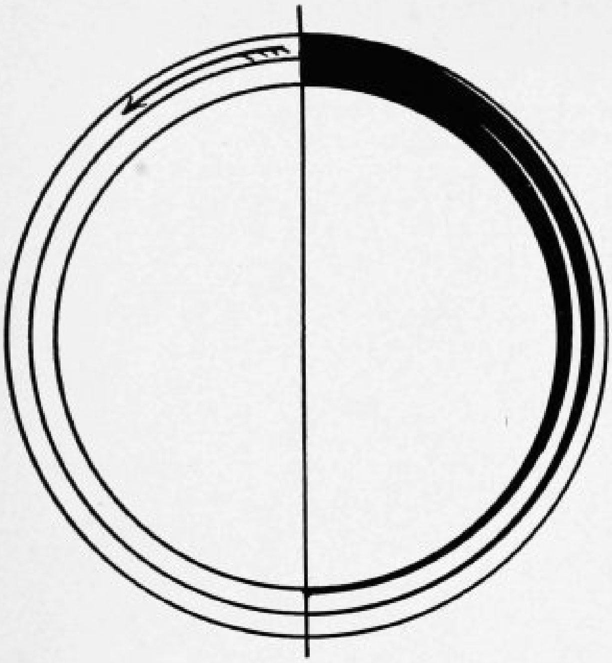


FIG. 12

posed motor, balanced both explosively and mechanically; also of a two cylinder motor paired and balanced explosively but not mechanically. In these motors there is a power impulse every 360 degrees and a lapse of 180 degrees between impulses.

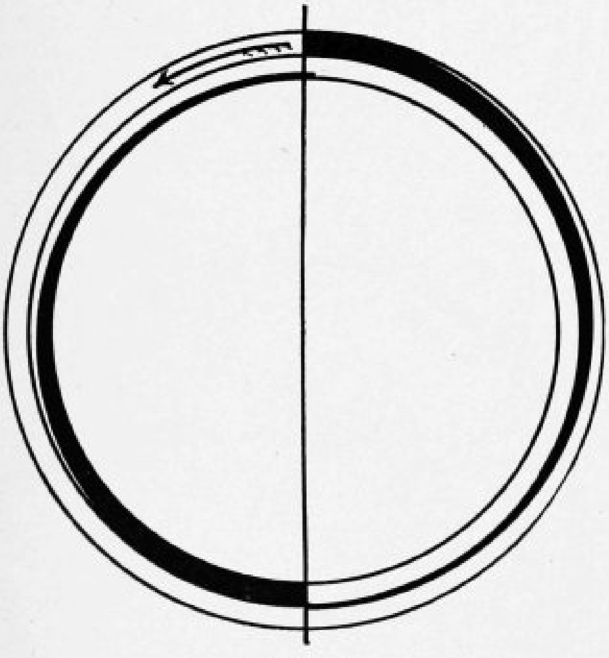


FIG. 13

Fig. 13 is a power diagram of a two cylinder motor paired and balanced mechanically but not explosively. In this motor there are two impulses in the first revolution and none in the second and a lapse of 360 degrees between the second impulse and the third.

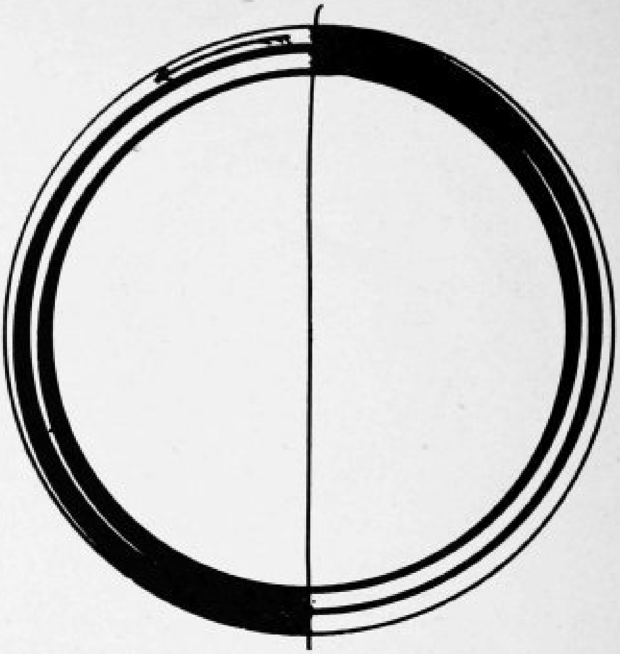


FIG. 14

Fig. 14 is a power diagram of a four cylinder motor, balanced both explosively and mechanically, two impulses on each revolution of the crank shaft.

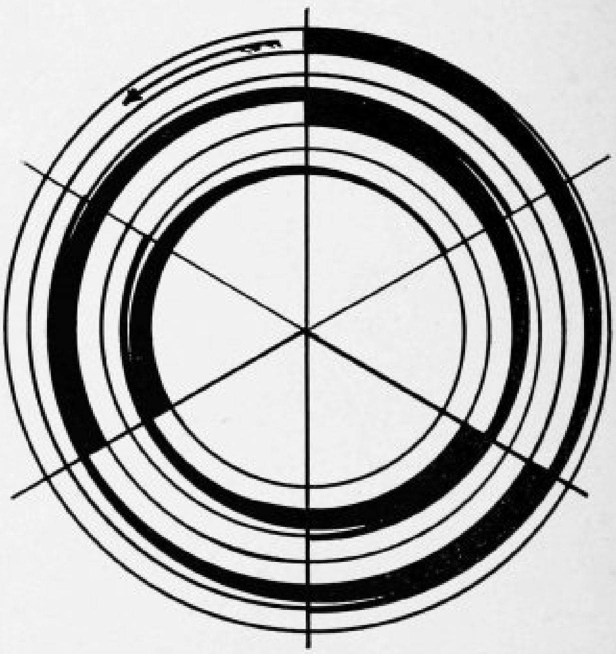


FIG. 15

Fig. 15 is a power diagram of a six cylinder motor balanced both explosively and mechanically. It has three impulses on each revolution of the crank-shaft, and one impulse overlaps the other 60 degrees.

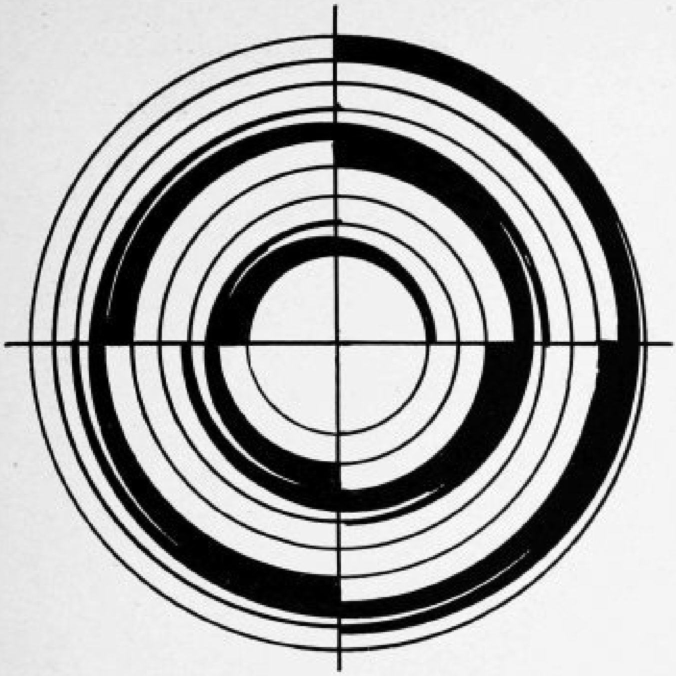


FIG. 16

Fig. 16 is a power diagram of an eight cylinder motor balanced both explosively and mechanically. This motor has four impulses on each revolution of the crank-shaft and one power impulse overlaps the other 90 degrees.

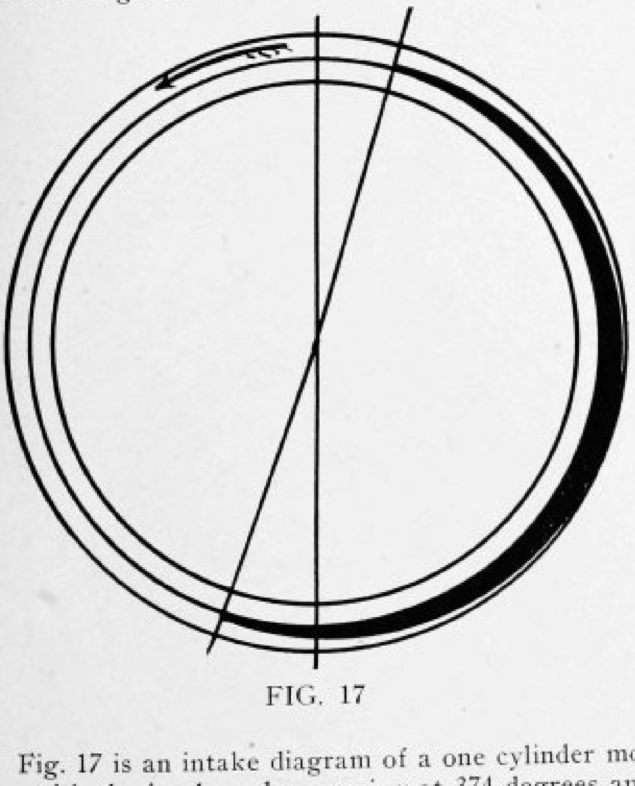


FIG. 17

Fig. 17 is an intake diagram of a one cylinder motor, with the intake valve opening at 374 degrees and closing at 556 degrees in the cycle. The heavy black portion represents the intake event, the width represents the amount of negative pressure during the event, and shows the greatest negative pressure at 450 degrees in the cycle when the piston is traveling out the fastest, and the velocity in the intake manifold is the highest at this point. The light portion of the diagram represents the part of the cycle where there is no intake valve open which in this motor equals 538 degrees. It is during this portion of the cycle that the heavy particles or heavy ends, as they are sometimes called, drop to the bottom of the manifold and are taken in at the next intake event in the shape of large drops or globules which cause poor combustion, carbon deposits and often short circuits the spark plug.

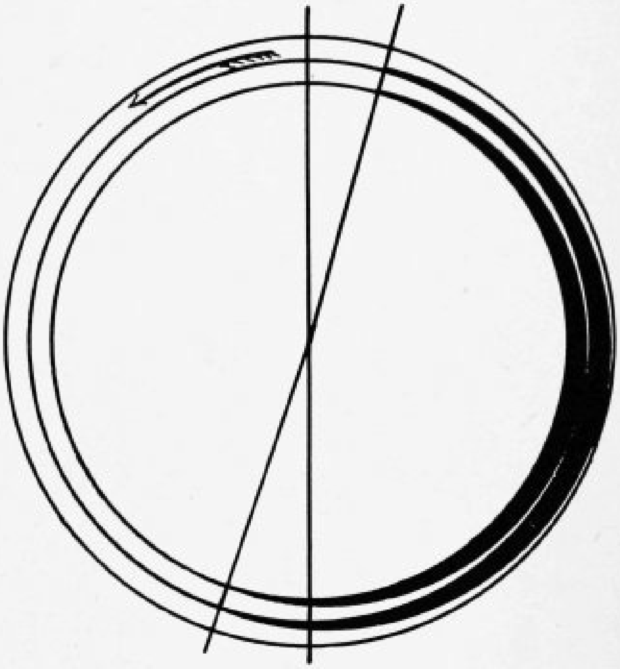


FIG. 18

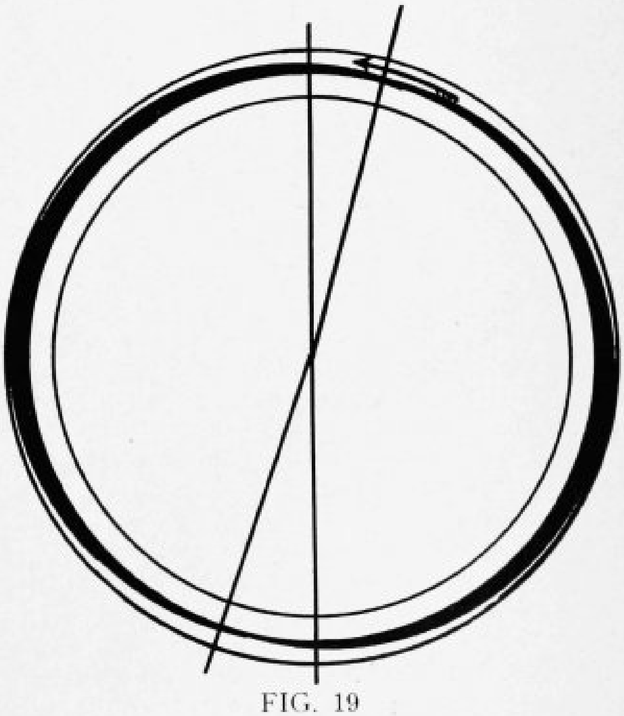


FIG. 19

Fig. 18 is an intake diagram of a two cylinder opposed motor balanced both explosively and mechanically or a two cylinder paired balanced explosively but not mechanically. In this motor there is one intake event in each revolution and an elapse of 178 degrees between intake events. It is during this time that the heavy particles or ends drop to the bottom of the manifold, and then are taken into the cylinder when the next intake valve opens which causes poor combustion, carbon deposits, and sometimes short circuits the spark plugs.

Fig. 19 is an intake diagram of a two cylinder motor where the cylinders are paired and balanced mechanically but not explosively. There are two intake events in one revolution and none in the next, with an elapse of 356 degrees between the second and third intake event. It is during this time that the heavy particles or ends drop to the bottom of the manifold, are taken into the cylinder when the next intake valve opens which cause poor combustion and carbon deposits in that particular cylinder and sometimes short circuits the spark plug.

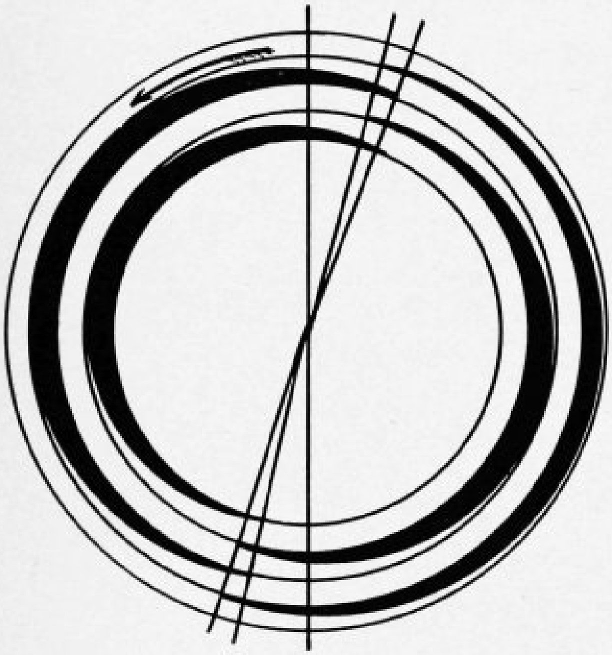


FIG. 20

Fig. 20 is an intake diagram of a four cylinder motor, balanced both explosively and mechanically. In this motor there are two intake events during each revolution of the crank shaft each event overlapping the other two degrees, which tends to keep the velocity constant, holds the heavy particle in suspension and permitting a more perfect combustion which in turn reduces carbon deposits.

Fig. 21 is an intake diagram of a six cylinder motor, balanced both explosively and mechanically. In this motor there are three intake events during each revolution of the crank shaft, each event overlapping the other 62 degrees which tends to keep the velocity constant, holds the heavy particles in suspension and permits more perfect combustion, thus keeping down carbon deposits.

FIG. 21

Fig. 22 is an intake diagram of an eight cylinder motor, balanced both explosively and mechanically. In this motor there are four intake events during each revolution of the crank shaft, each event overlapping the other 92 degrees which tends to keep the velocity constant and the heavy particles in suspension, and by obtaining a more perfect combustion reduces carbon deposit. In the above diagrams the same valve timing is used, although in practice, as the number

FIG. 22

FIG. 23

of cylinders increase the piston speed increases, the valve timing changes, and by lengthening the intake event the overlapping is still more pronounced than is shown in the diagrams, a distinct advantage.

From the above diagrams it is plainly shown that the multiple cylinder motor increases both the thermol and the mechanical efficiency.

Fig. 23 is a diagram of the master gear on a tractor traveling two miles per hour with five foot driving wheels. The diagram is laid out for a one cylinder motor at 400 R. P. M. with a 38 to I gear reduction; a two cylinder motor balanced explosively making 500 R. P. M. with a 45 to I gear reduction, and a four cylinder motor balanced explosively making 800 R. P. M. with a 72 to I gear reduction. In the diagram the heavy black spaces represent the power impulses. The width of the spaces represents the relative pressure during the power stroke on the gear tooth with the different motors. The light portion or space between the black spaces represents the elapsed time between one power impulse and the other and its effect upon the master gear, in the tractor. If the master gear shown in the tractor above referred to contains 72 teeth and the power impulses occur as shown in Fig. 23 with the one cylinder motor the power impulse would occur on every fourth tooth on the master gear. With the two cylinder motor the power impulse would occur at every 1.6 tooth. With a four cylinder motor the power impulse would occur on each tooth. The elapsed time between impulses and the number of teeth passing a given point becomes less with the increasing number of cylinders and the severeness of the shock grows correspondingly less, the pressure applied is more uniform and the torque more continuous, as the number of cylinders and revolutions increase. This decreases crystalliation or metal fatigue as it is sometimes called by the designing engineer, and increaes the mechanical efficiency. Reduces vibration, vibration is as injurious to the human body as to the machine and the high speed multiple cylinder motor will not only prolong the life of the tractor but will lengthen the life of the operator as well.

27. Tractor Equilibrium. Under certain conditions, tractors show an inclination to lift the front wheels from the ground. In fact, occasionally we hear of a tractor lifting up far enough and powerfully enough to tip over backwards, possibly resulting in the death of its operator. This dangerous action of a tractor is due to what may be termed "loss of equilibrium." A properly designed tractor should remain in equilibrium under all but the most unusual of conditions.

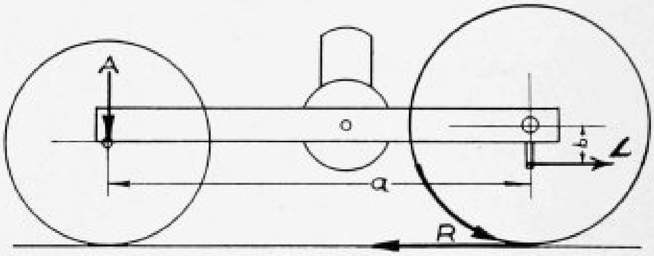


FIG. 24

The forces which act upon the equilibrium of a tractor (see Fig. 24) are three—the draw-bar load, the torque on the rear axle, and the dead weight carried by the front wheels. Since the draw-bar load and the dead weight on the front wheels both exert a down-

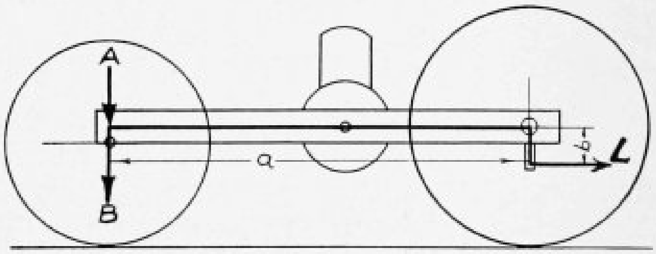


FIG. 25

ward pressure (see Fig. 25), while the torque on the rear axle exerts a lifting force (see Fig. 26) upon the front end of the tractor. It is quite evident that the equilibrium of the tractor depends upon the sum of the downward forces being at least as great as the lifting force C exerted on the front end by the torque on the rear axle. For a margin of safety, the downward pressure on the front end (A + B) should ex-

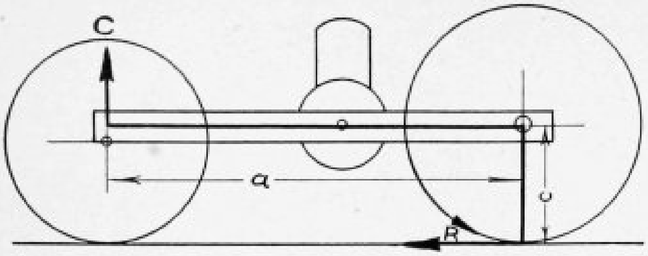


FIG. 26

ceed the lifting force C by several hundred pounds. This excess weight should be sufficient to maintain equilibrium under all reasonable conditions. As the frame of the tractor revolves on the rear axle when out of equilibrium, the three forces will act about the rear axles as a center. The pressure resulting from the three forces are best expressed in pounds pressure applied to the center of the front wheel, that is, at a distance equal to the length of the wheel-base from the center of the rear axle. Thus, it is apparent that, on the front axle, the dead weight, which is usually about one-third of the weight of the tractor W, has a force of A pounds at the distance of the wheel-base, or **a** inches from the center of the rear axle. The torque caused by the load L would equal the pounds of the load at the distance b, which is the draw-bar drop in inches. At one inch from the center of the rear axle, the pressure would equal the load L multiplied by the draw-bar drop b. The down pressure on the front wheel would equal (L lb. x b) divided by the wheel-base **a.** The torque on the rear axle, at one inch from the center, equals the number of pounds of rim pressure R (R = L) of the drive-wheel multiplied by the radius of the drivewheel. Dividing this number by the wheel-base a, we find that the lifting effect on the front wheel equals (R x c) ÷ **a**. When the tractor is in exact equilibrium, with no extra weight on the front end for a margin of safety,—

$$A + B = C$$

If the weight on the front wheel is increased by a few hundred pounds, for a margin of safety,—

$$A + B - C = \text{M. P. D.}$$

Expressing A, B and C in terms of L, R, W, a, b, and c,

$$\frac{W}{3} + \frac{L \times b}{a} - \frac{R \times c}{a} = \text{M. D. P.} = \text{(mean down pressure)}$$

If more convenient, the formula may be stated in words, as,—

$$\frac{\text{Wt. of Tractor}}{3} + \frac{\text{Load x Drawbar drop}}{\text{Wheelbase}} - \frac{\text{Rim Pr. x Drive-wheel Radius}}{\text{Wheelbase}} = \text{M.D.P.}$$

It is clear that the weight bearing down on the front wheel, $\frac{W}{3} + \frac{L \times b}{a}$, must always be sufficiently in excess of the upward pressure, $\frac{R \times c}{a}$, that the mean down pressure on the front wheel will be several hundred pounds, under normal conditions.

Suppose we consider a tractor having the following specifications and conditions:

W	equals	6000 lbs.
a	equals	80 lbs.
b	equals	10 lbs.
c	equals	30 lbs.
L	equals	3000 lbs.

Then, substituting these values in the formula, we have,—

$$\frac{6000 \text{ lbs.}}{3} + \frac{3000 \text{ lbs.} \times 10}{80} - \frac{30 \times 3000 \text{ lbs.}}{80} = \text{M. D. P.}$$

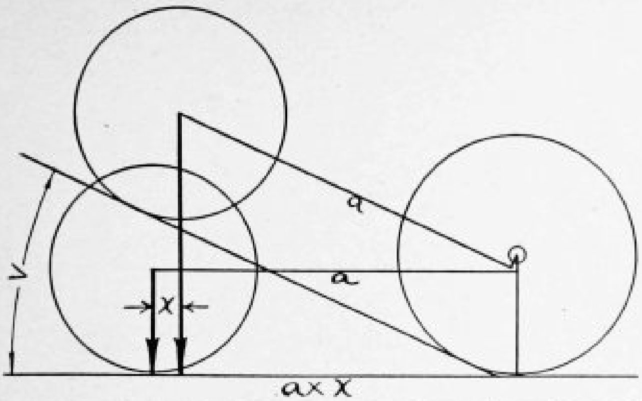
After completing the indicated arithmetical process, we have,—

$$2375 \text{ lbs.} - 1125 \text{ lbs.} = 1250 \text{ lbs.} = \text{M. D. P.}$$

If the values had been such that the M. D. P. would have been a negative number, the tractor would have been out of equilibrium under those particular conditions. Enough extra weight E should be added to the front end to make (A + E) + B — C equal to several hundred pounds. Lowering the draw-bar would also be effective in obtaining equilibrium, in that it would increase b, adding to the value of (L x b) ÷ a.

On an up-grade there is less weight on the front wheels than there is when on level ground, and, because of the increased load, both the lifting effect on the front end caused by the rear wheel torque and the down pressure on the front end caused by the load, are increased. However, the lifting effect of the torque on the front end increases proportionately more for a given increase in grade than the down pressure caused by the draw-bar load. Therefore, as the grade increases, the margin of safety is rapidly overcome. When applying the equilibrium formula to tractor performance on an up-grade, allowance must be made for the decrease in the dead weight on the front wheels. This is done by multiplying A by a certain number, x (see Fig. 27), which corresponds to the angle of a slope.

Thus, at six degrees of angle $\frac{W}{3}$ should be multiplied by .995 before its value is substituted in the formula. If the weight of the tractor is 6000 pounds, as in the example previously worked out, the dead weight on the front wheels would be $\frac{6000}{3}$ or 2000 pounds. If this tractor had been ascending a slope at an angle of six degrees from horizontal, the effec-



Angle V	X	Angle V	X	Angle V	X
1°	1.000	11°	.982	21°	.934
2°	.999	12°	.978	22°	.927
3°	.999	13°	.974	23°	.921
4°	.998	14°	.970	24°	.914
5°	.996	15°	.966	25°	.906
6°	.995	16°	.961	26°	.899
7°	.993	17°	.956	27°	.891
8°	.990	18°	.951	28°	.883
9°	.988	19°	.946	29°	.875
10°	.985	20°	.940	30°	.866

FIG. 27

tive weight, 2000 pounds, would be multiplied by .995, giving a weight of 1990 pounds.

As tractors are likely to be operated under quite unusual conditions occasionally, there should also be a fairly strong draw-bar extending a short distance to the rear. If the tractor should start to turn over backwards, the draw-bar, striking the ground, would lift the rear wheels from contact with their footing before the machine could turn over. A tractor without a draw-bar extending to the rear, would have nothing to prevent it from tipping over backwards, should it lift the front end enough to reach a sufficient angle of incline. The tendency to tip over backwards is usually greatest when the rear wheels, sinking into the mud, have been slipping and suddenly gain traction by having planks or other material thrown under the wheels. Since the machine is at a stand-still, the load is practically zero and does not help to hold down the front of the machine. The torque on the rear axle suddenly reaches a higher value than before, and causes a sudden lifting force on the front end before the machine can take up load enough to hold the front end down. If the rear wheels have sunk in the mud and the front wheels are still at the level of the ground, the machine is at an angle; and the loss of a part of the margin of safety is the same as that resulting from an up-grade of the same angle.

CHAPTER XVII

GAS TRACTOR OPERATION

1. In the preceding lessons we have taken up the fundamental principles, construction and care of every essential part of a gas tractor; and I earnestly recommend that if the operator fails to understand any part, he should study that part until he fully masters the principles of its construction and operation. Remember that the chain is no stronger than its weakest link. Remember also that efficiency of the tractor decreases as the different parts which make up its construction deteriorate; and the power delivered at the draw-bar continues to grow less while the fuel consumption increases.

Out of the total energy the fuel used by a tractor, **in the very highest grade machines, only 12.5 per cent gets to the drawbar of a tractor.**

The diagram Fig. 1 shows where the energy goes. That looks like a big loss, doesn't it Yet the gas tractor with 12.5 per cent is more efficient than the best steam tractor ever designed, which uses only four per cent of the power in the fuel.

Now the question is, **how are we going to save every bit of the 12.5 per cent of the power that the best tractor gives us?**

And the answer is, **by having men so well trained that they understand how to keep gas tractors and autos in perfect condition.**

Probably you know that some of the power generated by a gas engine is used up in getting to the drawbar of a tractor, but I doubt if you realized how much it is. This diagram shows. The width at the top represents the total power produced, and each shaded arm turning to the right is an **unavoidable power loss, in all** 87.5 per cent.

The Tractor is very simple in construction and easy to operate when it is understood. A mere fraction of the time required to break colts will enable one to master the Tractor. If there is any trouble, remember that it will almost invariably be found in lack of the operator's ability to run it, and not a defect in the Tractor. The difficulty is usually so simple that when found a man feels like "kicking himself" for not having seen it sooner. An expert was once sent four hundred miles, and at considerable expense, to determine the trouble with a large Tractor, only to find the gasoline tank absolutely dry!

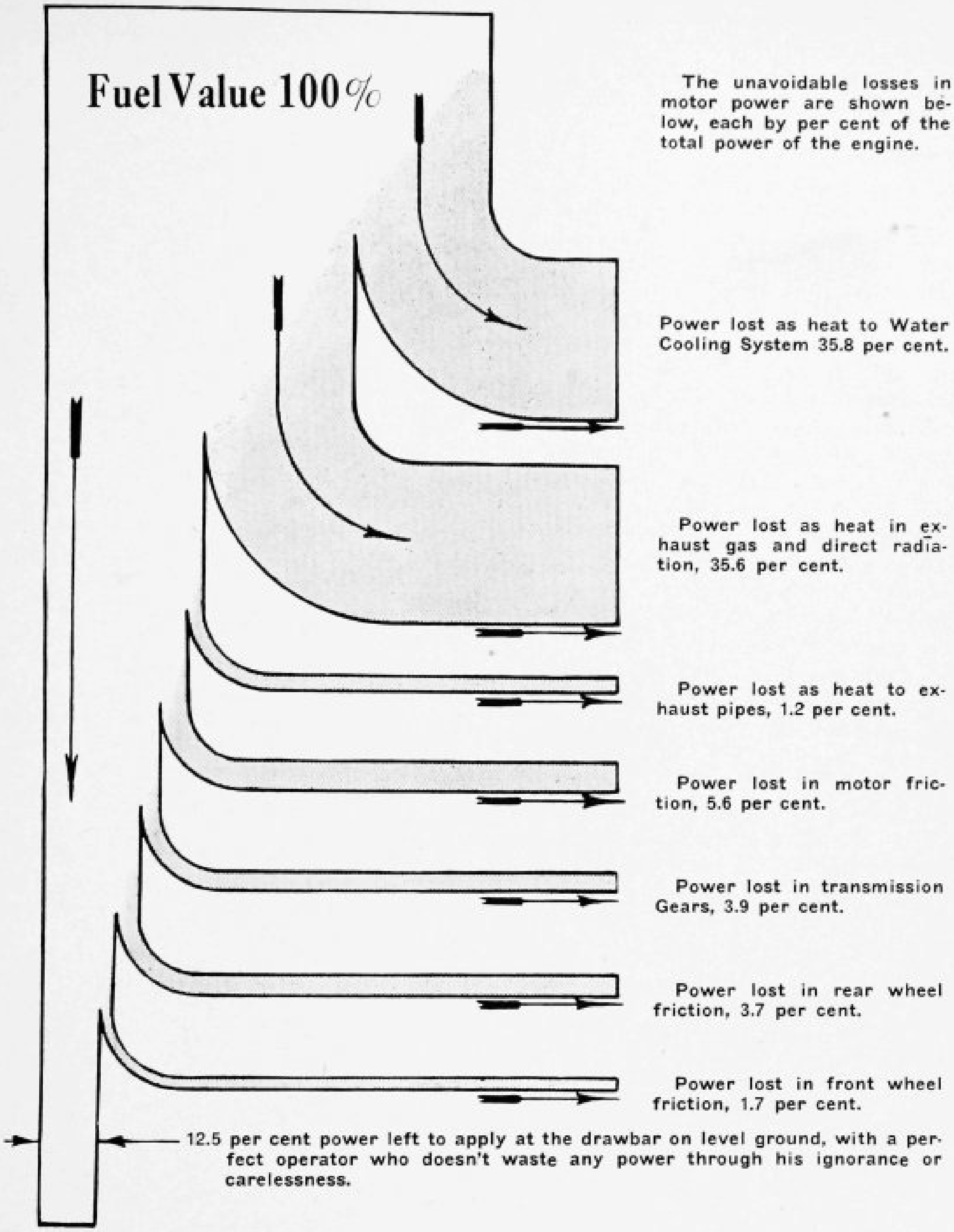
An intelligent man, fifteen hundred miles from home, purchased a magnificent mantel clock and sent it to his wife as a pleasant surprise on the anniversary of their wedding. For a short period it kept good time, but then refused to run. Bitter complaint was made to the dealer, who knew the clock was in proper condition when shipped, and was perfectly willing to fix it, if returned to him. It so happened that the family, after a few months, moved to the city where the clock had been purchased. It was returned, and the dealer remedied the difficulty in the presence of the purchaser **by winding it up!** This was an actual occurrence. Remember, it was a **philosopher,** and not a fool, who held the egg in his hand while he boiled his watch!

The Tractor will accomplish great results for you in saving horse flesh, doing your work better, quicker, with less wear and tear; and at less cost. But now comes the question of the operation and care of the Tractor. Men differ as widely in their success with tractors, as they do with horses. Some always have good healthy horses in fine condition, while others are regular horse killers. This is not due to "luck," but to intelligent care on the part of the successful manager of horses.

Do not be in a hurry. Take time to acquaint yourself with the tractor. Know thoroughly the theory of its operation, and do not think TOO SOON that you can improve the machine, for later you will find that the Tractor is a wonderful piece of mechanism just as it is. The inventor and manufacturers know the tractor business and are experts; so run the tractor intelligently AS IT IS. If you hear a thumping, or knocking, or any other symptom of trouble, stop your machine, find out the fault, and correct it before the trivial difficulty becomes a serious one.

2. **Break Your Tractor in Slowly.** Do not try the first day to see how much your tractor will pull. It is important that you take plenty of time. Many a machine has been ruined the first day it was put in service. It takes time for the different parts to right themselves and form a proper seat. On this depends, to a great extent, the success with which the motor will be operated. Poor oils are dangerous, as they have little or no lubricating value, and contain substances which cause wear and trouble. A majority of all motor trouble can be traced to the use of poor oil. New machines require more oil and grease than when properly broken in. But at all times be sure that they are properly lubricated, as oil is cheaper than repairs. It is poor judgment to use any oil other than the best for the purpose that you can procure. Do not always judge oil by the price, nor try to economize by using a certain oil just because it is cheap. Nine-tenths of a tractor owner's troubles can be traced directly to the use of oils and greases unsuited to the conditions under which they must work. Suitable oils can be obtained and in the long run will invariably be much cheaper.

The importance of good, clean lubrication cannot be overestimated. Because we realize what good lubrication means we feel that this item in the care and



From Fig. 1 we see that only 12.5 per cent of the total energy in the fuel consumed is left for useful work at the drawbar on level ground: and in soft fields, or hills, the loss is still greater.

operation of the tractor cannot be dwelt on at too great length, nor be too emphatically expressed.

The oil and grease for the tractor can and must be kept clean. Store the oil in a sheltered place where flying dust will not settle all over the container and mix with the oil when it is drawn out for the tractor.

Dust and grit must not be allowed to get into the crank case of the engine or other working parts of the tractor. Use a clean pail for transferring the oil from the container to the tractor, and do not carry the oil in an open pail across a field or anywhere in the open when wind is blowing dust about. Use a covered pail or a can with a stopper. Steel drums with faucets being dust, water, and sunproof, make good storage tanks for engine oil.

Exercise the same care in handling the cup grease. Keep the container free from dirt and when filling a grease cup, clean all the dust off of it before putting in fresh grease.

Transmission oil can be stored in steel drums the same as engine oil, and the same care in handling should be exercised.

Use Clean Oil

To get satisfactory service from a tractor, it is absolutely essential that the oil in the motor be at all times clean. Get your fingers into the oil in your motor every day. Look at it; feel it; and if it is black and gritty, or if it shows that there is kerosene mixed with it, drain it out on the ground, wash out the motor, and put in fresh oil.

The oil containers must be kept clean, and care must be exercised in transferring the oil to the motor. Even then, as the oil is worn out and fried away in a hot motor, the residue of the oil is constantly being washed back into the crank case, and if allowed to accumulate for any great length of time, will make the oil in the engine a better cutting compound than a lubricant, and will cut with telling effect on all of the bearing surfaces in the engine. In addition it causes undue carbon deposits to accumulate on the pistons, combustion chamber walls, spark plugs and valves.

When the oil shows the first sign of grit, or of having kerosene mixed with it, prepare to wash out the motor. If the oil is closely watched, it will not be necessary to drain any great quantity of oil when washing the motor, before you can get the proper number of hours' run on a given amount of oil.

CAUTION: Keep plenty of oil in the reservoir at all times. Do not allow the oil level to reach a point lower than one inch from the bottom of the glass in the oil gauge when the tractor is on level ground. This is the danger line.

Before washing the motor, pour a half pint of kerosene into each cylinder through the spark plug holes and allow the motor to stand two or three hours, or over night. The kerosene has a tendency to loosen up the carbon deposits on the pistons, combustion chamber walls and the valves. After time has been allowed for this process, the motor should be turned over a few revolutions to be sure that the kerosene is all out of the cylinders. Drain all of the oil out of the oil casing through the plug in the bottom, and wipe the oil from the splash compartments with a cloth. **Do not use waste inside of the motor housing.** Using a large syringe, or a small can if this is not obtainable, and kerosene, wash the interior of the engine housing, the splash compartments, the oil casing, and all working parts thoroughly, and wipe them dry with a clean cloth. Be sure that the opening to the oil gauge is not plugged up. Replace the plug in the bottom of the oil casing. **Test the oil pump to be sure it has not lost its priming.** Pour a little good clean lubricating oil into each cylinder and bearing to facilitate starting and to guard against the possible scoring of some of the parts by running without sufficient lubrication.

It is necessary, when advising how often to change oil, to rely somewhat on the operator's judgment. **Do not think your motor is being lubricated properly because there is a sufficient quantity of "oil."** The oil may appear all right when looking at it through the oil gauge, after having been used for some time, but on getting your fingers into it, you may find it in a dirty, gritty or thin condition and when this is the case, do not merely put in more clean oil—drain the old out and renew, as in putting in clean oil under these conditions, you are not remedying your trouble. With proper carburetor adjustment, good oil and good compression, it should not be necessary to change the oil more than once every thirty hours. On the other hand, if the carburetor is not adjusted right, or you have poor oil, or low compression is present, it will be necessary to change oil oftener than every thirty hours so if on examination, the oil is found thinned down or dirty and requires frequent cleaning, it is necessary to correct the cause.

RECEIVING A NEW TRACTOR FROM THE FACTORY

No. 3. When the Tractor Arrives. Have the car spotted at the platform or some other convenient place for unloading. Pay the freight. Thoroughly examine all boxes, crates and wrappings for breakage or shortage. If any are discovered, have them all noted on your freight receipt.

NOTE: The tractor company is not responsible for goods damaged or stolen in transit, because the tractor is purchased f. o. b. factory.

Be sure to use planks or plates between car and platform to run off on, in case you unload at the platform. If you do not place these plates or plank, you are liable to push the car off the track and cause delay or a bad smashup, especially if your platform is built higher than, and a distance away from the car. Be sure the car is well blocked so that it cannot possibly move up or down the track.

If there is no platform, a good way to unload a tractor is to haul some ties to the car and build a run-

FIG. 2

way as shown in this illustration. (See Fig. 2.) It is advisable to use straight ties. If these cannot be obtained, use others and toe-nail them wherever they look as if they might slip. Be careful in using creosote ties—they are slippery. Remember that a tractor is a heavy machine, and great care must be taken in removing it from the car. It is important in either method of unloading to see that the car is well blocked so that it cannot move. Successful unloading is only a question of care and good judgment on your part.

Unloading the Tractor

If you run the tractor off the car and down the run-way or onto the platform under its own power, it is necessary that you observe the following instructions closely before attempting to start the tractor. THESE INSTRUCTIONS ALSO APPLY TO ALL OCCASIONS BEFORE STARTING NEW TRACTORS.

Remove all crating and wrapping from around the engine and knock the blocks from under the wheels.

Always be sure to see that everything is out of the way.

No one should attempt the operation of a new machine which he has never seen before, without first looking it over carefully and becoming familiar with the various mechanisms and functions of its different parts.

Experience in actual work will give the operator opportunity to observe; and if he studies the traction book, he will soon become thoroughly familiar with the operation and care of the machine.

A: Get the spark plugs and spark plug wrench. Examine the plugs to see that the porcelain is not cracked, and the gap is one thirty-second of an inch between points. This is very important. Screw them into the cylinder firmly, and see that they do not leak.

B. See that the magneto is properly timed, and the impulse starter trips on D. C. and is in proper alignment, and securely bolted to the motor. Place the high tension cables on the distributor, and wire to the spark plugs in the order of ignition.

C. Fill the radiator with clean water. Always use soft water when available. If possible avoid water containing alkali. Never start the motor without first filling the radiator with water; if you do the motor will become over-heated causing the pistons to stick, and may result in scoring the cylinder walls.

D. Fill the oiling system with the best quality of gas engine cylinder oil. Pour one table spoon of oil in each cylinder through the priming cups; then turn the motor over eight or ten times to make certain the cylinder walls are well covered with oil. Fill all hard oil cups and screw them down till the oil squeezes out at the end of the bearings. This may require several fillings.

Particular attention should be given every bearing that they are clean and amply lubricated.

E. See that the supply to the carburetor is on the gasoline side. Fill the fuel tanks, and be sure to strain through a fine sieve or chamous skin. If fuels are not strained you are sure to experience trouble as they contain water and foreign matter which will clog the carburetor and cause you a great deal of trouble. Always fill the small tank with gasoline for starting purposes, and the large tank with kerosene, for operating.

F. Adjust carburetor so as to get a rich mixture on both light and heavy load adjustment. See that the float chamber fills with fuel.

G. Pour a small quantity of gasoline in cylinders through priming cups, being careful not to flood the cylinders.

H. Advance spark so that the low tension circuit is broken. ......

Trip the impulse starter, on magneto. Crank the motor over until you feel it starting on the compression event; then get a new position with the starting crank low down and come back quickly. Remember it takes three things to start a motor. A MIXTURE, A SPARK AND COMPRESSION. Always pull up when cranking a motor. Never push down. If when the motor is turned over D. C. it pops back at the carburetor, it is either wired to the wrong firing order, or there is an intake valve stuck open.

I. After the motor is started, adjust the light load adjustment so that the motor runs smooth on the governor. Do no touch the heavy load adjustment after the motor is started until a load is put on the motor, and the governor has opened one-third or more. See carburetor instructions.

J. See that the governor controls the speed, and the motor does not run over its rated R. P. M. Keep the governor well oiled, and clean, and working freely. Sometimes paint causes it to stick when the tractor is new.

4. Getting a Used Tractor Ready for Service. This is sometimes a difficult and perplexing task, especially when the tractor has been used by an inexperienced operator. When the motor has been run as long as it would continue to run. In attempting to repair a motor that has been run until it has broken down completely, adopt a system of elimination.

Overhaul the parts separately, as follows:

1. First, Clean off all the surplus grease and dirt.

2nd. Inspect for broken or badly worn parts, which must be repaired or replaced. Order necessary parts from the nearest branch house. It is important to specify motor number, tractor number, the letter and number of part.

3rd. Test the motor for compression, taking note of every cylinder. Examine the tappets for clearance. See that the valves are not held off the seat, but close properly.

4th. Remove the inspection plates; and while the motor is being turned over, see if the charge blows by the pistons. If it does, the pistons must be removed and examined; and if they are too badly worn, replace rings and pistons with new ones. It is sometimes necessary to have the cylinders rebored. Then oversize pistons and rings must be used.

5th. Examine the valves. They should be ground often, especially the exhaust valve. See that they seat perfect and remove all carbon from the valve stem and seat. The spring must be strong enough to hold the valve firm on the seat. Inspect the springs often by placing a screw-driver between the tappets and valve stem. By twisting the screw driver, raise the valve off its seat. While the motor is standing, the tension on all valves should be alike. Grind the valves and remove all black specks from the seat. See that the stems work freely in the guides, and do not stick or remain open. If more than one valve is removed at a time, mark them and replace them the same as they were removed.

6th. Clean all carbon from combustion chamber. Examine cylinder head gasket to see that it fits properly. It should not extend into the combustion chamber as the edge will get hot and cause preignition. Tighten the cylinder head bolts uniformly. Draw all up the same way and tighten again after the circulating water becomes hot.

7th. Examine all bearings for lost motion, taking up one at a time. Be sure all spring cottors are replaced and tight so they cannot move by the action of the motor, or they will wear and draw out, and result in a wrecked motor.

8th. Examine the fly wheel to see that it is laid out with the proper markings.

9th. Turn the motor in the direction of rotation until the exhaust valve No. 1 cylinder just closes. The mark, exhaust closes one and four should be under the pointer. If not, place the mark under the pointer and adjust the tappets so that the valve just seats on the mark. Repeat this on all cylinders; see that exhaust closes on the marks and intake opens. If there is much lost motion in the valve operating parts, or the motor has been tampered with, it may be necessary to find the proper clearance.

Set the cam shaft and time the valves. While the motor is being turned over, watch the clearance. Notice if the clearance remains the same while the valves are closed. If the cam shaft is sprung, the valves may be forced open when they should be closed. This is often the case when motors have been improperly handled.

10th. Examine the ignition system. See that the magneto is properly timed, and that the contact points are smooth, make full contact, and separate the proper distance. Clean the distributor. See that all low tension connections are tight, and all high tension parts and cables are well insulated, that the spark plugs are clean, the porcelaine is good and the gap is at the proper distance. See that the spark plugs reach into the combustion chamber, and that the magneto trips on D. C., or the contact points separate on D. C. with retarded breker box. See that the magneto is wired to the motor according to the proper firing order.

11th. Examine the clutch. See that it engages with the fly-wheel properly, and that the clutch facings are good. Never allow the metal of the clutch to come in contact with the wheel. Replace the lining if necessary.

12th. Examine the transmission. See that the bearings are in good condition and the pitch line of the gears come together properly and shift easily. Examine the oil, and if found dirty, wash out with kerosene, and renew with a good transmission grease.

13th. Examine the differential. The pinions may be badly worn, and the teeth broken out which makes hard steering. See that the end thrust has been taken care of, and the bevel gears and pinions mesh properly, and are well oiled.

14th. Examine the master pinions and gears. See that the teeth are worn evenly and mesh properly. It is often necessary to move the rear axle one way or the other to get the proper alignment.

15th. Examine the wheels for worn hubs and loose spokes. See that all rivets and bolts are tight, and the hubs properly oiled.

16th. Examine the frame. See that all rivets and bolts are tight. See also that the bearings, boxes, motor and transmission bolts are tight. This is important to keep all parts in proper alignment.

17th. Examine the water circulating system. See that the radiator and water connection are free from dirt, that all hose connections are tight, and the circulating pump is packed properly. Lubricate the fan shaft bearings and see that the fan revolves freely and does not strike. Have the fan belt of good material and of proper tension.

18th. Examine the fuel supply system. See that the tanks are cleaned out, and that there are no kinks in the supply pipe line. Clean dirt and water out of strainer and carburetor; leave no cracks in the shellac coating and not water logged. See that the needle and secondary air valve seats properly.

19th. Examine the governor and governor valve for lost motion and wear. If it is badly worn, good regulation is impossible, and the badly worn parts must be replaced with new parts. See that it is properly oiled and kept free from dirt.

20th. Give everything the twice over. Fill the radiator with clean soft water, and fill the fuel tanks. When filling, always use a strainer to remove water and dirt.

See that the gasoline flows to the carburetor, and the float chamber fills up properly. Adjust the carburetor so as to get a rich mixture both on light and heavy loads. Pour a small quantity of cylinder oil in each cylinder and turn over eight or ten times, having everything in readiness. Prime with gasoline, and start in the usual way.

5. Burning Kerosene. When operating on kerosene, always start on gasoline and continue to run on gasoline until the motor is hot; and when there is no thermostatic control, continue to run on gasoline until the circulating water is hot. Kerosene, if taken into a cold cylinder, will condense on the walls, cutting the lubricating oil on the walls and piston, and leaving the cylinder without lubrication. It is apt to work by the piston into the crank case, and destroy the lubricating oil in the oiling system. It is accountable for a large percentage of the repair bills. Such as pistons and rings, reboring or new cylinders, crank shaft and connecting rod bearings. If no theremostat is used to keep the circulating water to a high temperature, a canvas should be placed over the radiator so as to keep the air from circulating through the tubes until the temperature gets near the boiling point. This should be done when traveling against cold winds or in cold weather, so as to keep the pistons, cylinders, the lubrication of all parts in good condition. If the motor pops back at the carburetor when operating in cold weather it is an indication of too cold a motor.

6. Symptoms. To be a competent operator of an internal combustion motor, the operator should familiarize himself with the following symptoms, which are the first indications of approaching trouble.

POPPING BACK AT CARBURETOR

- GENERAL
  - No fuel in supply tank.
  - Stoppage in supply pipe line.
  - Stoppage in fuel strainer.
  - Intake valve stuck open.
  - No clearance at tappets
  - Weak or broken intake valve springs.
  - Improper wiring.
  - Not proper firing order
  - Loose primary connections.
- WATER IN CARBURETOR
  - Water in float chamber will cause popping back occasionally and more frequent as the accumulation continues regardless of loads, and speeds.
- AT LIGHT LOADS ONLY
  - Improper low speed carburetor adjustments.
  - Leaky secondary air valves.
  - Leaky intake manifold above throttle or governor valve.
- HEAVY LOADS ONLY
  - Slight stoppage in supply pipe line only allowing small amount of fuel to seap thru.
  - Slight stoppage in fuel strainer.
  - Slight stoppage at float valve.
  - Improper high speed carburetor adjustment.
  - Weak secondary air valve spring.
  - Dirty distributor.
  - Hot spark plugs.

MOTOR MISSING

- LIGHT LOADS AND HIGH SPEEDS
  - Loose low tension wires.
  - Contact points too far apart.
  - Oil and carbon on spark plugs closing the gap.
  - Contact point arm tight so it does not operate quickly.
  - Too rich a mixture.
  - Valve stuck open.
  - High tension cable off the plug.
- AT HEAVY LOADS
  - Contact points rough.
  - Contact points do not meet fair and square.
  - Contact points out of alignment.
  - Dirty distributor.
  - Spark plug gap too far apart.
  - Accumulation of oil and dirt on outside of spark plug and distributor.
  - Poor insulation on high tension
  - Poor or disconnected condenser.
  - Dirty distributor.
  - High tension cables short circuited.

The best recommendation for any farm machine is the reputation that it has established for satisfactory work in the hands of users who have invested their money in it.

The user is the court of last resort. What is said about the machine in theory goes to him for judgment in the light of actual practice. He weighs the merits of the machine as they are revealed in real farm work over a period of years. His verdict determines the success or failure of the machine as a marketable product.

In the following pages you will find explained and illustrated a few of the tractors, which have been tried and proved practical.

WATERLOO BOY

A Three-Plow Tractor

12 H. P. at Drawbar—25 H. P. at Belt

The Heart of the Waterloo Boy Tractor

A Powerful Two-Cylinder Engine

The success of the Waterloo Boy Tractor is due basically to the practical advantages of its powerful engine.

This engine is the product of more than twenty-five years of experience in making successful farm engines.

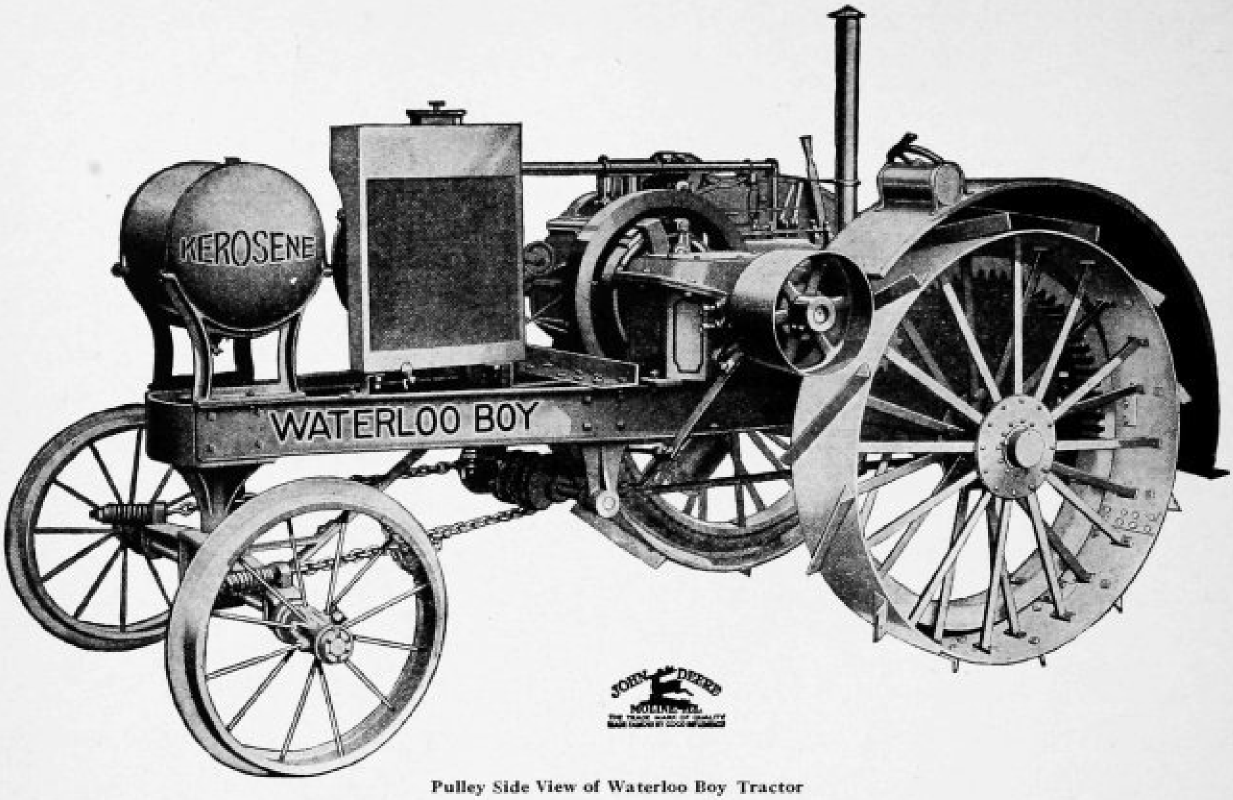
It is built and thoroughly tested in our own factory.

It was the first part of the tractor designed.

The other parts were designed to give the farmer the greatest possible advantage of the power given by the engine.

The engine, of the heavy-duty type, is capable of delivering 25 H. P. continuously. This size is generally regarded as the most practical for general farm use.

This engine is built to burn kerosene, and to burn it completely, because kerosene is a far cheaper fuel than gasoline.



Pulley Side View of Waterloo Boy Tractor

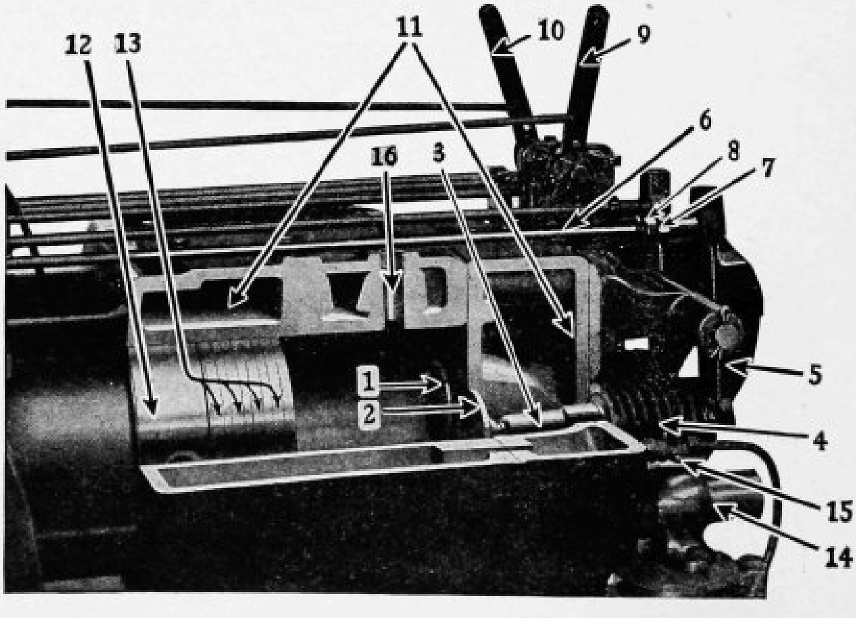
The engine is particularly designed for heavy-duty work. It is a twin-cylinder valve-in-the-head type, with cylinders placed horizontally side by side and cast in one piece, and with an original device for gasifying kerosene that is fully protected by patent.

This two-cylinder design makes it possible to have large valves, large water jackets, a short, rugged crank shaft, wide, durable bearings and great power from moderate motor speed. All of these features are necessary to a heavy-duty motor of the 12-25-horse power type where continuous operation under a heavy load is required.

Furthermore, this two-cylinder design fulfills the requirements of perfect burning of kerosene.

Cylinder Cut Away to Show Working Parts

1. **Intake Valve**—When this valve opens, gasified kerosene passes directly from the patented manifold into the cylinder—no chance to reliquify.
2. **Exhaust Valve**—When this valve opens, the hot exhaust passes through the patented manifold, keeping its walls sufficiently heated so that it converts kerosene into gas.



The intake and exhaust valves are opened and closed mechanically by means of cams on a cam shaft operating through the valve gear. The relative timing of the valve movements is regulated accurately when the engine is built. Re-timing is necessary only after the crank shaft or cam shaft has been removed. The operator, by carefully following printed instructions can do the re-timing himself.

3. **Replaceable Valve Guide.**
4. **Valve Spring.**
5. **Rocker Arm.**
6. **Tappet Rod,** adjustable for length by means of tappet rod end (7) and securely locked by nut (8).
9. **Spark Lever** in advanced position.
10. **Throttle Lever**—Motor speed can be regulated by means of this lever when necessary.
11. **Water Jackets** in cylinder and in cylinder head. Extra large for efficient regulation of temperature.
12. **Piston** in which is fitted four elastic durable piston rings (13) for preventing gas leakage.
14. **Schebler Carburetor**—Gives proper mixture of air and kerosene.
15. **Water Valve** to stop pre-ignition under heavy load.
16. **Spark Plug Hole.**

Patented Manifold Converts Mixture into Pure Gas

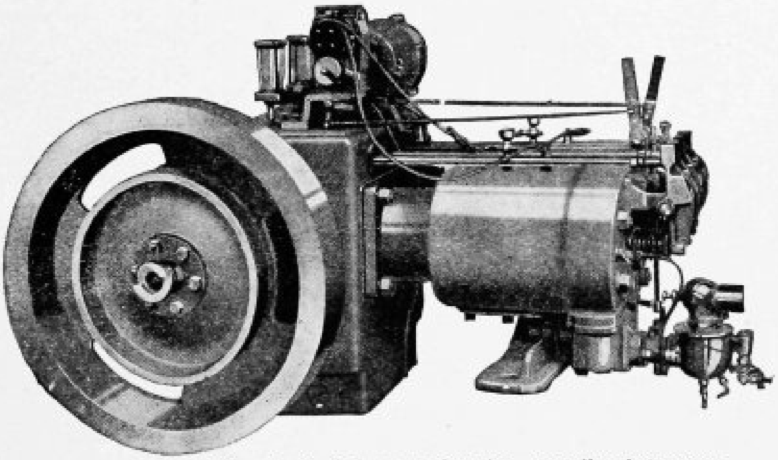
From the carburetor, the mixture of air and kerosene passes as a mist or vapor directly into the manifold.

This manifold plays the big part in preparing the fuel for perfect combustion, and is fully protected by patent. No other tractor has it.

The importance if this special manifold will be better appreciated when we consider that kerosene, because of its nature, cannot be broken up fine enough, and reliquifies too quickly to be economically used in the ordinary engine. Therefore, it must be fixed into a dry gas before it can be successfully burned. Hot water or boiling heat is not sufficient to gasify all of the kerosene quickly enough to be burned.

And here's another important thing to consider: After the gasification, the gas cannot safely pass through something cooler than the cylinders, where it is to be burned. That gives opportunity for recondensation of the gas back to kerosene. If this kerosene passes into the cylinder, it will not be burned. Instead, it will work past the piston rings into the crank case, where it will mix with the oil. That will destroy the oil's lubricating quality, cause the danger of burned-out bearings, and cause useless waste of oil.

The requirements of perfect kerosene-burning are that the vapor passing from the carburetor be acted



Flywheel side of Waterloo Boy's kerosene burning, non-vibrating motor

The Waterloo Boy's System of Perfect Kerosene Burning

To follow the system by which the Waterloo Boy's motor burns kerosene perfectly, let us start at the carburetor.

This simple device gives a proper cold mixture of air and fuel. Clean air reaches it through a stack that extends to a level above the dust. The needle valve is set for the proper proportion of air and fuel in the mixture and is then left alone. A butterfly valve, connected with the governor, controls the size of opening in the passage leading from the carburetor through the manifold to the cylinder, regulating the motor at all speeds.

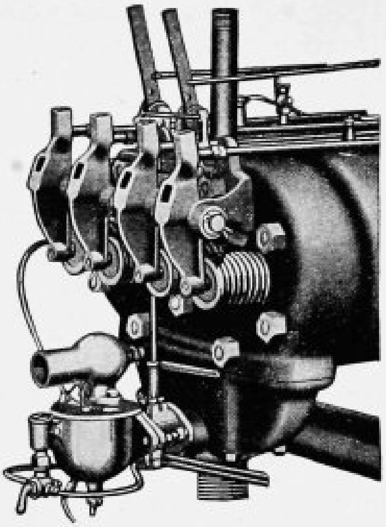
on by a heat intense enough to gasify it, and that this gas must pass directly into the cylinders before it has had a chance to reliquify.

The Waterloo Boy's Patented Manifold meets these requirements perfectly.

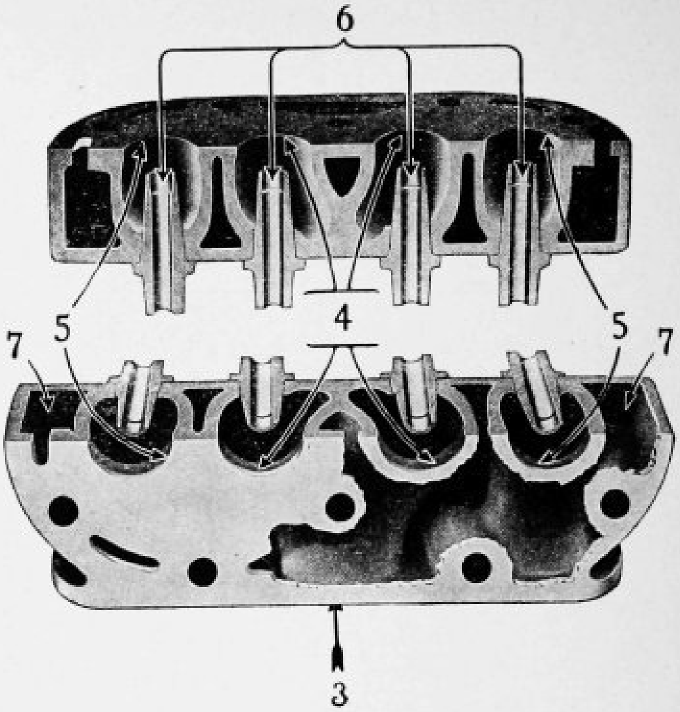
Note in the illustration at the upper left-hand corner of page 220 that the manifold below the cylinder head is a combination of the motor's exhaust and intake.

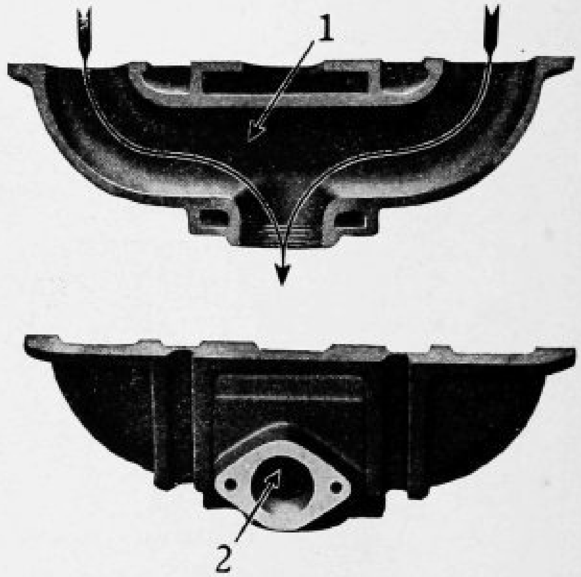
Then note the sectional views to the right. At the top is the cylinder head cut in two and with parts cut away to show intake and exhaust passages. Below is the patented manifold cut in two.

The exhaust from both cylinders (5) goes through



View showing close connection of carburetor, manifold and cylinder head. Note that the patented manifold is a combination of the exhaust and intake.





the manifold passage (1) keeping it heated in operation.

Kerosene vapor goes from the carburetor into the manifold's intake passage at (2) circulate over the heated metal, becomes a fixed gas before entering the cylinder head at (3) and then passes directly through the intake valve parts (4) into the cylinders.

The secret of this manifold's great success lies in the fact that it gasifies the kerosene in the manifold instead of the cylinders. The passage of the gas from the manifold to the cylinders is short and direct with no opportunity for recondensation.

As a result, every particle of the fuel is **completely burned** at all speeds of the engine, giving maximum power. No kerosene is left in the cylinders to work past the piston rings, mix with the lubricating oil in the crank case, and destroy its lubricating quality.

Positive Spray Oiling System

This positive prevention of kerosene getting into the crank case is the big reason why the Waterloo Boy's motor can operate continuously in heavy-duty work with a comparatively small quantity of oil. The simple, positive oiling system also helps to secure real lubrication economy.

The oil is carried in a reservoir below the crank case. A pump in this reservoir forces the oil in a continuous flow up through sight-feed glasses on top of the motor, thence through two tubes opening into the crank case. The action of the crank breaks up the oil into a spray that keeps all of the motor parts bathed perfectly. For absolute safety's sake, more oil than is needed is pumped into the crank case continuously, but none of it is wasted. The surplus returns to the reservoir and is repumped.

Simple, Reliable Ignition

The Waterloo Boy is equipped with the well-known Dixie high-tension magneto with impulse starter—the magneto that gives a spark of the same high intensity at both advance and retard.

Flywheel—Hangs in middle of chassis. Ample size to give smooth running of engine.

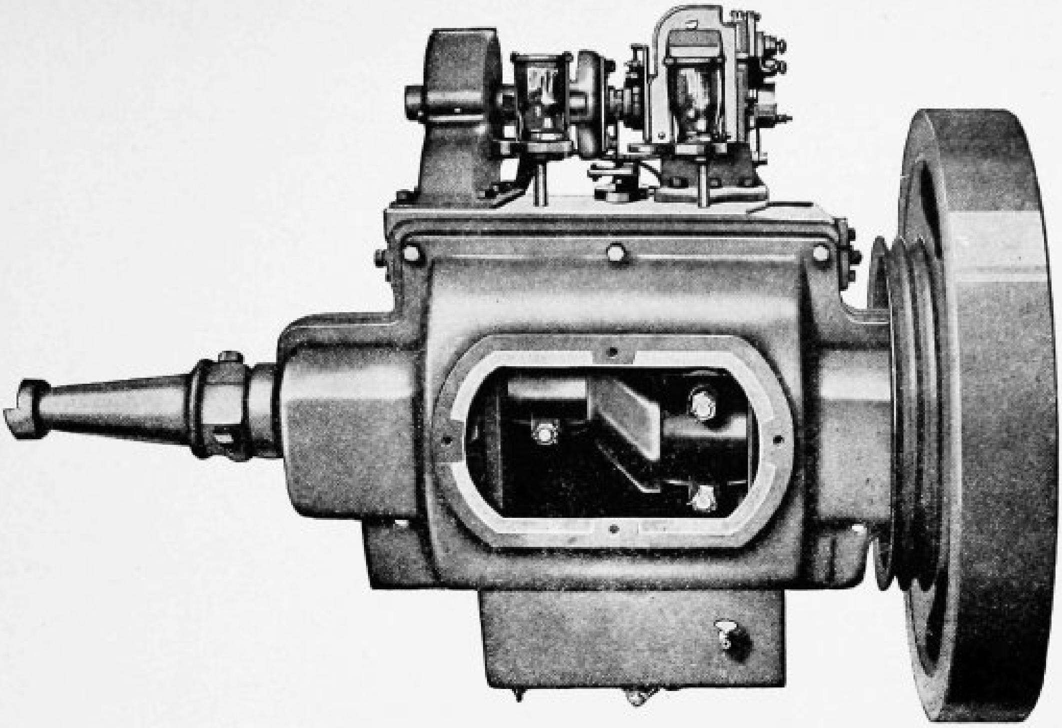
Crank Shaft Main Bearings—2½ inches in diameter by 5½ inches long. Babbitt-lined, bronze-backed.

Connecting Rod Bearings—Marine type, 2½ inches in diameter by 3½ inches long.

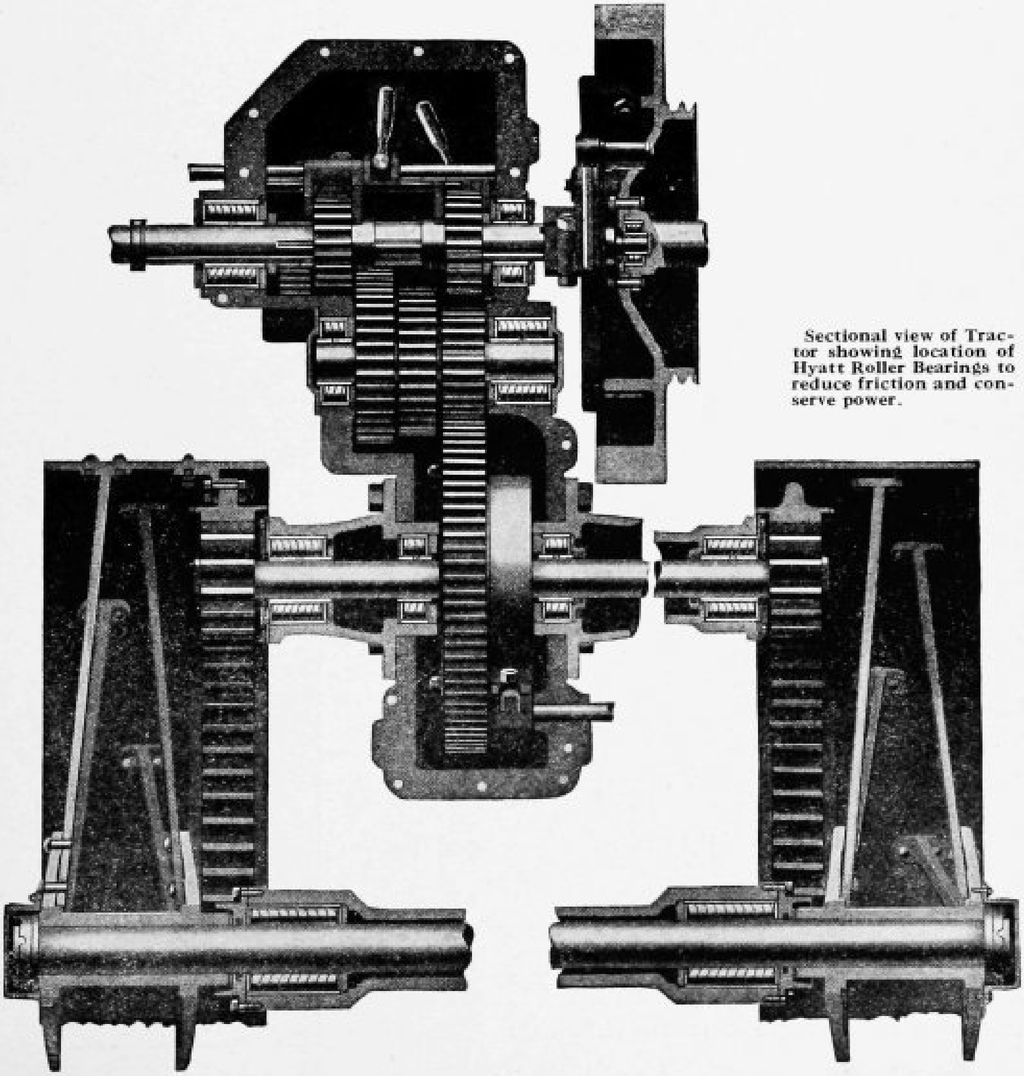
Two-Throw Crank Shaft—Short, rugged and perfectly balanced. Prevents vibration, thus making engine long-lived.

Counterweights.

Starting Quill.



Crank Case View of Motor with Inspection Plate Removed



Sectional view of Tractor showing location of Hyatt Roller Bearings to reduce friction and conserve power.

Crank Shaft Gear.
Cam Shaft Gear.
Cam Shaft.
Oil Reservoir Try Cock for testing oil level.
Oil Pump Rod—Pump in oil reservoir beneath crank case forces up through sight feed oilers (12) from where the oil passes in continuous streams through tubes (13) into crank case, where it is broken up into a spray that keeps all motors parts perfectly lubricated. Surplus oil returns and is re-pumped —no waste of oil.
Dixie Magneto—High tension with impulse starter. Simple and reliable. Gives same intense spark at advance and retard.

Powerful Brake

A powerful contracting brake band is placed on the differential drum. The brake is operated by a foot lever, conveniently placed for the operator, and functions promptly when sudden stopping of tractor is desired. The foot lever may be latched down so that the brake is set. This is very convenient on hills and also in doing belt work.

Eleven Hyatt Roller Bearings

Eleven Hyatt Roller Bearings are used on the Waterloo Boy Tractor—three on the engine extension shaft, two on the intermediate shaft, four on the differential shafts, and two on the rear axle shaft.

These are all of the important parts of the tractor where power-conserving bearings are needed. The Hyatt Roller Bearings have an established reputation everywhere for their special ability to reduce friction and conserve power.

All of the Hyatt Roller Bearings in the transmission and differential are of the heavy-duty type, with a hardened and ground sleeve that fits on the shaft. This increases the bearing surface, minimizes wear, and keeps all gears in better mesh for a longer period of time.

Note in the accompanying illustration how the efficient Hyatt Bearings are located at every essential point to reduce friction and cause comparatively small loss of power from motor to drawbar.

With proper lubrication, these bearings will last as long as the tractor.

Dustproof Housing with Detachable Inspection Plates and Covers

The illustrations on the next page show clearly how the important matter of accessibility to the Waterloo Boy's gears and bearings is obtained.

The illustration below shows how the gear housing is divided so that the entire upper half can be taken off, disclosing all of the gears and bearings.

The illustration to the right, which is a top view of the gear housing, shows the two inspection plates, either one or both of which may be quickly taken off.

Durable and Efficient Final Drive

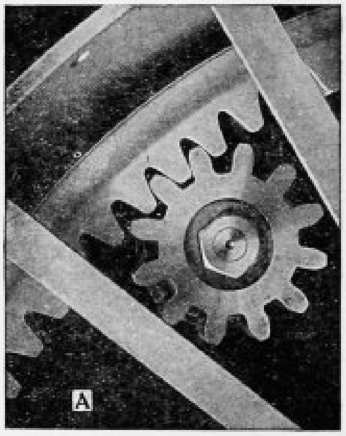
The Waterloo Boy's final drive is accomplished by operating a chilled semi-steel pinion in an internal gear mounted on the wheel. The large internal drive gear is fastened securely with ears direct to the rim of the wheel. The main drive pinion engages this gear with bearings on two cogs. This puts the leverage next to the rim, where there will be the least strain on the gear. These gears have a face of approximately three inches, which gives them more size and weight than the average bull gear on even a 20-40 tractor.

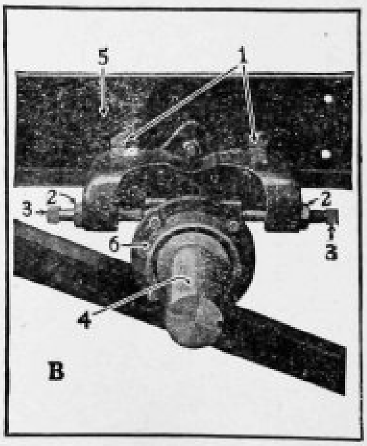
A shield is put over the lower part of the gear to keep grit and dirt from dropping into it or being thrown into it. As the wheel turns over, any dirt, that may have been gathered by the gear, drops out before coming to the drive pinion.

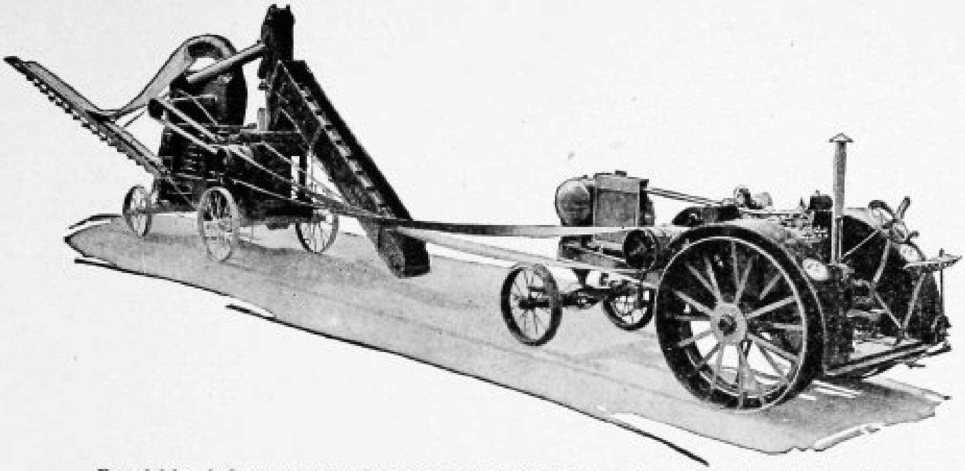
The Waterloo Boy's type of final drive was adopted after careful study of and experiment with other types. This investigation resulted in the conclusion that in the work which a tractor is required to do, a partially exposed final drive gear, made of suitable size and with friction on it reduced to the minimum, is the most successful. The success of this final drive in the operation of the tractor in actual farm work has supported this conclusion.

Simple Adjustment for Keeping Pinion and Gear in Proper Mesh

Continued good working qualities of the Waterloo Boy's final drive are further protected by provision for a simple rear axle adjustment for maintain-







Furnishing belt power for a John Deere Corn Sheller--no gears in mesh at belt work

ing proper mesh of drive pinion and gear. Any farmer can make this adjustment. Note the illustrations explaining it.

Rear Axle Adjustments

Proper mesh of pinion and gear shown in A may be secured by means of adjustment on rear axle shown in B. By loosening double nuts (1), lock nuts (2) on set screws (3), the axle (4) may be pushed forward or backward on the frame (5) by loosening one of set screws (3) and tightening the other, after which all set screws and nuts should be securely tightened. Rear axle shaft (4) rotates on a Hyatt bearing and the rear axle cannon (6).

This adjustment enables the owner to prolong the life of the gear. It is an easy adjustment to make.

THE NEW HART-PARR 30

The Birth of the Oil Tractor Idea

Back in the late nineties, C. W. Hart and C. H. Parr, two young men in the Engineering Department of the University of Wisconsin, began a companionship that ended in a partnership and the founding of a great business enterprise. They had an idea in common—that of building a machine to relieve the drudgery of farm life and one that would conquer the difficult soils of the Northwest Prairies.

The Dream Comes True

Side by side, early and late, they worked out their ideas. Their persistence won over many obstacles and their dream was finally realized. They produced the first oil tractor known to the world and experienced the phenomenal good fortune of having it a success. The results of their efforts have proved to be more far-reaching than they ever dreamed.

The Old Reliable Hart-Parrs not only conquered the virgin soils of the Northwest Prairies but paved the way for the New Hart-Parr "30" and other tractors that have played such an important part in winning the world war and making it possible for the progressive farmer of today to successfully cope with a demand for higher wages, shorter hours, increased cost of conducting the farm and maintaining the farm home.

The day has come when a cheaper and more effective source of power than horses is demanded and the tractor solves the problem.

The ability to do the work in a hurry and at the right time means larger crops, hence larger profits.

Tractors Allow Farmers More Leisure

It is the leaders in every farming community who are buying the tractors—especially the young, progressive men who are making money rapidly, winning the admiration of their neighbors and increasing the production of our fertile farms.

You live but once. To get your work done quickly during the day and enjoy the evening in town with your family is one of the pleasures of modern power farming.

Buying Too Little Power Is an Error

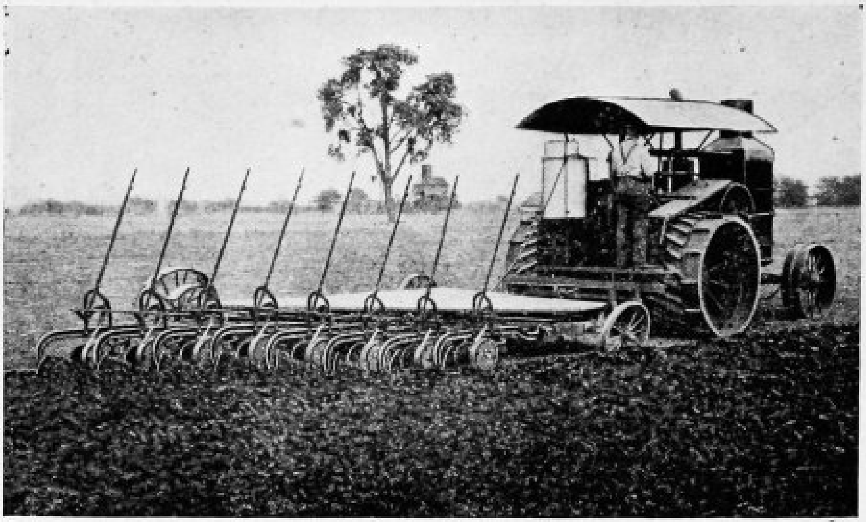
In developing and bringing out the New Hart-Parr "30," we have never once wavered from our ideal of embodying all the fundamental principles of good tractor construction.

The chief mistake that tractor buyers have made in the past is buying a machine of too limited power. One reason for this is that manufacturers have had the habit of rating the horsepower of their tractors at its extreme capacity. Then, when hard plowing or hilly land is encountered, there's a shortage of power for the overload.

Draw-bar rating is especially deceitful in this respect and since it is influenced by so many varying conditions, we don't specify draw-bar rating. We have built the New Hart-Parr "30" with sufficient power to pull three plows even under unusual conditions. Hence we call it a "three-plow" tractor and refrain from stating any figures that might be misleading.

What Is Draw-bar Rating?

We have told you that draw-bar rating is misleading. The reasons are plain. Draw-bar horse-



The Old Original Hart-Parr "30-60"

power represents the horsepower developed by the engine—

(1) Less the power lost in the transmission.
(2) Less the power necessary to propel the tractor,
(3) Less what is used by friction of the cleats of wheels in the ground, and
(4) Less the power necessary to drive these cleats into the ground.

From this you can readily see that draw-bar horsepower is impossible to rate, unless ground conditions are specified, and as the ground conditions differ practically every place, it means that when anybody rates the draw-bar horsepower, it is of little value, because no two conditions are the same.

Some states have made it necessary that draw-bar rating be given, and in such states (to be on the safe side) we are rating our engines 15 draw-bar and 30 B. H. P.

Factory tests show that the New Hart-Parr "30" has an average pull in pounds on draw-bar of 2,600 on high gear and 3,900 on low gear. This really is about 21 horsepower draw-bar under good conditions.

The Power Plant of the New Hart-Parr "30"

Kerosene motor construction is not a new thing with us. Since we put the first kerosene burning tractor on the market, years ago, we have proved to the world that kerosene power is the best, the cheapest and the mightiest power for tractor service.

If kerosene could not be used in tractors as successfully as gasoline, we could not make this statement, but the New Hart-Parr "30" burns kerosene as successfully as gasoline engines burn gasoline and at about one-half the cost.

The Motor

The New Hart-Parr "30" is all built in our own shops. This means a great deal as applied to motor construction. We prefer to build it: First, because of our long experience in building kerosene motors; secondly, because we have been particularly successful in building kerosene motors that have unusual power, bulldog tenacity and long life.

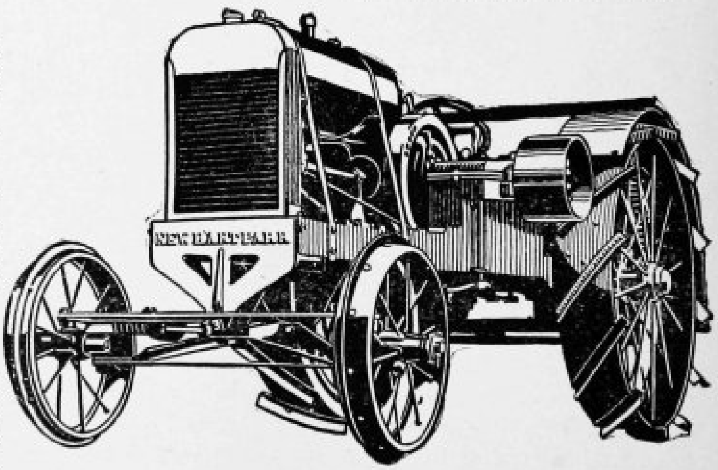
The New Hart-Parr "30" has a two-cylinder, four-cycle, twin horizontal, valve-in-head engine with a 6½-inch bore and a 7-inch stroke. Study the comparison of the two-cylinder and four-cylinder motors on page ten and you will see why we prefer the two-cylinder.

A Perfect Motor for Three-plow Work

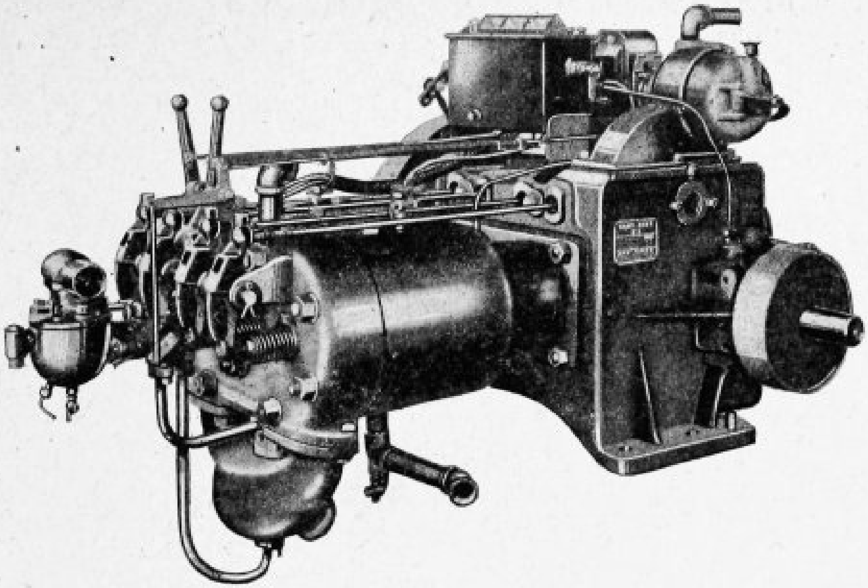
The normal speed of our motor is 750 revolutions per minute. It makes a perfect motor for pulling three plows under a wide variety of soil conditions. Its equipment, its sure response to varying loads, make it an ideal motor for belt work.

Adjustments Easily Made

Study the pictures of the motor parts. Notice its simplicity, its accessibility, its strength. In less than five minutes every part is accessible for any necessary adjustments. Notice, too, how easily the adjustments can be made and yet how positively and securely the



The New Hart-Parr "30"



parts are held. It takes but a moment now and then to keep the New Hart-Parr "30" in perfect working order.

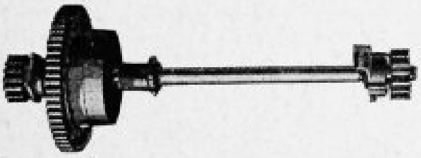
The motor is the heart of a tractor. The New Hart-Parr "30" has a strong heart.

The Transmission

Heat treated, forged steel, cut gears running in oil are used in the transmission which is of the selective sliding-gear type. We use a Hyatt Roller Bearing on the intermediate shaft and S. K. F. Ball Bearings on each end of the engine extension shaft. Two speeds forward give two miles an hour in low and three miles in high. This not only gives you the proper speed for the best plowing and discing, but it also gives you flexibility for different speed requirements. There is one speed reverse on the New Hart-Parr "30."

The Differential

One of the features of our differential is the continuous shaft from one bull drive pinion to the other. The shaft is especially strong and is carried on large S. K. F. Ball Bearings at each end. This is much stronger than the two-piece shafts commonly used. The bearings as well as the large bevel differential gears are in dust proof and oil tight cases. These large gears give added strength where strength is vital.



The valve rocker arm, governor arms and sleeve, front steering links, steering post support, gear shifter, control lever etc., should be oiled several times daily.

CAUTION: Do not oil valve stems with anything except a small amount of kerosene or distillate occasionally. The use of anything else will cause the valve stems to gum and stick in their guides.

The Dray Kerosene Shunt

The new Dray Kerosene Shunt was developed in the Hart-Parr plant. It is used only on New Hart-Parr "30" tractors and herein lies the serret of our abundant and flexible power. It means not only additional horsepower but it means that the New Hart-Parr "30" is supreme in the tractor field as a kerosene tractor.

It is a simple device. Just study the cut shown. At full load, you notice, the mixture from the carburetor goes directly to the cylinder, but on an idling load the mixture must travel downward through the heating chamber. The chamber is heated by the exhaust. There is nothing in this arrangement to get out of order, yet it is highly efficient.

Correct Mixture at All Loads

By taking cold fuel on full load we are able to get maximum power with that bulldog persistence that so delights New Hart-Parr "30" owners.

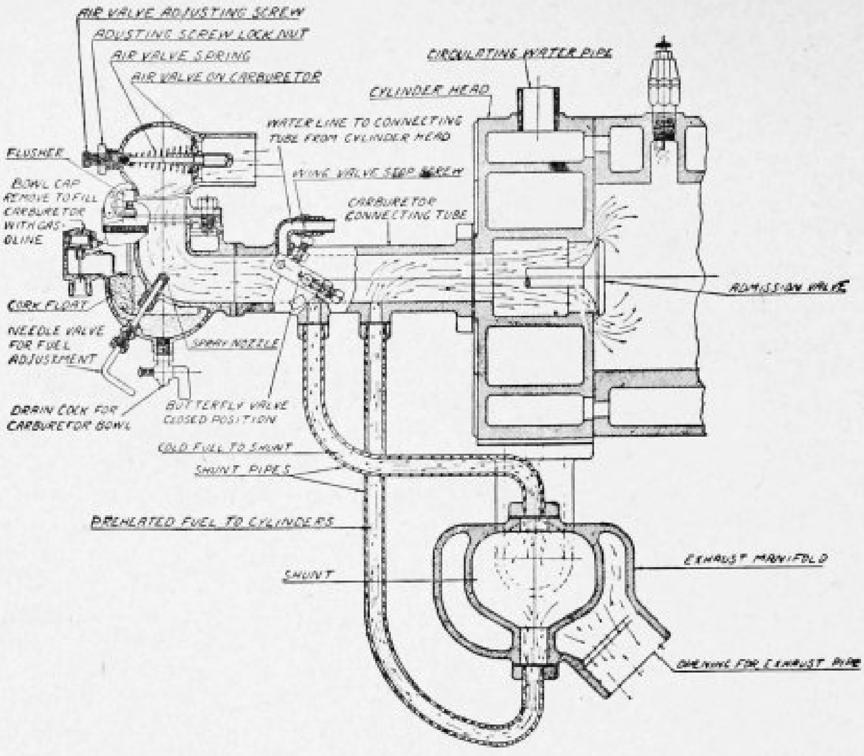
Extensive tests prove that a cold fuel mixture on full load develops more power than any other method. This is because all the expansion of the fuel takes place in the explosion chamber, admittedly the only place where power is developed.

The hot mixture, so made by being forced by the valve downward through the shunt, gives a smooth running engine at light load. In addition, the shunt produces such a perfect mixture that little if any carbon deposit is left after the explosion.

Produces Flexible Power

The supreme test of our method of fuel intake is its flexibility—that is, the New Hart-Parr "30" will "pick up" perfectly from no load to full load without misfiring, without throttling and without delicate adjustment of the carburetor. This is especially advantageous when cutting ensilage or doing other work with quick power changes.

Kerosene does not vaporize as easily as gasoline and so a certain amount of heat must be added. Ordi-



narily the heat from the cylinder walls is sufficient for this, but at very light or no loads, as when stopping to adjust or clean a plow, additional heat must be added. In addition, kerosene when burnt cold gives approximately 20 per cent more power. There is a Butterfly Valve in the fuel intake manifold that is automatically controlled by the governor on the tractor. On light loads or no load this butterfly valve closes, making it necessary for the fuel to be taken by the kerosene shunt through the exhaust manifold, which pre-heats it and gives smooth even running at no load and light loads. At full load the butterfly valve permits the direct intake of the fuel in a cold state. This will need no adjustment at any time.

Water Adjustments (and when needed)

No water need be injected into the intake manifold at ordinary loads, but as the load is increased, the temperature of the cylinder soon becomes so high as to cause the charge to ignite before the proper time, producing a sharp metallic "pound." When this occurs, just enough water should be admitted to stop the pound. Too much water reduces the cylinder temperature and is likely to stop the motor.

Valve System

The valve operation is controlled through the cam shaft and gear, cam rollers, valve pushers, valve push rods, valve rocker arms, and valves.

Valve Timing.

It is very important that the operation of the valves be correctly timed. This depends both on the proper relation between crank shaft and cam shaft and the proper adjustment of valve push rods.

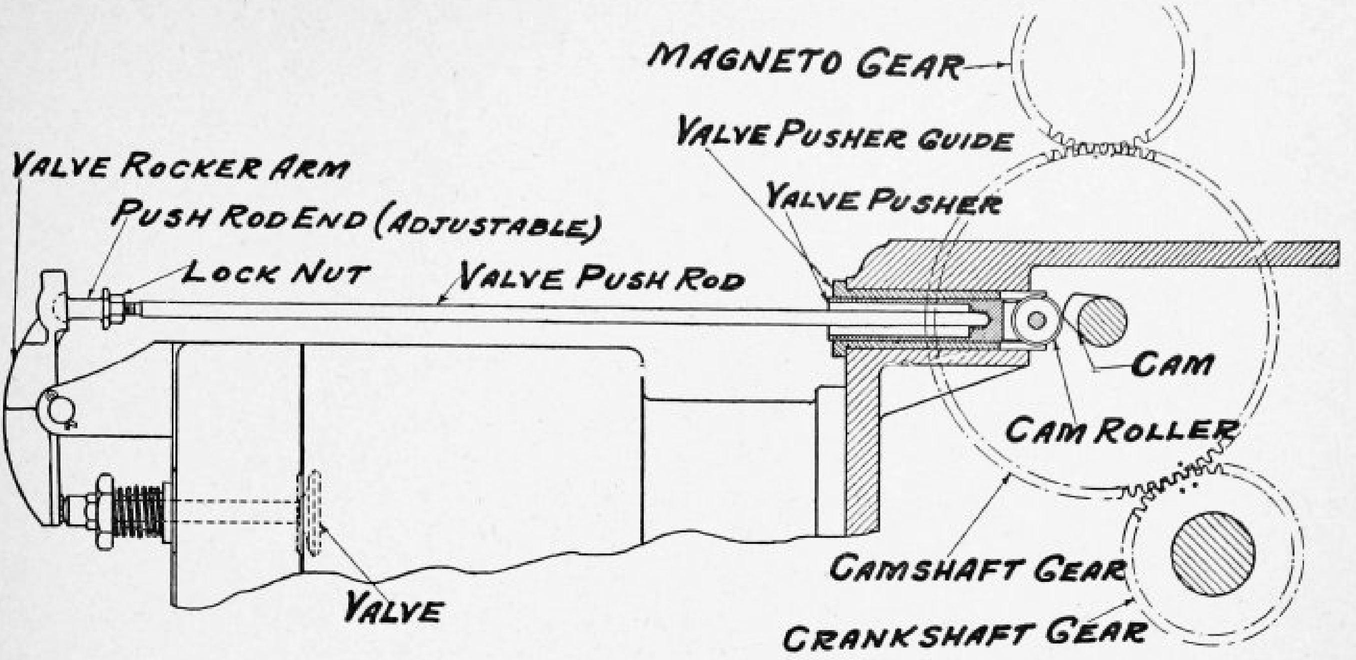
All valve operations are located or "timed" from one or the other of the motor dead centers. Thus, when at the stationary point nearest the cylinder head, this piston is said to be "on inner dead center;" and when it is at its greatest distance away from cylinder head, it is "on outer dead center." These points are marked on top of the flywheel with reference to a straight line along the joint between crank case and crank case cover. When the right hand piston is on inner dead center, the left hand one is on outer dead center.

The right hand intake valve should open about 5 degrees after the right hand piston passes inner dead center on first revolution which would mean that the dead center mark on flywheel would be past the reference line about 1 3-64 inches. The intake valve should close about 35 degrees after outer dead center, first revolution, or after the outer dead center mark has passed the line about 7 7-64 inches.

The right hand exhaust valve should open about 45 degrees before the piston reaches the next outer dead center second revolution, or about 9 7-16 inches ahead of the outer dead center mark on flywheel. It should close when piston is on the next inner dead center, third revolution. The valve operations for the left hand cylinder should be timed in the same way, but with reference to the proper dead centers for that side. These points are all marked on the fly-wheel, but the operator should be able to check them up according to the proper dead centers.

Adjusting Valve Push Rods.

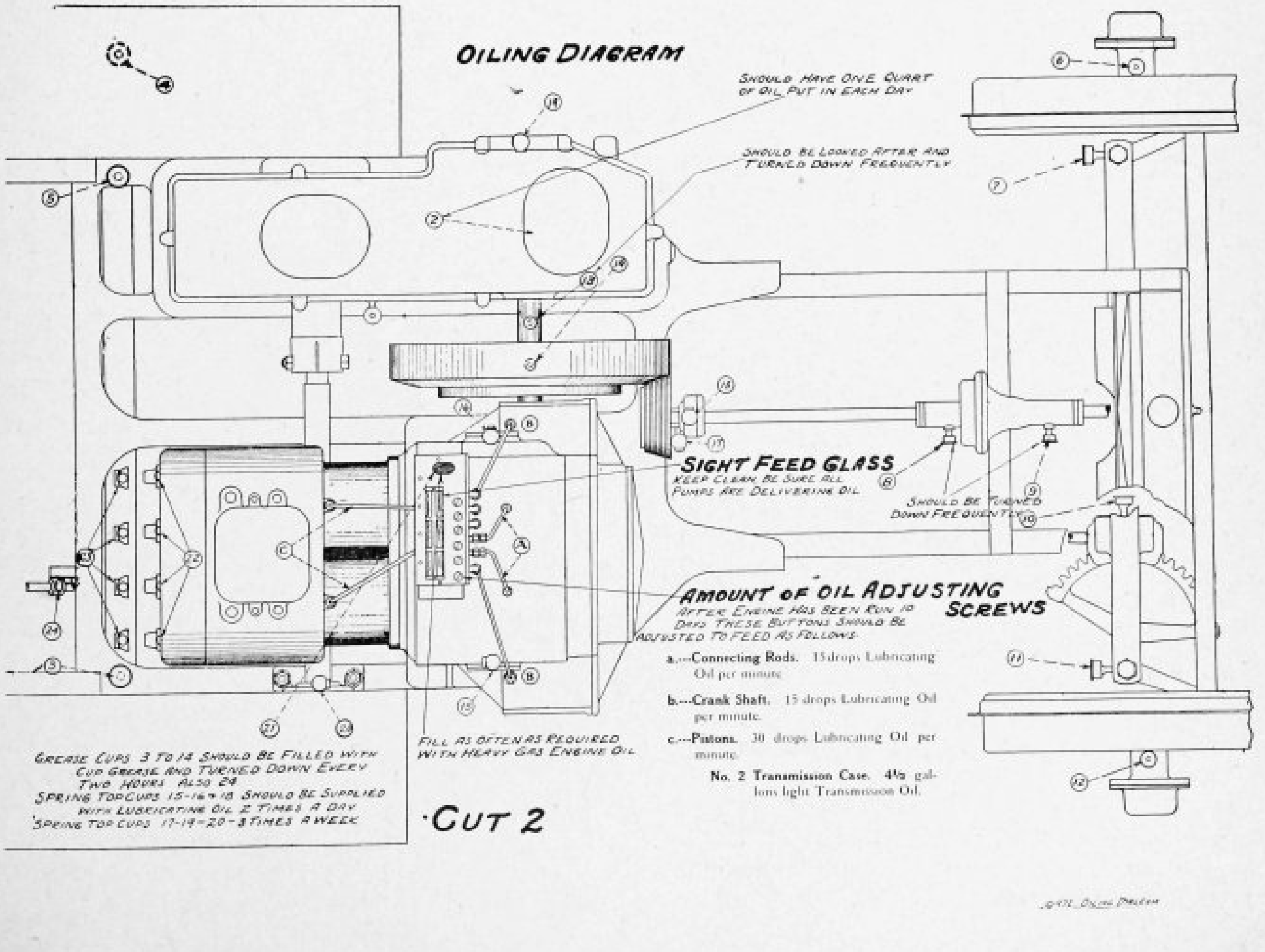
The greatest clearance between end of valve push rod and valve rocker arm should be about 1-64 of an inch when engine is well warmed up. This is ad-



justed by loosening the lock nut on rear end of valve push rod and screwing into or out of the valve push rod adjuster. Shortening the rod causes the valve to open later and close earlier, while lengthening rod opens valves earlier and closes it later.

Timing Valve Gears.

If for any reason it is necessary to remove either crank shaft or cam shaft, care must be taken that the crank shaft gear and cam shaft gear are properly timed. Turn crank shaft until left hand piston is on



CUT 2

inner dead center. Two teeth on crank shaft gear will be found marked with a prick punch. Place between these two the single tooth marked on cam shaft gear. Likewise two adjacent teeth on cam shaft gear are marked, between which must be placed the single marked tooth on the magneto gear.

Lubricator Instructions

The lubricator lubricates the two crank shaft bearings, the two connecting rod bearings, and the two pistons. These are the most important bearings on the motor and care should be taken that the oiler is kept well filled with a good heavy Kerosene Motor Oil. Check the amount fed by each feed pump through sight feed glass occasionally and see that it feeds the following number of drops per minute:

Pistons	30 drops each
Connecting rods	15 drops each
Crankshaft bearings .	15 drops each

If for any reason you suspect that any bearing is not being properly lubricated, make an immediate investigation. Remove oil pipe where it attaches to bearing and see if passages are clear. Also see that oil hole leading to bearing is free from all obstructions. This should be done after engine has been running a while and oil has warmed up slightly. To increase amount of oil, turn adjusting screw on top of pump cover to the left; to decrease, turn to the right.

It is of vital importance that no dirt or water be allowed to get into the lubricator to cut the bearings or clog up the pipes. For this reason, the top should be kept screwed down and the filling screen should never be removed. Even with care, there will be a collection of water and sediment in the bottom of the lubricator. This should be drained out once a month by removing the plug in the bottom and then the lubricator flushed out with kerosene. After draining out kerosene and refilling, the hand lever should be given about two dozen turns to be sure that oil reaches the bearings.

Care of Grease Cups.

Grease cups are especially valuable in bearings exposed to dirt, in that the grease is constantly working out at the ends of the bearings, and has a tendency to keep dirt from entering. To secure this result, however, they must be properly used. Grease cup 13, Cut 2, should be given a couple of turns every two hours.

Care of Cup Grease.

Care must be taken that grease cups are screwed down until grease begins to show at ends of bearings. Special care must be taken to keep grease pails covered and grease free from dirt and trash. Grease cups should be wiped off before unscrewing, so that dirt will not be carried up inside.

Kind of Cup Grease.

Any good grade of cup grease that is not too hard to squeeze out of the cup with reasonable amount of compression may be used.

Transmission Case Oiling Instructions.

The transmission case should contain about two gallon of heavy transmission oil.

This should stand about two inches deep on the lower part of large differential spur gear, from which it is thrown on all other gears in the case and also into the ball and roller bearings.

About once every four weeks this oil should be drained out by removing the plug at the bottom, flushed out with kerosene and replaced with fresh oil. Care must be taken to keep all gaskets and hand covers tight.

Ball and Roller Bearings.

All the ball and roller bearings on the tractor are taken care of through grease cups and mechanical oiler lubrication except the right master pinion bearing, which should be oiled once a week, and rear pump shaft support bearing which should have oil several times a day. These bearings should be oiled with transmission grease or transmission oil. Especial care must be taken to keep all dirt out of these bearings while oiling. Clean off all dirt from around plugs in housings, and wash with kerosene. Remove plugs, drain out old oil, flush with gasoline or kerosene and fill one-third full of clean oil.

Differential Gear Case.

When tractor is assembled, differential gear case is well packed with cup grease and since it runs in an oil bath, should require no further attention from the operator. If the differential is taken apart at any time for overhauling or repairs, it should be repacked with cup grease before being replaced.

THE RUMELY OILPULL
14-28 H. P.

The addition of the 14-28 to the OilPull line of tractors answers the plea of farmers in all parts of the United States and Canada—"Gives us the same OilPull in a smaller size." And here it is—100 per cent OilPull throughout—a smaller edition of the tractor that has become **famous** for its dependability, efficiency and low cost of operation.

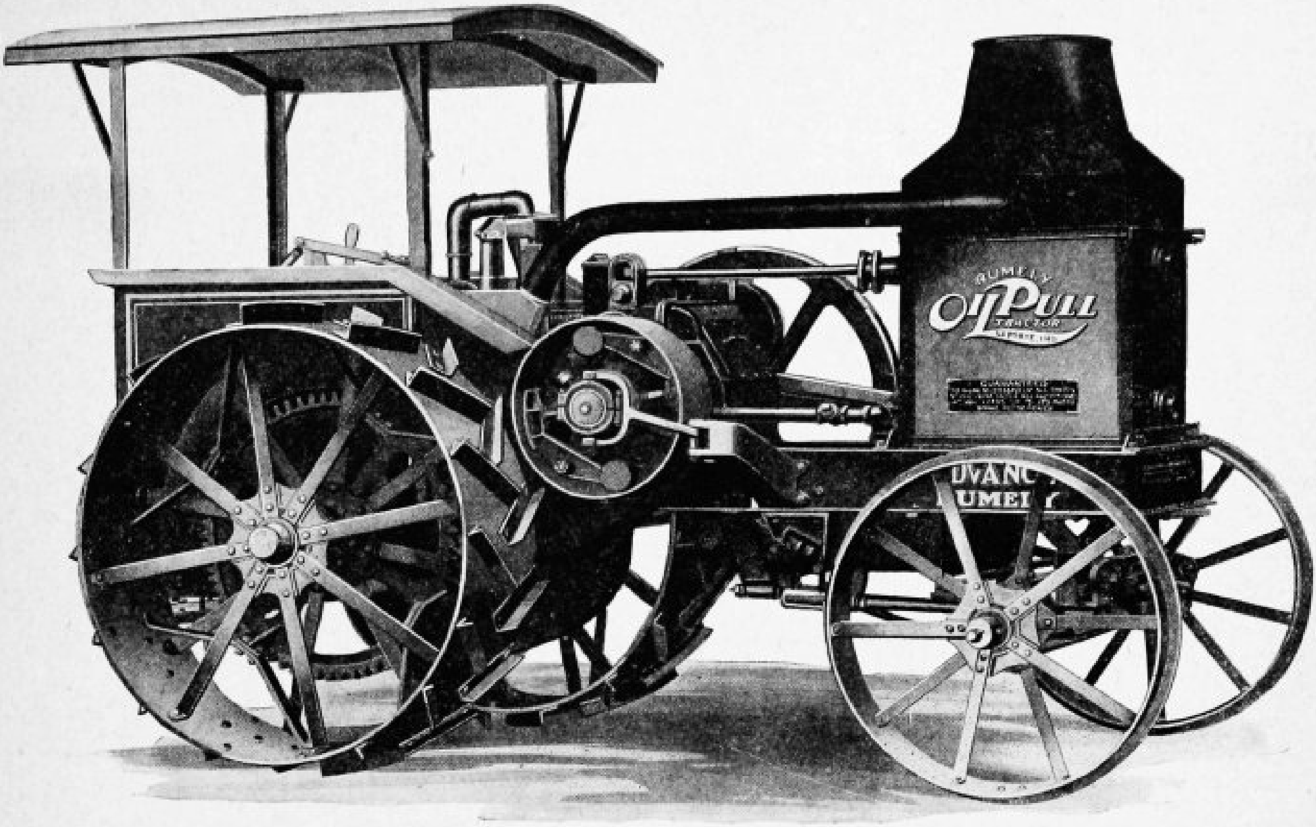
Just as the larger sizes have made a reputation for absolute dependability, strength, long life, ability to efficiently and economically burn low grade fuel oils, automatic speed control, oil cooling and ease of handling—just so does the 14-28 fulfill all expectations for real OilPull Service.

Big Power With Light Weight

"Right weight" best expresses the lightness of the 14-28. It weighs but 8700 pounds with all equipment and full tanks light enough to meet every requirement, yet in no way has strength or power been sacrificed. It is a **big power** outfit. Lighter than six good horses, the 14-28 OilPull has the pulling power of twelve, plus the ability to work without resting.

Easy to Operate

In designing the 14-28 close attention has been given to ease of operation and convenience in hand-



Rumely Oil Pull Tractor "16-30"

ling. To make starting the easiest possible, the 14-28 is regularly equipped with an air starter. An autombile type steering device makes guiding easy, to which the large front wheels contribute. The 14-28 is short turning—it will turn in a 17-foot radius. The platform is but a step from the ground—a convenience that needs no explanation. All operating levers are within easy reach and all working parts, while carefully protected, are easily accessible for inspection. A comfortable seat means something in a day's ten-hour run—the fact that it can be swung out of the way when not in use is an extra advantage.

Fuel System and Carburetor

The fuel system used in the 14-28 has been fully explained in the preceding pages. The Secor Oil Fuel System is common to all sizes of the OilPull tractor —the **only** system by which kerosene or lower grade oil fuels can be used **successfully** in a tractor. This system, as you know, provides means for enabling the governor to exert a simultaneous and continuous triple control of (1) the quantity of fuel charge, (2) proportion of the fuel mixture, and (3) the internal temperature.

We emphasize again that oil is superior to gasoline for fuel **only** when fuel mixture proportions and combustion chamber temperatures are **instantaneously** and **automatically** readjusted to harmonize with every change in working conditions.

In the 14-28, as in the larger sizes, the fuel that is cheapest for you to buy is the fuel your 14-28 will handle, and handle **successfully** and **economically—at all loads, under all conditions, all the time, any place.** Remember that an iron-clad **written guarantee** goes with every OilPull tractor—absolute protection for the owner, with no time limit.

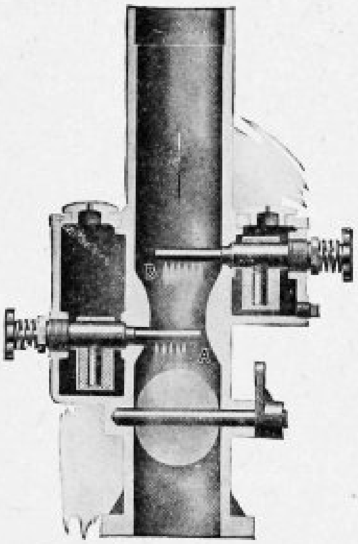
The 14-28 carburetor is a remarkably simple apparatus, entirely free from floats, springs, balls, internal automatic mechanism or complicated parts, requiring frequent adjustment, or changing to suit damp or dry weather. It consists simply of a vertical tube of peculiar internal shape, surrounded by three divided chambers for kerosene, water and gasoline, each having a needle valve. Below the fuel chambers the throttle valve is placed, which is coupled direct to the governor and accurately measures and proportions each charge of mixed fuel, air and water that goes into the cylinders.

The gasoline chamber is used only in starting, and as it has no other use, there are no automatic means for getting gasoline into it. A bronze plunger pump working off the cam shaft lifts kerosene and water to the carburetor, the surplus draining back through overflow pipes.

A jacket on the exhaust pipe heats the intake air with means for regulating the amount of heat. This is necessary in cold weather only.

The air first goes through a cleaner where the dust and grit are removed, and then enters the top of the carburetor, passes through the venturi and mixes with the kerosene and water, the relative quantity of each being regulated by the governor controlled throttle valve located in the lower part of the carburetor. From here the mixture goes direct to the combustion chamber of the motor to be consumed.

In outward appearance it follows general lines of carburetor construction, as practiced by builders of internal combustion engines. The internal construction, however, is radically different from that of carburetors of other builders. This carburetor is very similar in design to that of our earliest carburetor patent.



Sectional View of Carburetor

The above illustation shows a cross section of the 14-28 carburetor. It will be noted that the central cylindrical passage has a restricted portion forming a venturi tube. The oil fuel nozzle is located in the under portion of the venturi, while the water nozzle is located above.

Due to the peculiar shape of this passage and the relation of the nozzles to it, the proper quantity and proportions of fuel and water are **automatically** fed to the engine at all times, regardless of load.

The action of the engine piston produces a partial vacuum in the carburetor passage, and this relative vacuum in the zone marked A varies with the load, so that the **correct proportion of fuel is always exactly suited to the existing load.**

In the zone above the venturi marked B, a relatively strong vacuum prevails during the heavy loads, but decreases very rapidly as the load is reduced. At the low loads the vacuum is reduced to such an extent in this zone that no water is fed.

Thus we have a means whereby the fuel mixture is **automatically fed under governor control in correct proportions at all loads**—the water being automatically supplied in correct proportions for the higher loads only and none at all being admitted for the light loads.

The effect of water fed at low loads is injurious, for if fed in quantity it will interfere with the operation of the engine, and in any case will cause fuel waste.

The Motor

The 14-28 power plant is a two-cylinder, horizontal, valve-in-head motor, designed and built by us for this particular tractor, and to successfully use the cheap oil fuels for which this tractor is recommended. Low speed, accessibility and oversize working parts are noticeable in the 14-28 motor.

It has an easily removable cylinder head, make and break ignition of our own make, with a wide range of spark adjustments, force feed and splash lubrication, and all important bearings split and made adjustable for wear.

By removing the cover plate on the crank case all interior parts can be inspected and minor adjustments made, or the connecting rod caps can be disconnected, and then, removing the cylinder head allows the piston and connecting rod to be pulled out from the rear.

Two spur gears operate the entire mechanism of the motor, with two additional spur gears to drive the circulating pump. The clutch is of the expanding shoe type, proved by many years of use to be best suited for traction work. Adjustment of one shoe automatically adjusts the other.

The 14-28 motor is governor controlled, the speed of the engine being **automatically** and **instantaneously** adjusted to the load. The extreme close regulation of the Rumely OilPull tractor is universally acknowledged, and the 14-28 is no exception.

Automatic Lubrication

The piston, crankshaft, and connecting rods are lubricated by an automatic force feed oiler, which can pump oil at any temperature and against a pressure of 2,000 pounds to the inch, and combined with the large bearing surface absolutely protects the user against bearing trouble, which is common to motors using splash alone. All minor bearings and parts are subject to a heavy splash from the crank case, the oil being kept up to the proper level by a constant supply from the lubricator. This system of oiling absolutely insures a positive, constant lubrication of all working parts.

Cooling System

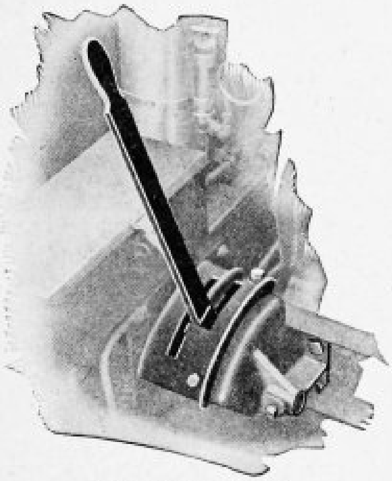
As all OilPull tractors, the 14-28 uses oil instead of water for cooling. A centrifugal pump attached to the motor, circulates oil through the cooling system. As mentioned in the fore part of the catalog, the advantages are many of using oil for cooling instead of water—oil does not evaporate, deposit scale in the cooling jacket, will not boil at the higher temperatures necessary to the use of kerosene, and will not freeze. The 14-28 can be operated in the coldest weather without ever draining the radiator—it can be run on the hottest day with no danger of boiling. Also, oil cooling does away with a cooling fan, which consumes power and is a source of trouble and annoyance.

As cooling oil does not evaporate as does water, once filled the OilPull radiator will go indefinitely without replenishing.

The Radiator

It is only fair to credit part of our OilPull success to our special design of radiator (patent applied for). Every owner and user of an OilPull will be witness to the fact that the ordinary radiator troubles, common to most tractors, have been entirely eliminated from the OilPull. The design of the OilPull radiator provides maximum efficiency for the given cooling surface employed, so that our radiators are much less bulky than the less efficient radiators.

The steel radiator is composed of hollow, flat sections made from heavy galvanized sheet steel, and is built in one separate unit and then bolted to the frame. Our design also provides for disassembling the radiator with ease, affording easy access to every part.



Gear Shifting Lever

Band Wheel and Clutch

The expanding shoe type of clutch has long been acknowledged the most satisfactory, and today is the most widely used on heavy duty farm tractors. The one defect of this type of clutch has been the difficulty of so adjusting the toggles that the pressure on all shoes is equalized. But in the 14-28, by the simple method of connecting opposite toggles independently of the hub, we have entirely overcome this defect. Adjusting one toggle is sufficient, as the pressure is always exactly equal on both shoes. Adjusting one **automatically** adjusts the other.

Raybestos-faced shoes, dust-proof collar, and correct proportions and balance make this a distinct advancement over any tractor clutch in use, and one instantly appreciated by the experienced operator.

The clutch is operated by a hand lever located on the platform, with a brake gripping the band wheel face, by the same motion of the lever that disengages the clutch.

The 14-28 can be lined up with a thresher or other machinery, backed into the belt, and the belt started and stopped by the operator, without leaving the cab.

The Transmission

When designing the transmission for the 14-28, we did not simply try to devise a method of driving the rear wheels by the power from the motor, but also to use that power with the least possible loss, lost power being caused by friction, with its consequent wear and frequent repairs.

The exceptionally high drawbar pull and low fuel consumption prove the 14-28 transmission to be as efficient and free from friction as any power transmitting mechanism yet devised.

All transmission gears are of special hardened steel, with machine cut teeth of the proper pitch.

The pinion on the band wheel hub drives the gear on the reversing shaft which extends through the case, both being machine cut and running in an oil tight and dust proof case on the outside of the frame.

The reversing and countershaft are high carbon steel, accurately ground and running in Hyatt heavy duty roller bearings. The four splines on the reversing shaft are milled from the solid shaft, instead of inserted keys.

All gears on both shafts are accurately cut and hardened, thereby imparting maximum resistance to wear.

The differential shaft is high carbon steel, ground and carried by two babbitted bearings, which are split and adjustable for wear by means of shims. With the cover off, the entire differential unit may be lifted out by removing the two bearing caps.

The steel differential spur gear is machine cut and so constructed that the eight springs (shown in illustration) absorb all jerks and shocks and help materially in prolonging the life of the transmission.

The master pinions are steel castings, case hardened, with four and one-quarter inch face, and both keyed so as to be easily changed.

The entire transmission is enclosed in a two-piece, dust proof, oil tight case. The transmission case is a semi-steel casting, securely bolted to the under side of the frame. The lower half is removable for inspection or adjustment.

The complete transmission runs in an oil bath, all parts being constantly and thoroughly lubricated by splash.

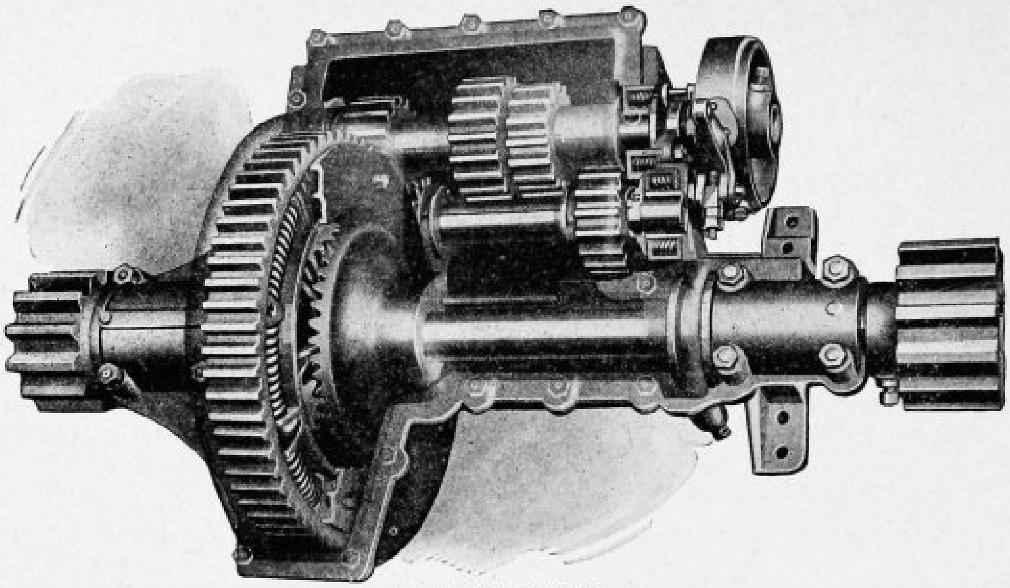
The Rumely OilPull

(18-35 and 30-60 H. P.)

These are the medium and large sizes of the Rumely OilPull which hhave been on the market for years and which have a universal reputation for long lasting dependability and economy.

They handle all tractive and belt jobs, the 18-35 pulling up to and including six bottoms in plowing; the 30-60 pulling up to and including 10 bottoms, depending upon the nature and condition of the soil. The 18-35 will handle any separator up to a 30-inch cylinder, with all attachments; the 30-60 will run the largest separator made.

There is little difference in the general design and construction of the 18-35 and 30-60. The latter, of



The 14-28 Transmission

course, is more powerfully made, to do bigger work, but the main difference is that the 18-35 is a single cylinder machine, the 30-60 being double cylinder.

In the following pages we are but briefly covering the 18-35 and 30-60 for the simple reason that all three sizes operate on the same principle. The fuel system is identical; the same strength and long lasting construction is used; close automatic speed regulation, oil cooling, etc., all fully covered in the fore part of this catalog.

The Carburetor

The patented system by which the OilPull so successfully handles oil fuel is fully covered on page 230. Exactly the same system is common to all sizes of the OilPull. So we will confine ourselves here to the description of the Secor-Higgins carburetor used on the 18-35 and 30-60 OilPull sizes.

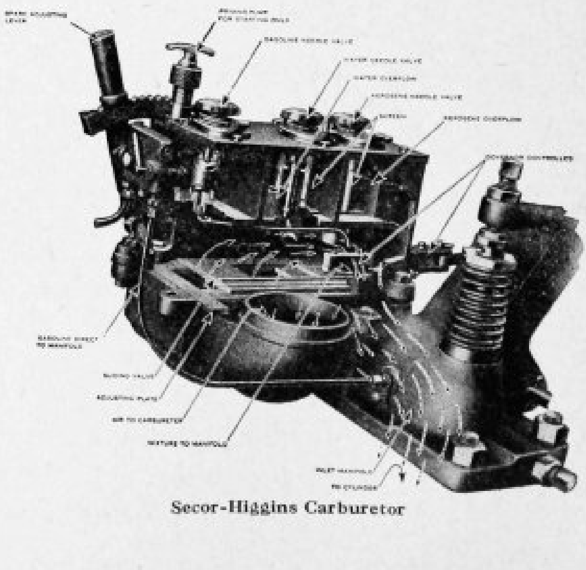
The carburetor, as may be seen in the illustration below, is divided into upper and lower sections, the upper section being again divided into three compartments. The compartment farthest to the right is for the kerosene, the middle one for water and the one farthest to the left for gasoline. All open into the lower section.

The lower section is the mixing chamber. In the bottom of this are three rectangular openings. The two openings on the left hand side admit air to the mixing chamber; the one on the right is the opening to the manifold through which the mixture of kerosene, water and air passes directly into the cylinder. A plate which is controlled by the governor slides back and forth over these openings. The openings in this plate are arranged so that when it is pulled to the right the outlet to the cylinder is made smaller, while the air inlet is also reduced to a lesser extent through the uncovering of the opening at the left hand of plate.

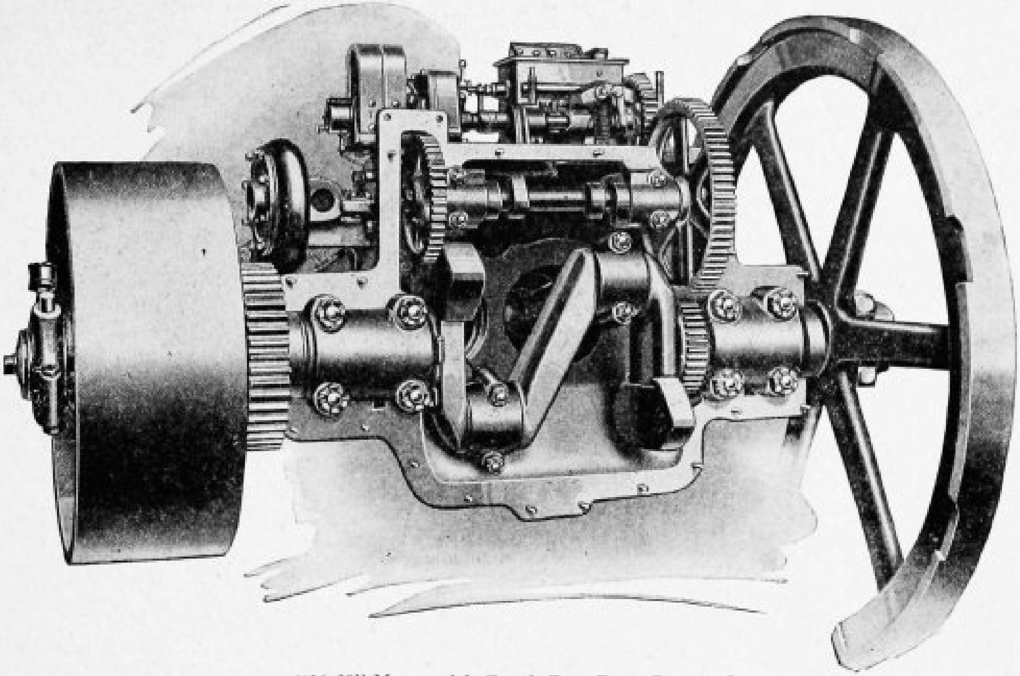
Needle valves in the kerosene and water chambers control the maximum amount of fuel and water to be fed. These need be set only once at full load and the carburetor under governor control then takes care of the adjustment for all other loads.

For example, at light loads the sliding plate is in the position shown. Then the outlet to the cylinder is small and the air opening at the left is comparatively large, so that the suction in the mixing chamber is not very great. With an increase in the load, the governor moves the plate over to the left till at full load it is as shown in dotted lines.

In this position the entrance to the cylinder is made larger, while the air inlet area is also increased but to a lesser extent. Thus, the suction is increased, thereby inhaling an increased quantity of fuel into the cylinder, but the proportion of air increases at a greater ratio than the fuel. This makes a leaner mixture at heavy loads and a richer one at light loads, so that the fuel mixture varies automatically as compression changes and proper proportions are provided for complete combustion at all loads.



Secor-Higgins Carburetor



"16-30" Motor with Crank Case Cover Removed

Gasoline is used only for starting, just enough to warm up the cylinder, this much being injected into the gasoline compartment by a force pump and just enough gasoline is furnished to the carburetor for starting. As soon as engine picks up speed, the oil is turned on and gasoline turned off.

Notice the simplicity of every part of the Secor-Higgins carburetor. Nothing to require expert handling—nothing to get out of order. No springs, floats or check valves to wear out. Everything automatic, so that perfect control is assured. When the load is light, suction is not great enough to draw the water into the mixture, supplying the fuel in just the right condition for such loads. At about half load and above, suction draws in water in increasing proportion to the kerosene and air.

Water, fed in correct proportion, decreases fuel consumption and increases the power of the engine. It also makes the mixture burn more slowly, keeps it cool, and scours the cylinder, cleaning out the carbon particles, which would otherwise cause pre-ignition and hammering. It gives the piston a steady push rather than a sharp blow, and greatly adds to the power developed.

That is the secret of the Secor-Higgins carburetor. By it, all difficulties of using cold kerosene in internal combustion engines are overcome, and with it the Oil-Pull occupies the unique position of being the **only** tractor that will **successfully** burn low grade fuel oils **at all loads, under all conditions.**

INTERNATIONAL
15-30 H. P. KEROSENE TRACTOR

Practically any kind of farm work that can be done with horses is as easily done with a tractor, and in the majority of cases with a saving of expense and time. There are some few exceptions, such as planting or cultivating corn, which can best be done with horses except where a motor cultivator is used. All operations on a grain farm, however, from plowing to hauling the crop to market; all operations in corn growing with the exception of those mentioned above; all work in hay making except operating sweep rakes and stackers, can profitably be handled with a tractor. Besides this, fully one-half of the time of the tractor can be employed to advantage in belt work. Outside of the regular farm work, there are many other jobs, such as pulling stumps, piling logs, loading lumber, road building, and hauling crops to market which can profitably be done with a tractor.

Does All Kinds of Belt Work

The tractor will operate every belt driven machine within its capacity—the feed grinder, circular saw, silo filler, thresher, husker and shredder, hay press, and many other machines, all at low cost, because the International 15-30 uses kerosene for fuel. A tractor is more conveniently handled on belt work than a portable engine, for the reason that it propels itself, and for this reason it is easier to line it up with the machine to be driven than an engine that is mounted on wheels and must be drawn into place by a team.

Drawbar Power Greater Than Horse Pulling Power

The average horse is capable of a continuous pull equal to about one-tenth of his weight. The International 15-30 pulls at its high speed of 2.4 miles per hour 2,350 pounds, or a little more than one-fourth its weight. At its lower speed of 1.8 miles per hour it pulls 3,125 at the drawbar.

This greater pulling capacity together with its ability to keep it up for 24 hours a day if necessary makes the tractor a more economical producer of power than horses.

No matter how cold the day in winter or how hot the day in summer, the tractor is not affected. It is always ready for a hard job. The flies cannot bite it, nor the dust choke or blind it. It gets no diseases to which horses are subject nor no sore shoulders, and its effort is only limited by your requirements. As long as it gets fuel, oil and water, it gives power. To the man who has experienced shortage of power at the height of a busy season, this feature cannot help but appeal strongly. At such a time it is necessary for him to take advantage of every hour. With the tractor this is possible. Full power is available as early or as late as he likes. There is no delay on account of feeding, harnessing, or other care. One man handles a greater amount of power with the tractor than is possible with horses. To operate two gang plows with horses would require two drivers. To operate four plows with a tractor requires but one. This is the way the tractor solves the help problem.

No Injurious Soil Packing Caused by a Tractor

The wheels of the International 15-30 have been made of a large diameter and with wide rims, so that the pressure per square inch is much less on the soil than that of horses. The pressure of each drive wheel of the International 15-30 is about 10 pounds per square inch, whereas that of a 170-pound man wearing a No. 8 shoe is about 14 pounds to the square inch, and a 1400-pound horse pulling a load causes a pressure varying from 18 to 33 pounds per square inch. In order to satisfy ourselves that there was no injurious soil packing caused by the tractor, we questioned 110 owners of tractors in the Northwest. Of these, 101 say that the tractor causes no injurious packing, while 22 of this number claim that the effect of the tractor going over the soil is beneficial. Only nine of the entire number questioned attributed any injury to their crops to the tractor and had no substantial proof for their statement.

A Four-Cylinder, Valve-in-Head Engine, Built from the Ground Up to Operate on Kerosene and Low-Priced Distillate—Not a Rebuilt Gasoline Engine

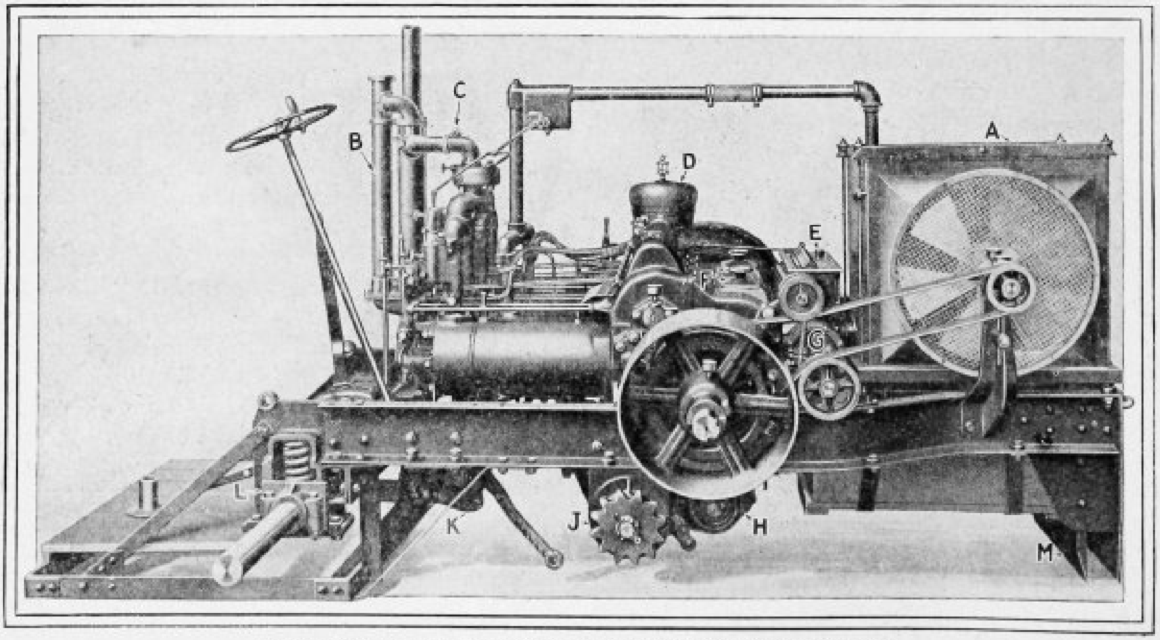
A, cooling tank
B, air intake pipe
C, air damper
D, governor
E, mechanical oiler
F, hand holes in crank case
G, water circulating pump
H, brake band
J, transmission
K, steering worm and sector
L, spring mounted rear axle
M, front bolster

Engine Conservatively Rated

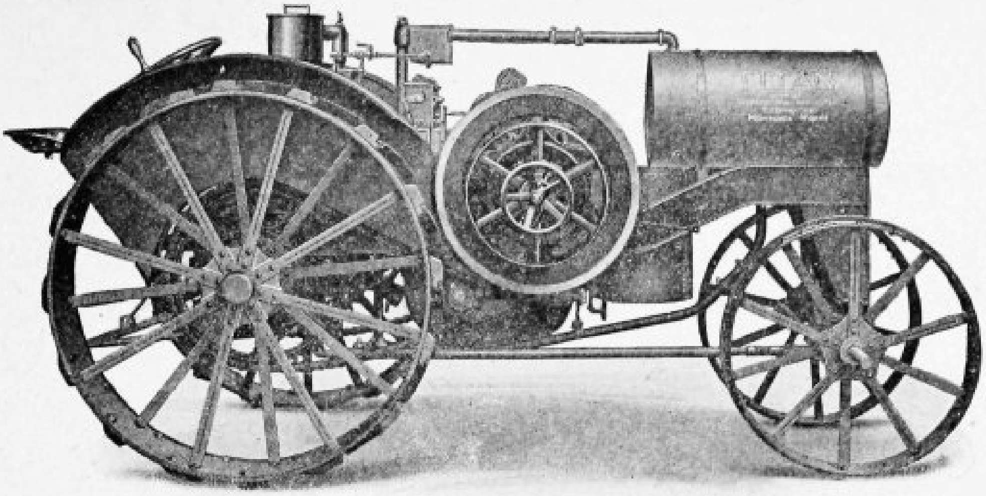
Every International 15-30 engine must develop several horse power in excess of its rated power before it is allowed to go out on the tractor. This enables the tractor to develop its rated power at practically all altitudes at which tractors are usually operated.

Engine Protected From Dust

The engine of the International 15-30 is of the four-cylinder valve-in-the-head type. It is set horizontally on the front because it has been found that in this position the weight can be kept lower upon the tractor and power can be transmitted to the drive wheels without the use of bevel gears, which every



Engine Cooling System, Frame, and Platform of International 15-30



engineer will tell you are wasteful of power. The crank case is entirely enclosed, so that every working part which might be injured by dust or sand is protected.

Frame and Wheels of Bridge-Like Construction

The frame of the tractor is built up from pieces of structural steel formed to the proper shape and put together with rivets, much as a bridge is built. You know that a bridge withstands tremendous strains and gives good service for years when properly built. A tractor frame built along these lines, then, should give the very best service. The wheels, too, are built up by riveting the spokes to the cast hubs and to the rims. The spokes are set staggered, so as to make an extremely strong and rigid wheel.

Chains for Final Drive

The power of the engine is transmitted to the rear wheels through a final drive, consisting of chains and sprockets. This form of drive has proven through repeated experiments to be most satisfactory, because by using it, it is possible to mount the tractor on springs which would not be possible with a gear drive. Chains are less likely to get out of alignment than gears, and if slightly out of alignment do little damage, while gears would rapidly wear out under such conditions. The use of chains and sprockets saves considerable weight and also saves time for the owner in case of injury to the sprocket, for he would still be able to use his tractor with one or two teeth broken out of the large sprocket, while such an accident to gears would put the tractor out of commission. All gears and chains used on the International 15-30 are enclosed and completely protected from dirt.

THE I. H. C. MIXER

A Successful Mixer

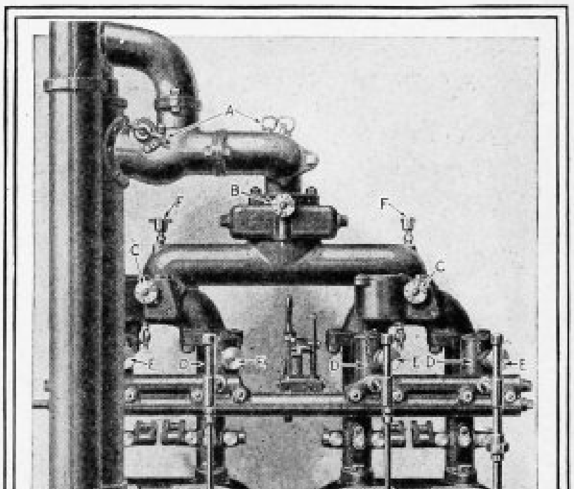
In the design of the fuel mixer, the efforts of the builders to work with the laws of nature are very apparent. Instead of placing a carburetor below the cylinders and depending upon the suction exerted by the pistons to draw the mixture of air and fuel up into the cylinders, the mixer is placed directly above the cylinders, so that gravity would help the pistons in drawing in the fuel. A very short intake pipe is the result and the fuel does not have much chance to condense between the point where it is vaporized and the cylinders.

Warm Air Available

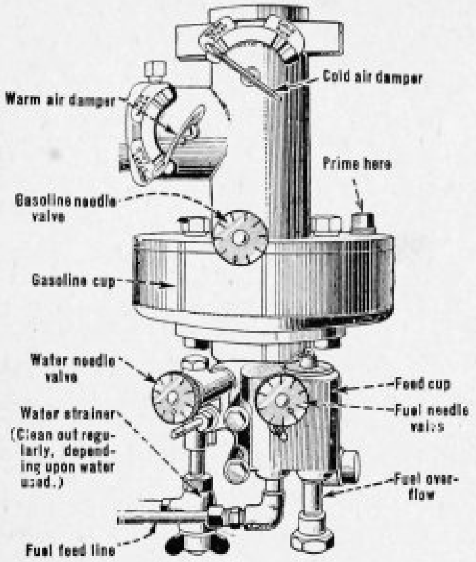
In extremely cold weather, more satisfactory operation can often be secured by the use of a small amount of warm air with the fuel. This can be secured by partially closing the cold air intake and drawing a portion of the air used with the fuel from the jacket B, Illust. 10, which surrounds the exhaust pipe.

Mixer Ajdustments Simple

One needle valve D, Illust. 10, controls the gaso-



Illust. 9. Rear View Fuel Mixer



line supply for all cylinders, but in order to get the best results, there is a separate needle valve for kerosene for each cylinder. This gives a close adjustment and enables the owner to get the greatest economy of fuel and the most even operation. The water valve is automatic after once being opened and needs no special adjustment. See E, Illust. 10.

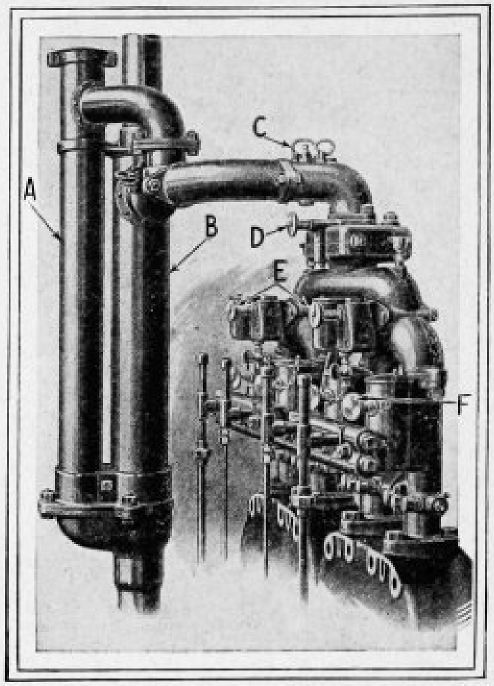
Water Reduces Heat and Carbon

If a kerosene engine has been operating under load for a few minutes, without water supplied to mixer, a peculiar click in the cylinders is heard. This indicates that on account of the high temperature at which kerosene burns there is improper ignition in the cylinders, due to the heating of some parts which cannot be reached by the cooling water in the cylinder jacket. The 15-30 International mixer is equipped with a water valve F, Illust. 10, so arranged that after the water has once been turned on, as when starting the engine, it will automatically supply the correct amount of water spray with the fuel to reduce the heat in the cylinders and prevent this troublesome ignition. Among other things accomplished by water spray entering the cylinders is to assist in the combustion of the fuel to the extent that there is very little, if any, deposit of carbon in the cylinders. This in itself is a decided advantage over a gasoline engine, which is troubled by carbon deposits a greater part of the time.

Only Clean Air Used

All the air that is used in the engine passes through the inlet pipe. The air intake is above the dust zone. This insures clean air at all times. See A, Illust. 10. Clean air means less wear on the working parts. This extended air intake pipe is the simplest possible way of getting clean air.

Owners everywhere are pleased with the International 15-30 because it is easy to operate, its construction is simple, and the high grade of materials used insures long life and durability.



Illust. 10. Side View Fuel Mixer

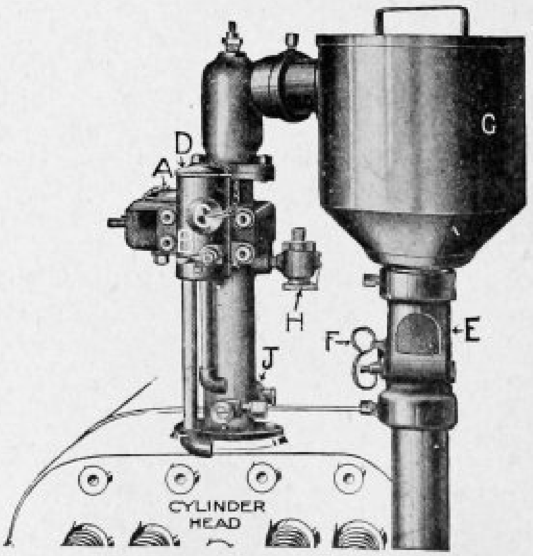
To Start Engine

1. Turn the crank on the mechanical oiler 40 to 50 times when starting the engine, to make sure that the cylinder, crank shaft and piston are getting sufficient oil.

2. Put some cylinder oil on the gland "A" of kerosene pump, disengage side rod "B" from pump arm "C" and pump by hand until the feed cup on the mixer is full.

3. Set magneto for starting engine: To do this, throw small lever out of position in the direction of the arrow, so that the pawl will fall into notch ("A").

4. Crank engine until first explosion occurs, then remove starting crank, and close relief valves on the bottom of cylinder.



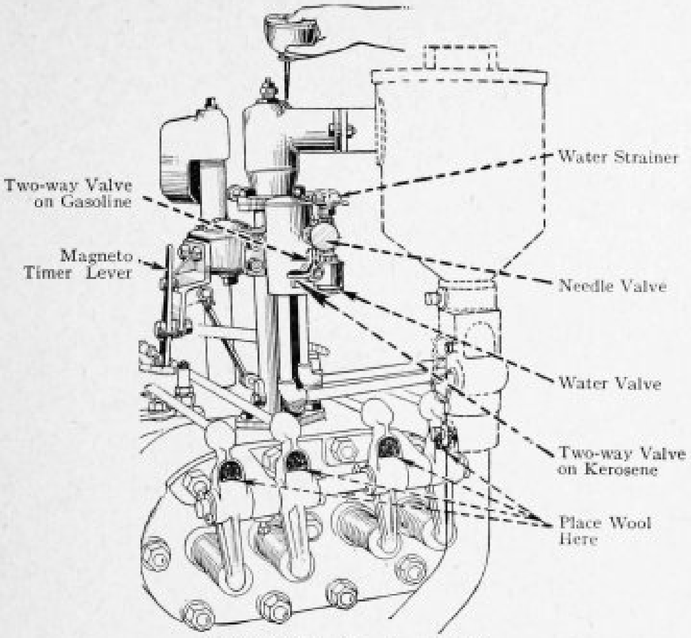


Illustration No. 7. Mixer

5. Push the magneto timer lever on the mixer forward as far as possible, to the position marked "LATE" on the quadrant. This gives a late spark.

6. Place the two-way valve in a vertical position, this being the position for running on gasoline.

7. Open needle valve to marked position.

8. Open relief cocks on bottom of the cylinders by means of the compression relief lever.

9. See that the water valve on mixer is closed.

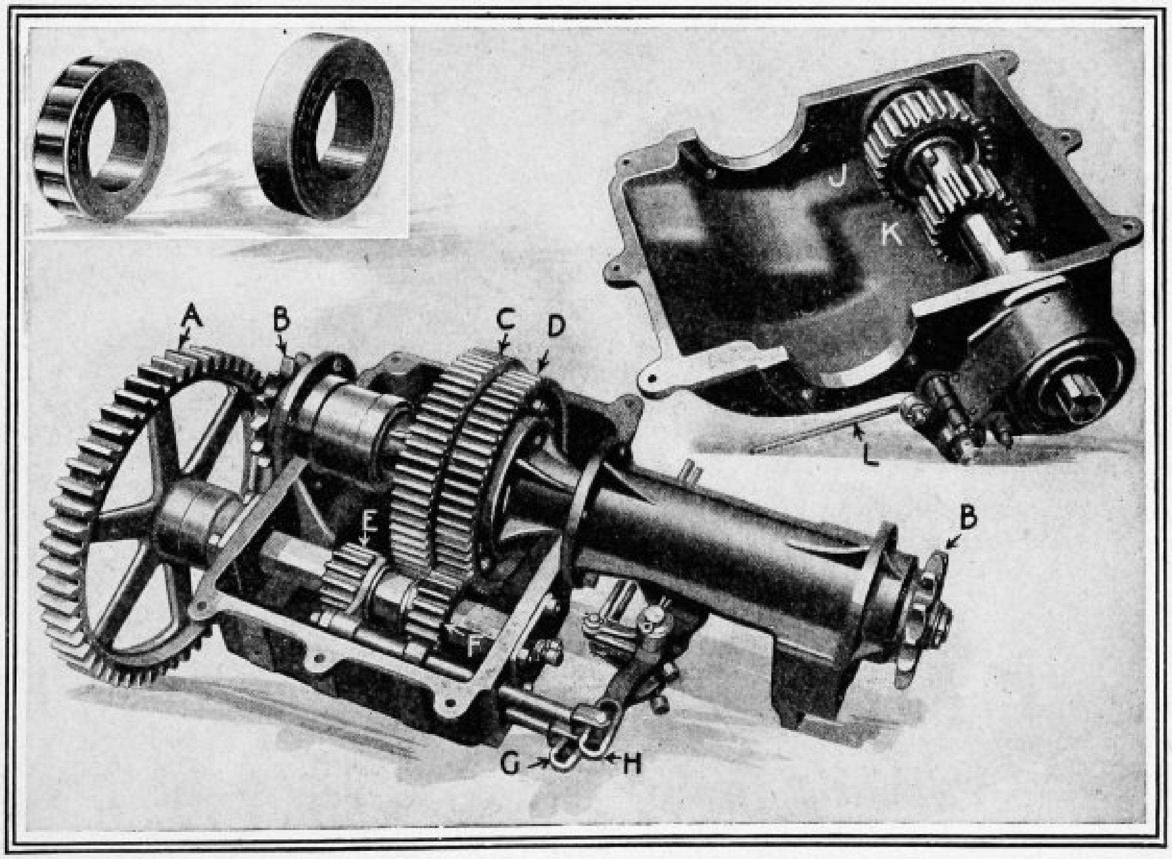
10. Leave cold air inlet in mixer open.

11. Prime engine with gasoline, using the spring bottom oil can shipped with the tractor.

Transmission Completely Enclosed

The power from the engine is delivered to the rear wheels through the transmission gears. By means of these gears, it is possible to control the forward and reverse speeds of the tractor with a single lever. The differential gears located within the gears C and D make it possible for the tractor to turn corners without the loss of continuous power being applied

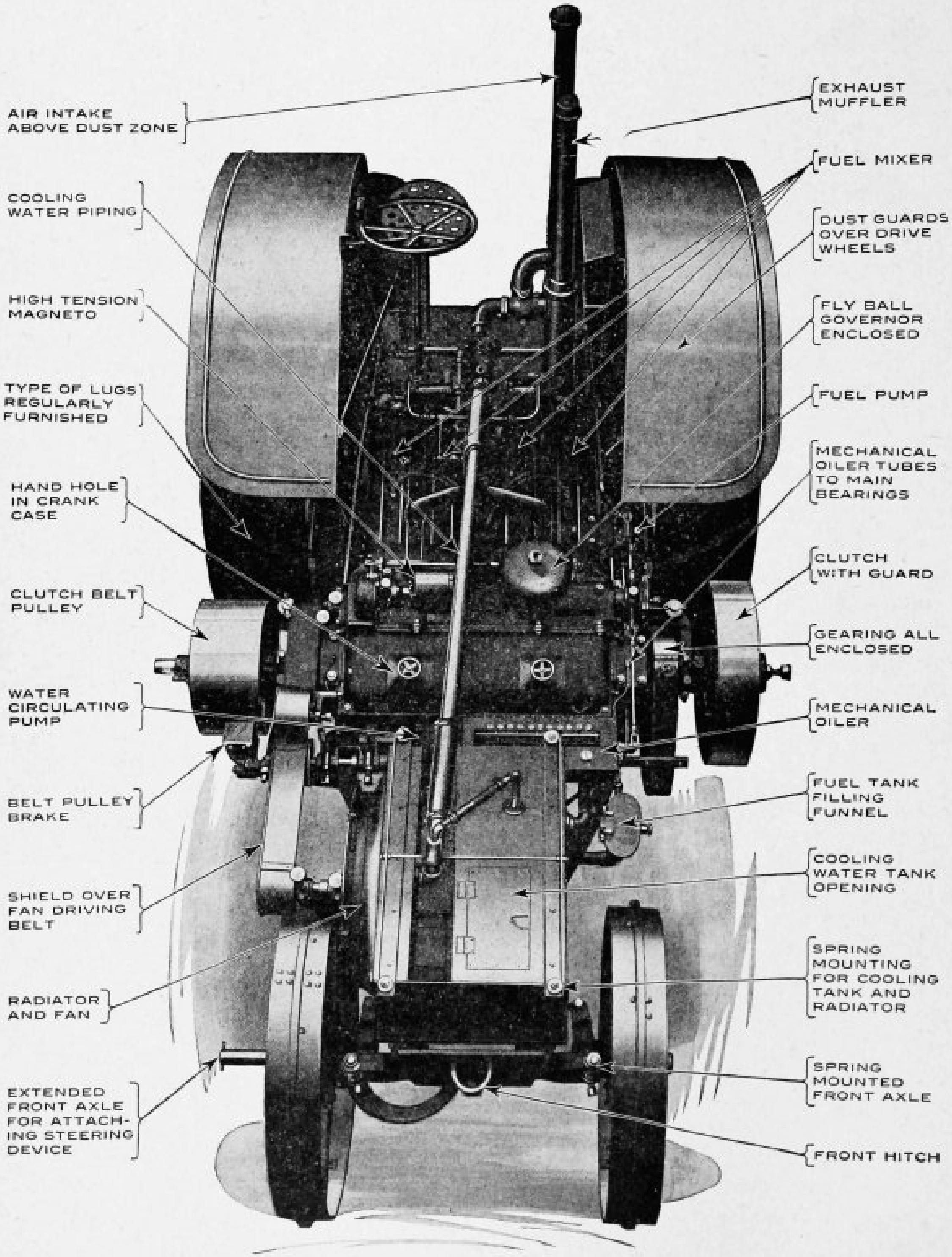
A, countershaft gear
B, driving sprockets
C, high speed gear
D, low speed gear
E, high speed pinion
F, low speed pinion
G, reverse gear shifting lever
H, forward speed gear shifting lever
J and K, reverse pinions
L, brake operating rod

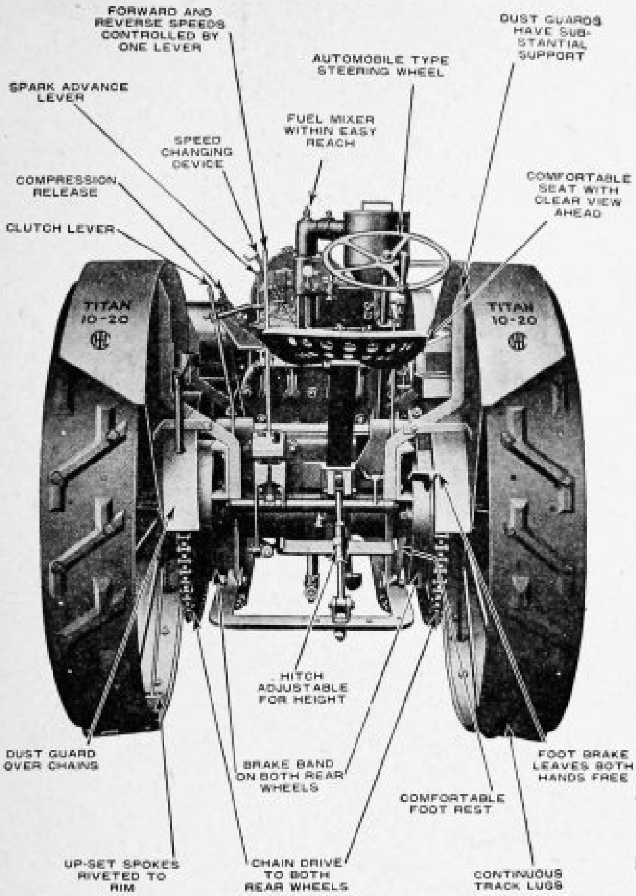


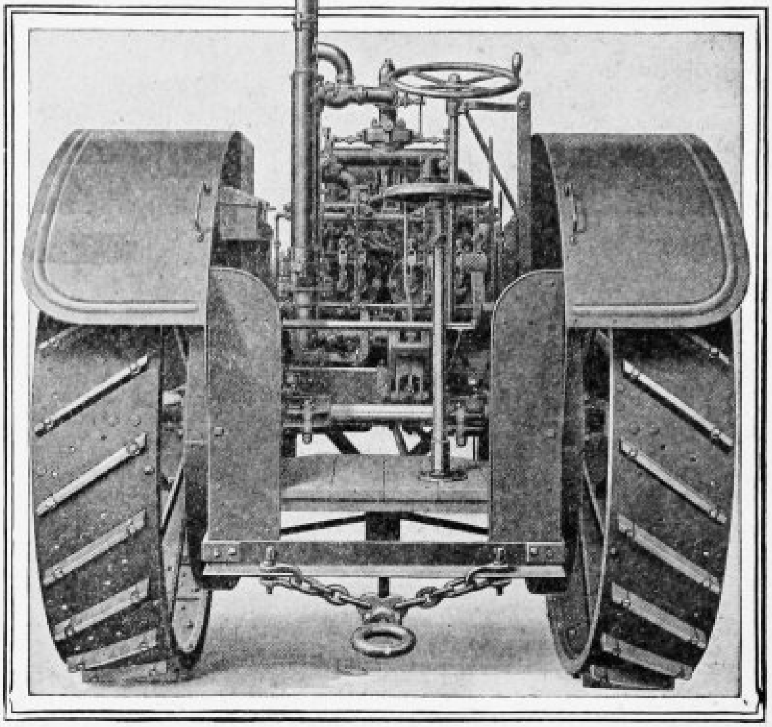
The transmission gears are entirely enclosed and run in oil. The principal bearings are roller bearings, as shown in the upper left hand corner to both the driving wheels. The larger gears, C and D, Illust. 18, continually dip into a bath of oil in the base of the transmission case as they revolve. They pick up this oil between the teeth and carry it to the smaller gears, thus keeping a continual film of oil between the teeth of all gears, which reduces wear to a minimum. The reverse gears J and K, are never out of engagement with the driving gears of the transmission. This makes possible the application of a brake acting upon a drum on the outside of the transmission case.

Brake Controlled by Foot Lever

A brake for stopping the tractor when working in the field or on the road, consists of a drum extending out of the transmission case of the tractor. The contracting brake band acts on this. It is operated by means of a foot lever conveniently placed below the driver's seat within easy reach.







The convenience and comfort of the operator have been considered in the design of the International. Note the spring mounted seat and platform

LIBERTY TRACTOR

LIGHT WEIGHT LIBERTY—4-Cylinder—4 Plow—1-Man—Kerosene Tractor—Absolutely dust-proof—Practically no breakage or repairs. All working parts over-sized running in oil.

It is designed by engineers who have made a life long study of mechanics, strength of materials and the requirements of modern farm machinery.

Scientifically constructed of high grade materials throughout, insuring LONG LIFE and FREEDOM FROM BREAKAGE and REPAIRS and permitting it to be lgiht in weight by having the material properly distributed, insuring ECONOMY OF FUEL.

The roller bearings are so nicely adjusted that you can easily push the tractor across the floor—adding greatly to fuel economy.

It is handsome in appearance, has no array of projecting attachments, but looks simple, strong and sturdy.

Every feature of the LIBERTY TRACTOR has been given careful study. It is manufactured by an organization that has but one purpose in mind—PERFECTION in every detail.

It is the Best Tractor for the farmer because tractor troubles are eliminated.

Specifications for Liberty Tractor

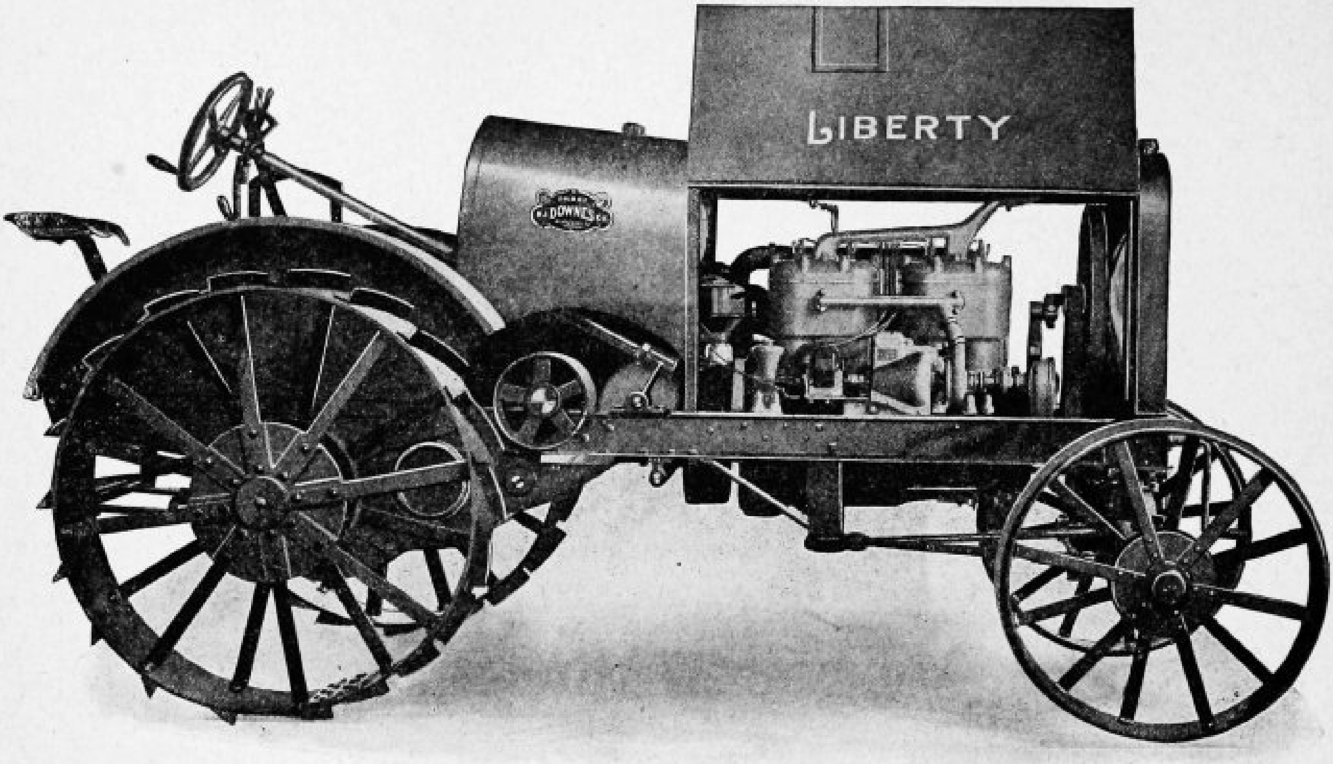
Four Wheel Type driving through Live Axle to Two Rear Wheels.

Motor used in LIBERTY TRACTOR is 5-inch bore, 6½-inch stroke, 34 B. H. P.

CLUTCH—Two shoe expanding type. Large diameter easily adjusted.

TRANSMISSION—Two speed forward and reverse. Low speed 2½ miles per hour. High speed 4½ miles per hour. The gears are all made from special steels cut, hardened and ground. All gears, including Bull Gears, run in oil in a dust-proof case. Shafts are all ground to size and fitted with Roller Bearings and Ball Thrust Bearings are provided where necessary. **The Transmission Case is a high-grade semi-steel casting, oil-tight and dust-proof, rigidly fastened to frame.** Bearing housings are all accurately machined integral with casting, which maintains the gears in proper alignment. All bearings and gears are easily removable and interchangeable. A large hand-hole gives access to all parts. The differential gears are cut and hardened and mounted on roller bearings and distribute power equally to the drive wheels.

REAR AXLE—The Rear Axle is 3¼-inch diameter, special steel, and transmits power direct to drive wheels from steel cut gears which are also enclosed in the transmission case, and is mounted on extra



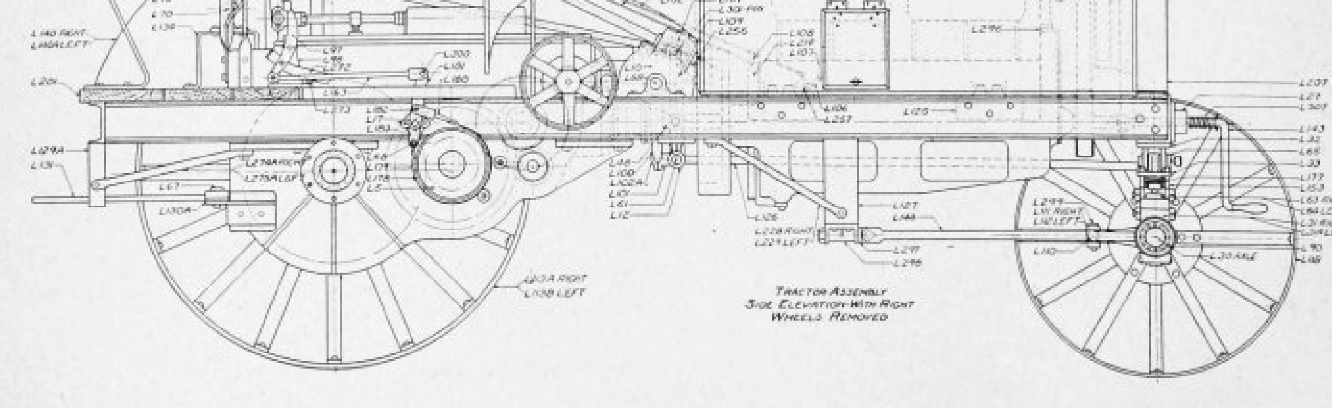
large roller bearings. The Bull Gears are fitted to rear axle with a taper, which makes them easily removable.

BELT PULLEY—The Belt Pulley is 12x8 inches, crown faced, and runs at 900 RPM, giving a belt speed of 2,600 feet per minute. It is mounted on a roller bearing equipped, independent shaft, driven by a separate gear which is disengaged by a convenient lever from outside the case so the pulley does not run when tractor is plowing or on road. The belt pulley is operated by same friction clutch and lever as transmission.

BRAKE—An efficient service brake is provided for holding Tractor on grades, at all times independent of gears.

FRONT AXLE—I Beam construction with Chrome Vanadium steel, semi-elliptic spring. Knuckle type front spindle, which makes easy steering.

DRIVE WHEELS—Two 48x12-inch driven thru



TRACTOR ASSEMBLY
SIDE ELEVATION—WITH RIGHT WHEELS REMOVED

live roller bearing mounted real axle. Flat spokes. Drive wheels extension 6 or 8 inches.

FRONT WHEELS—Two 36x8-inch Roller Bearing mounted. Flat spokes.

COOLING—Extra large tractor type radiator, with 22-inch fan and forced water circulation by centrifugal pump. Enclosed type with no water loss. Nonfreezing solutions may be used in cold weather.

LUBRICATION—The Lubrication is so well complete and well taken care of that it requires practically no attention. There are no open oil holes and an oil can is unnecessary.

FRAME—5-inch Steel channel, hot riveted and well braced. Three-point support. Wheel Base, 97 inches; Width 66 inches; Weight of Tractor, under inches; Width 6 6inches; Weight of Tractor, under 5,800 pounds.

CHASSIS—The Motor and Transmission is mounted on three-point supported frame. Spring mounted on front axle. The clutch is contained in the flywheel and is connected to transmission through universal coupling. A comfortable seat is provided on a suitable rear platform from which the operation of plows and tractor can be easily observed. The steering wheel and control levers are conveniently located to the operator's seat so that the whole machine is easy to handle.

Transmission in the Liberty Tractor

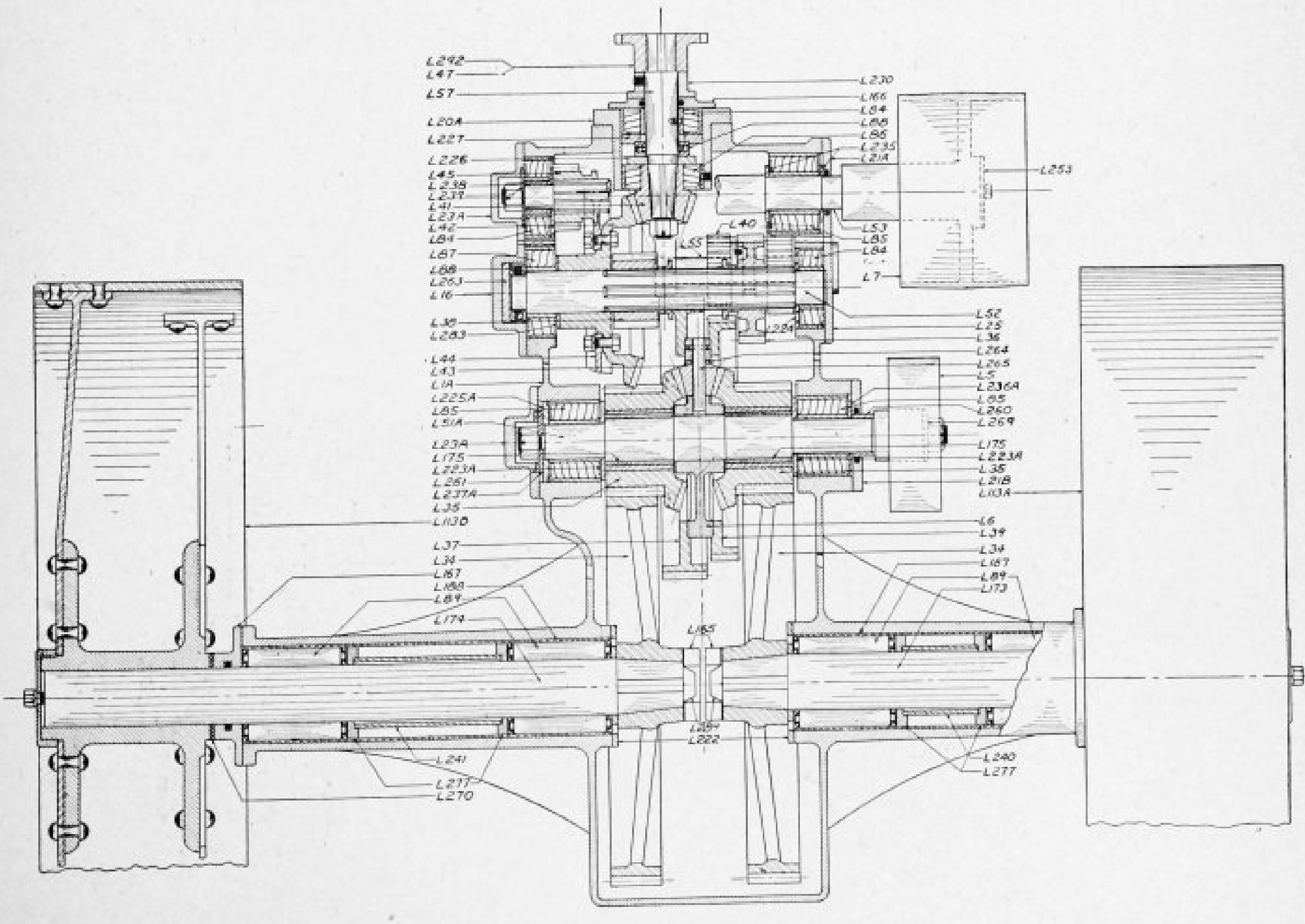
The illustration shows the arrangements of the gears in the unique LIBERTY Transmission case.

The transmission is of the sliding gear type with two speeds forward and one reverse. The speeds are changed by means of the Gear Shifting Lever, operating on a quadrant. This lever operates a cam plate with slots cut for rollers which, in turn, move the gears without any possibility whatever of two sets of gears being in mesh at the same time.

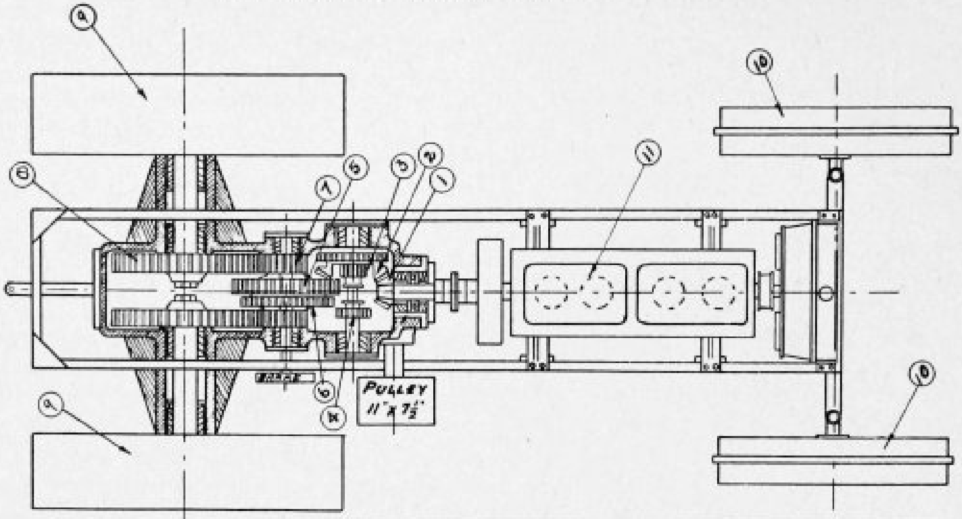
The Shifting Bar for the pulley gear is on the front of the Transmission Case and is moved to the right to throw the pulley into service. This is provided to make it possible to plow without running the pulley.

For belt work, after the set is made and Transmission Case is filled according to instructions, place gear shift lever in neutral, shift pulley gears into position and use clutch as for traction work.

This case is a heavy one-piece casting, which forms the rear section of the chassis, as well as the axle housing and gear case. It is oil tight and has a dustproof cover that can easily be removed for inspection. Roller bearing housings are accurately machined so as to always maintain gears in proper alignment and reduce friction to a minimum. All bearings and gears are easily removable and interchangeable. A large hand hole gives easy access to all parts. The large



LIBERTY FOUR PLOW TRACTOR



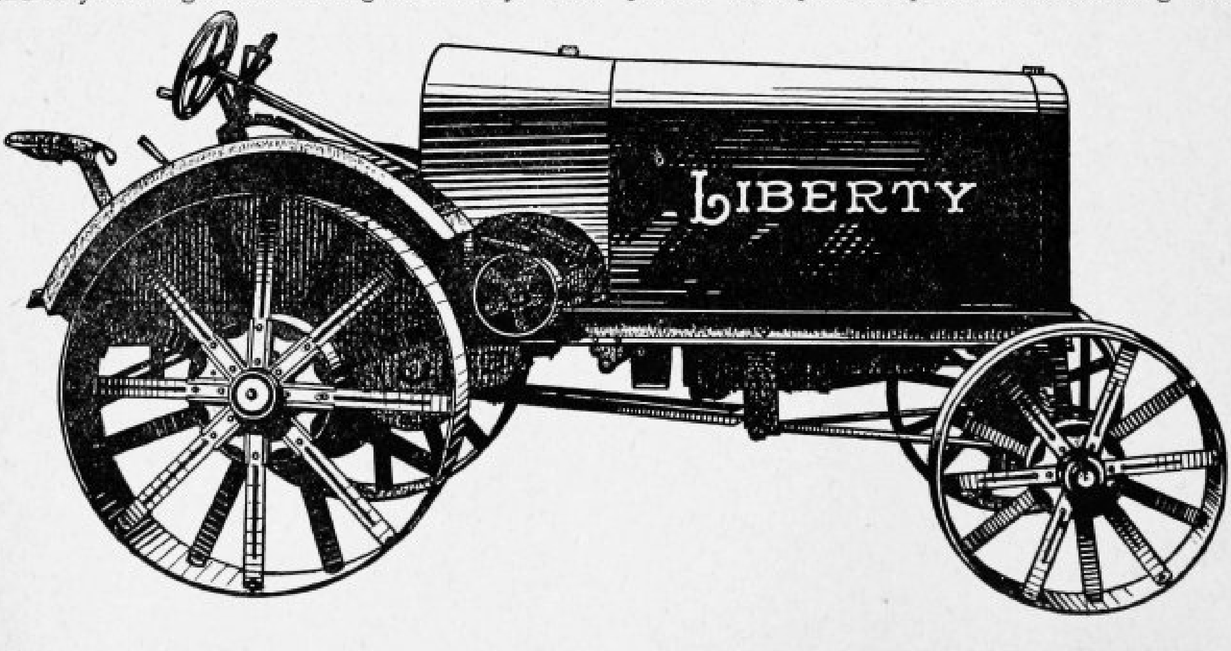
		No. of Teeth	Pitch Dia	Face		
1	Bevel Drive Pinion	15	3¾	1¾"	9	Drive Wheel—48" Dia.—12" Face ½" Thick
2	" " Gear	45	11¼"	1¾	10	Front " —36" " 7" " ⅜" "
3	Low Pinion	16	4⅝"	2⅛	11	Four Cyl. Kerosene Motor—5" Bore—6½" Stroke
4	High "	24	6"	1⅜		Gear Ratio—High—25.6—At 4½ Miles per Hour
5	Low Gear	64	16"	2⅝		" " —Low—44 " 2½ " " "
6	High "	56	14"	1⅝		All Gears Hardened Steel—Mounted on Roller
7	Master Pinion	18	6"	3"		Bearings.
8	" Gear	68	22⅝	3"		

drive gears are manganese steel—ground accurately to size, while the differential gears are special steel—cut and tempered and mounted on roller bearings. The rear axle is 3¼ inches in diameter, of special steel, runs on roller bearings and transmits the power directly to the drive wheels.

Oil is carried by the motion of the gears to every part of the transmission case and every bearing is kept continually flooded with oil, so there is never any chance for hot or "stuck" bearings.

The gears and shafts are all run at the factory, both free and under a load, so that they are all very free and easy running before leaving the factory. The tractor is given exhaustive endurance tests, both on drawbar and belt and no tractor is permitted to go out till it tests up above the rated horse power. It is run on both Kerosene and Gasoline and all minor adjustments of magneto and carburetor are made, so when the tractor reaches the final purchaser it is ready for business.

The above shows a ground plan of the LIBERTY TRACTOR, showing in detail the frame, motor, transmission and wheels. Notice the simple, straight line effect—no unsightly curves or offsets. The front end rests on the axle on a pivot at the center, making a perfect three-point suspension and enabling the LIB-



ERTY to go over any kind of an uneven surface without undue strain. Every little detail has been worked out with a view constantly in mind of a machine that will always render the most efficient service to the user.

The clutch is of the expanding shoe type and is adjusted by turnbuckles with right hand threads. A ball joint is placed in the shoe end of the adjusting screw which allows free action in engaging and disengaging.

The farmer who gets a LIBERTY will realize what real tractor performance is. At the various fairs and demonstrations the LIBERTY has deservedly received the unstinted praise and approval of countless farmers and dealers from all over the country. Farmers who have used LIBERTIES have been loud in their words of commendation.

If it has proven good for them it will do the same for you.

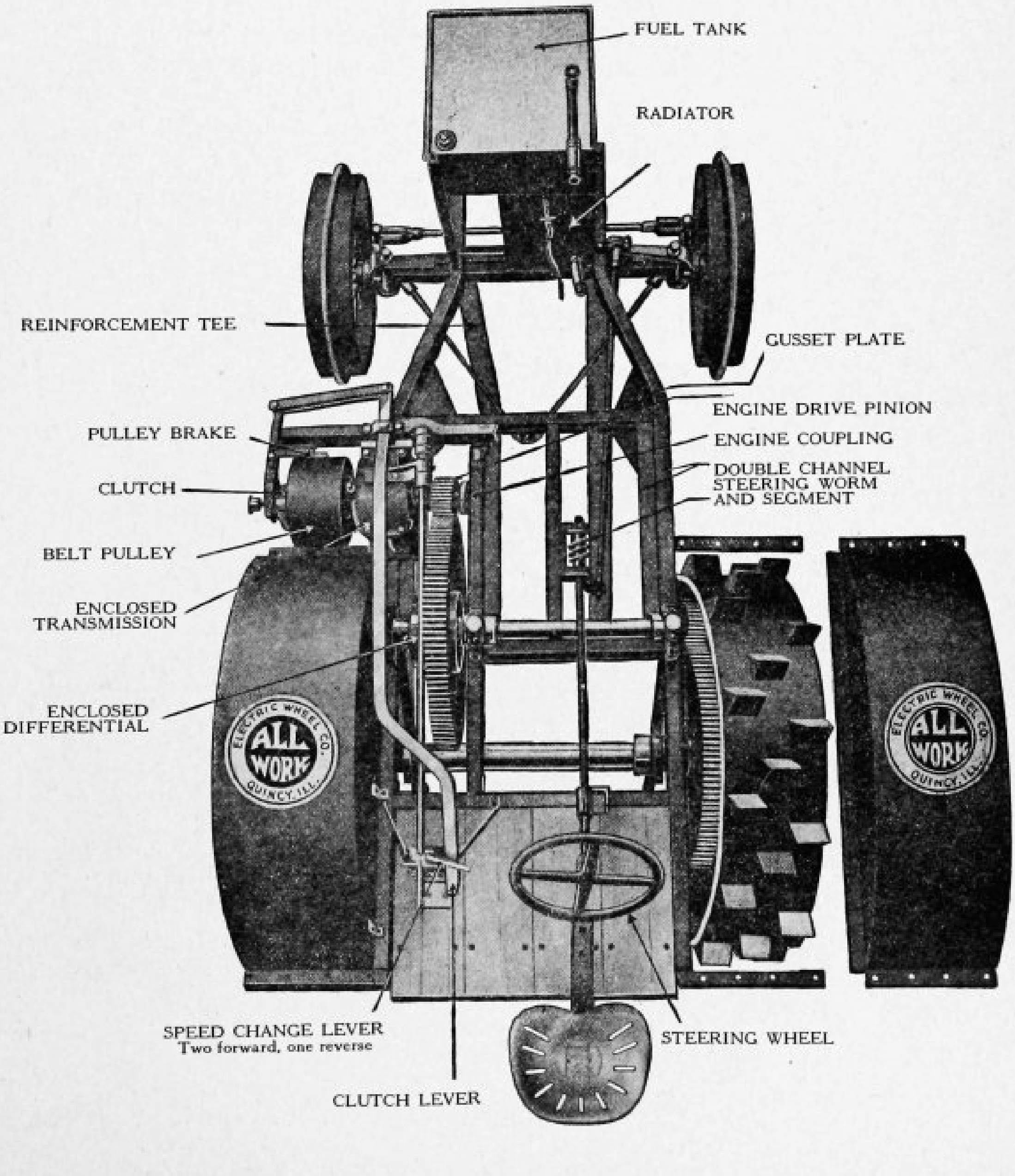
ALLWORK KEROSENE TRACTOR

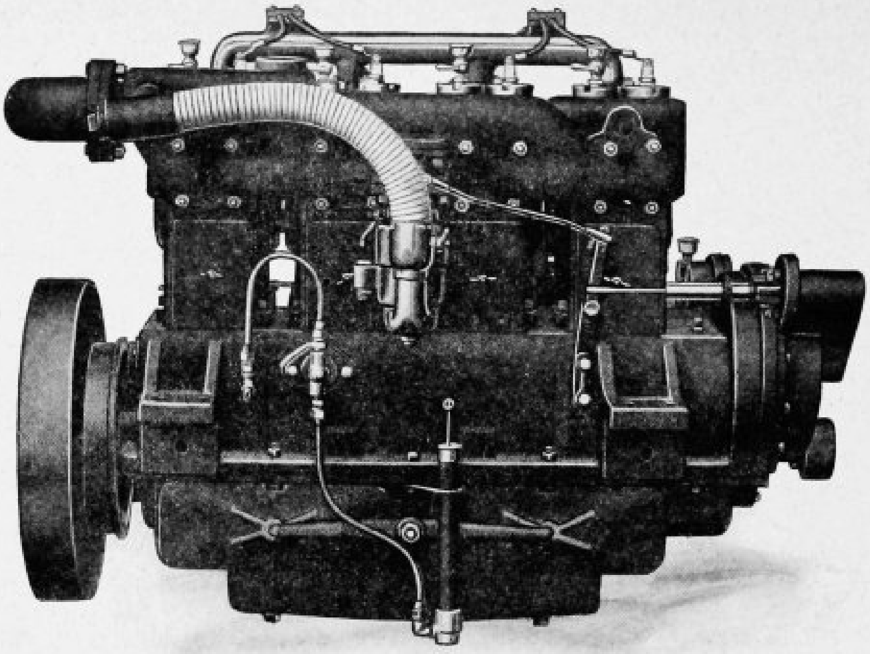
For fifteen years the Electric Wheel Co. has been building Tractors and for the past five years has had the present model, "The ALLWORK Kerosene Tractor" on the market.

Hundreds of farm owners who have made bigger profits from their farming operations by the use of the ALLWORK stand ready to testify to the merits of this machine.

Plowing, harrowing, discing, seeding, haying, harvesting, threshing, ensilage, cutting, silo filling, shredding, corn husking, corn shelling, baling, stone crushing, feed grinding, road grading, wood sawing, hauling, manure spreading—all this work can be done economically with the ALLWORK and much cheaper, better and quicker than with horses.

This clearly illustrates the simplicity of our construction, its compactness, ease of control from the driver's seat and the directness with which the power

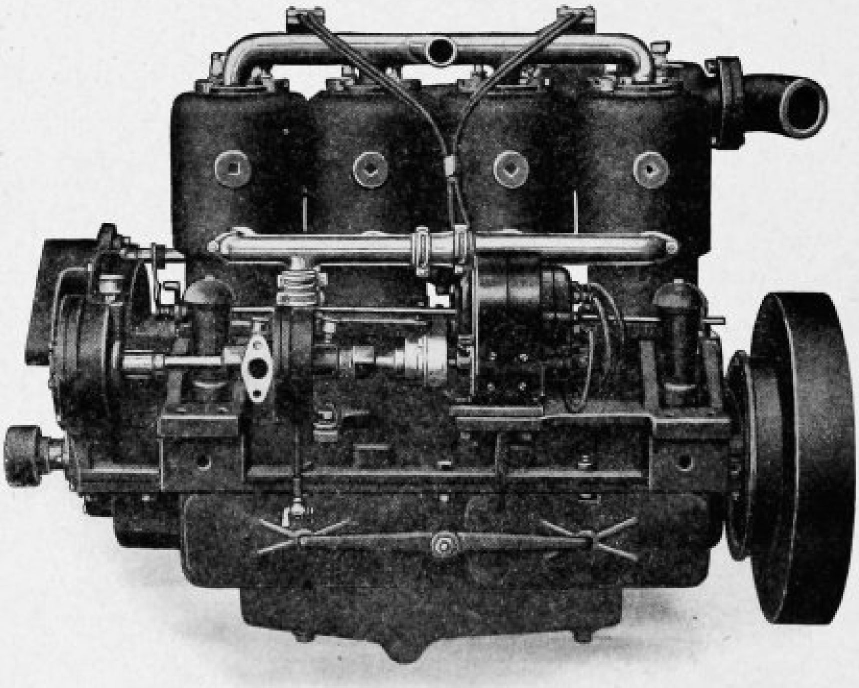




Kerosene Manifold Side View of Motor

is transmitted to the driving wheels. The gear covers have been removed in order that it may be seen no chains or bevel gears are used. On the plowing speed the effect is just the same as if the engine drive pinion were keyed to the crankshaft of the motor for no gears in the transmission case are used. There are only two gear reductions, which means the least possible number of parts subject to wear, all of which are thoroughly enclosed from dust and dirt.

We believe that in the truck shown above we have all that could be asked in simplicity without sacrificing any commonly accepted mechanical principles or introducing any features that would cut down efficiency and lasting qualities of the machine or make necessary



Front or Magneto Side View of Motor

constant adjustments to keep it in proper running order.

Specifications of Our 5x6 Four Cylinder Engine

Crankcase: Made of best gray iron, with four inspection plates on the lower half, and a drop bottom which can be detached by simply removing a few small capscrews. This provides instant access to the motor bearings, for inspection or adjustment, and is a feature of accessibility that will save hours of time. This detachable bottom of the crankcase also constitutes an oil reservoir which can be removed and cleaned out in a very few minutes. The main bearings are contained in the upper case, throwing most of the wear on the caps which are easily adjusted or replaced. The motor has two oil fillers located in convenient positions.

Cylinders: Of high quality, close grain gray iron, each cylinder a separate unit bolted firmly to the crankcase. This construction facilitates ease of handling, makes replacements inexpensive and aids in cooling. Cylinders are of the "L" head type, 5 inches bore and 6 inches stroke.

Valves: Made with best gray iron heads electrically welded to steel stems and are interchangeable. Valve mechanism is adjustable and all wear can be quickly taken up through valve plates on the sides of the cylinders provided for this purpose.

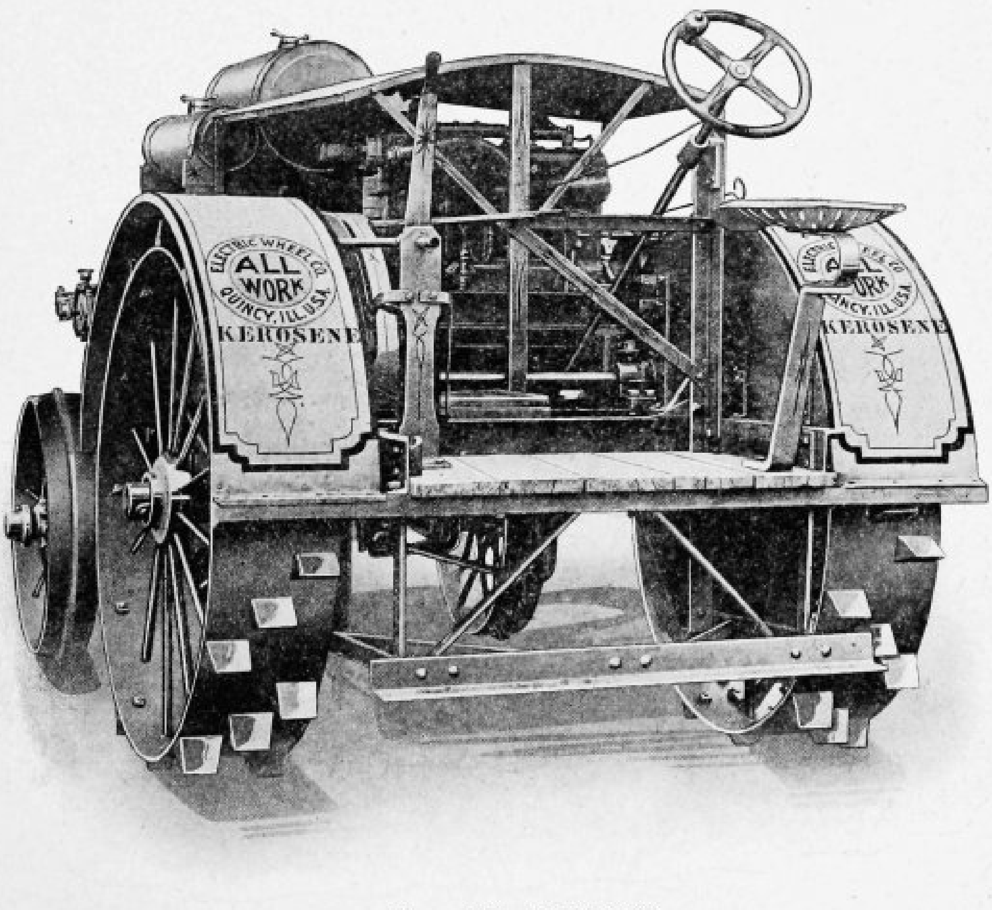
Pistons: Long and as light as good practice will allow. Made of the finest quality metal, ground to a perfect fit, polished and provided with oil grooves and recesses to prevent too much oil working past the piston and carbonizing in the combination chamber.

Piston Pins: Open hearth low carbon steel, case hardened and ground to a perfect fit; locked in position by set screw and cotter key.

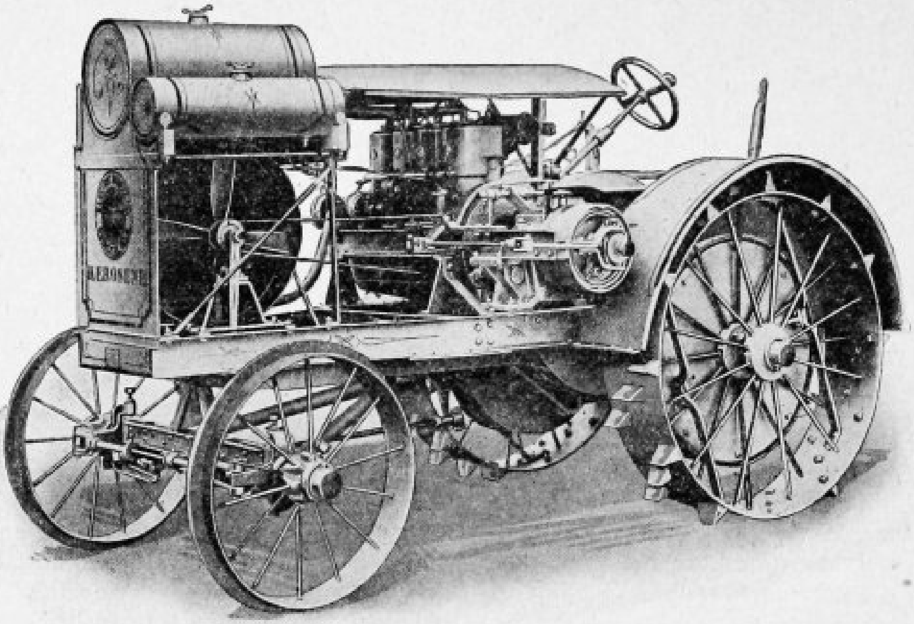
Connecting Rods: Rods are drop forged from I-section carbon steel, double heat treated. Crankpin end furnished with ⅝ in. chrome nickel steel bolts, heat treated, giving unusual strength to these vital parts.

Crankshaft: Is of the five main bearing type, drop forged from .50 carbon steel, double heat treated, machined and ground to exact size. Flange for attaching flywheel is forged on shaft. It is 2¼ in. in diameter at the main bearings and 2 in. in diameter at the connecting rod bearings, making an unusually strong and large shaft. Only the highest class motors have five main bearings supporting the crankshaft, and the ALLWORK motor is furnished with this construction to produce smoother power, guarantee long life and make less adjustments necessary.

Camshaft: Of 1 in. steel, forged in one piece, machined, case hardened and the working surfaces ground on a specially designed machine, insuring absolute accuracy of timing. Phosphor bronze and genuine babbitt die cast bearings.



Rear View of the ALLWORK



Belt Pulley Side of the ALLWORK

Bearings: There are five main bearings on the crank shaft, totalling 15 3-16 in. in length, all of genuine babbitt, accurately ground to fit and supplied with shims to allow ample adjustment. The connecting rod bearings are die cast bronze lined with genuine babbitt, hand scraped to a perfect fit, and are 2¼ in. in length. Piston pin bushings are of phosphor bronze pressed into rod.

Timing Gears: Of highest quality steel, all helical cut on automatic hobbing machines to obtain quiet running and best results mechanically.

Oiling System: The self contained, or constant level system of lubrication is employed. A cam driven plunger pump takes the oil through a strainer to separate splash pans under each connecting rod, where a constant level is maintained. This method is conceded to be the simplest and lubricates perfectly, regardless of the position of motor when running the right hand wheels in the furrow or on a hillside. An oil gauge in plain view of the operator indicates the oil level.

Governor: Flyball, throttling type completely enclosed in the gear case cover, running in oil and is adjustable when idle or running. Governor throttle is of the butterfly type and is separate from the carburetor throttle. It responds quickly and supplies the proper amount of fuel to take care of the varying loads thrown on the motor.

Manifold: Engine is equipped with a special combination intake and exhaust manifold whereby kerosene is used as fuel equally as well as gasoline. It is so arranged, the operator can use gasoline exclusively if so desired.

Normal RPM: 800.

Rating: 14 H. P. at the drawbar and 28 H. P. at the belt, which is guaranteed by our warranty.

Cooling System

We use the Perfect Tractor Radiator with anti-rust brass cells and a large 23¼ in. light weight aluminum fan running at 2,000 RPM. for cooling the motor. A shaft driven centrifugal pump maintains a constant circulation of a large volume of water through the spacious water jackets while the circulation of air around the separate cylinders aids wonderfully in keeping the engine cool. The radiator is 25 per cent larger than recommended for a 5x6 motor and is of ample capacity to cool the engine in the hottest weather with practically no evaporation.

There is no reason for a tractor using 10, 20 and 30 gallons of water each day; the perfect cooling of the ALLWORK motor is conclusively demonstrated by the fact only a few gallons of water need be added to the radiator each week.

Magneto

Our tractors are regularly equipped with a Kingston Magneto, which is high tension, single system, of the very highest quality, operating without batteries or coils, neither of which can be used in connection with this type of magneto. It produces an extremely hot spark, uniform in heat value at different speeds whether in advance or retarded position.

The Kingston Double Impulse Starting coupling is furnished, which makes starting easy and safe. It consists of a mechanism, which when the engine is cranked, is automatically released and turns the armature fast, delivering a positive spark for starting, at every half turn of the crank, and eliminates the necessity of spinning the motor or using dry cells.

The materials used are the very best, adopted only after exhaustive tests have proven they will stand the duty required of them. The workmanship is of the highest grade, no departure from established standards of accuracy and finish being permitted. The Kingston is manufactured as a quality product,—the best in ignition—and this policy will not be sacrificed for quantity.

Air Cleaner

In pursuance with our policy of making the ALL-WORK just as efficient and durable as possible, a first class Air Cleaner is provided to prevent access to the carburetor and motor of sand and dust with their destructive, abrasive action on the wearing parts. This equipment will be particularly appreciated in those parts of the country where scanty rainfall means dust laden air the year round.

Carburetor.

Our carburetor is the famous Kingston and is the simplest and most satisfactory we have ever used. It is made of a special high grade alloy, designed with a view to compactness and greatest adaptability. Cup is radial, float is of cork treated with shellac, fuel control valve mechanism is of highly efficient type, the seat being hard bronze; auxiliary air is controlled by 5 bronze balls and is thoroughly automatic, no springs are used and results are always right. Constant air is supplied through a perfect venturi tube, the spray nozzle being so located that a thoroughly atomized spray is produced at all speeds.

There is but one control adjustment, the needle valve. Valve cock is located at lowest point of cup to free it from water and foreign matter. This carburetor is perfectly automatic, producing a proper mixture at all speeds, there is not a phase of its adjustment that can change after its initial setting.

Complete Specifications of the Allwork Kerosene Tractor

The ALLWORK weighs 5,000 lbs. and develops 3,000 lbs. drawbar pull on high gear; it handles three plows with ease under ordinary conditions and four plows for light plowing with favorable soil conditions.

Engine: Heavy duty, four cylinder, 5x6 kerosene motor built in our own factory. Develops 28 H. P. at the belt and 14 H. P. at the drawbar, running at 800 R.P.M., and we fully guarantee this rating.

Frame: Is channel steel construction, reinforced with steel angles in all corners and hot riveted. Driver's seat on rear platform, conveniently located within easy reach of all controlling levers.

Wheels: Rear wheels 48 in. diameter, 12 inch face, fully equipped with pyramid lugs; front wheels 32 inches in diameter, 6 inch face, steering band.

Front Axle: Front axle is of the autmobile type, with steel axle ends and steering knuckles. These steering knuckles, with swivel connection, give perfect oscillation and enable our tractor be easily handled and turned in a 12-foot radius, a turn that is shorter than most tractors are able to obtain from the old-fashioned cumbersome style of chain steering.

Rear Axle: 2 7-16 inch diameter cold rolled steel, running in roller bearings—a big power saving feature.

Transmission: Sliding gear, selective type, two speeds forward and one reverse. Gears cut from forged steel, enclosed in dust-proof case and running in oil. No gears in mesh when engine is doing belt work, and no gears in the transmission case used for the plowing speed.

Speeds: Low 1¾ miles per hour, working speed 2½ miles per hour.

Gears: All gears are steel and all have cut teeth, except the bull gears and pinions. Direct gear drive to the rear wheels, eliminating objections to the chain drive with its heavy wear and breakage and the frequent adjustments necessary to keep it working properly. A direct gear of this type is very much preferred to the use of their bevel gears or chains in tractor construction.

Clutch: Friction disc type, adopted after several years' experience with the different types, as being the most satisfactory in action and most easily adjusted. Plates are lined with non-burning Raybestos and take hold gradually with less shock to the motor than other types.

Differential: Bevel gear type, entirely of steel, enclosed in dust-proof case filled with oil.

Control: Two levers, one operating the clutch, the other the speed changes. These levers, together with the steering wheel, are all within easy reach of the operator's seat.

Steering: Automobile type with worm and segment, giving quick, positive action and doing away with all slack motion that is inevitable with chains, cables, springs, etc. Tractor turns in a 12 foot radius.

Pulley: 12 in. diameter, 7 in. face, belt speed 2500 feet per minute.

Covering of Parts: All working parts thoroughly enclosed, dust-proof and provided with self oilers. Our engine has all working parts thoroughly protected, the governor, all valves, etc., being enclosed, so that no parts can be injured by exposure.

Fuel: We build our own motors and they are especially constructed and guaranteed to burn either gasoline, kerosene or distillate, with equal effciency. The fuel is heated in the bowl of the carburetor, and by means of our special equipment, is converted by the exhaust heat into a gas on the way to the combustion chambers. This gas is burned without the use of water, and with as little or less carbon than when using gasoline. A smoky, murky exhaust indicates imperfect combustion in the cylinders with excessive carbon deposits; the clear, clean exhaust of our engine shows how perfectly and completely fuel is exploded and burned.

Our kerosene engine has been fully tested out during the past five years on the farms of thousands of our customers, who report results superior to any other tractor on the market at the present time. The engine develops its full rated horse power on kerosene and we can fully recommend the use of the lower grade fuel in our engine for obtaining maximum results at the lowest cost.

Dimensions: Width over all, 6 ft. 4 in. Height over all, 5 ft. 9 in. Length over all, 10 ft. 5 in. Wheel base, 6 ft. 8 in

Weight: Actual 5,000 lbs.; shipping weight about 5,400 lbs.

THE BATES STEEL MULE.

The Bates Steel Mule is a product of a company who for thirty-five years have devoted their plant and their skill to building power plant machinery.

The Bates Corliss Steam Engines are known all over the world for their durability and their wonderful efficiency.

Almost every engineer of electric lighting or power plants knows of the Bates Corliss Engine, and the reputation of the Bates Company for building high grade products.

For the past seven years this organization has devoted itself to building crawler type tractors, and the testimony of the hundreds who have them in daily use, shows that the same skill in design and workmanship that characterized the Bates Corliss Steam Engines, is reflected in their crawler type tractors. Combined with that of the two front wheels on their center provided axle, allows the tractor to move smoothly and evenly over the rough variations in the ground without that pitching and tossing action so common in crawler tractors of the rigid type.

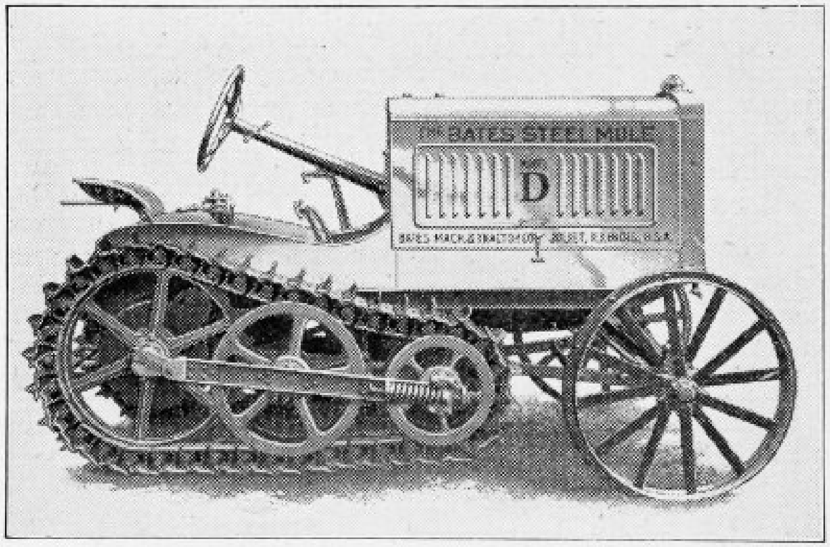
This flexibility does away with any stress or strain that might otherwise be present and therefore contributes to the long life of the machine.

From the front wheels to draw bar the Bates Steel Mule runs on nickel steel roller bearings, which practically eliminates all friction and wear.

In combination with the crawler these nickel steel roller bearings give the Steel Mule an unusually large proportion of power at its draw bar.

The Motor

The motor is a heavy duty, overhead valve, vertical type with large bearings and a thoroughly dependable oiling system. It is the most efficient kerosene burning motor on any tractor built. The head of the motor contains the valves and is easily removable so that when the valves need regrinding, it can be done easily and properly.



General Construction

The general construction of the Bates Steel Mule consists of a powerful and rigid power plant mounted on extremely flexible ground members.

The motor and transmission case are put together as a unit power plant and make one rigid continuous body that cannot be racked or twisted by any action of the rough ground over which the tractor must travel.

With the clutch and transmission bolted directly to the motor, there is no chance of the transmission parts getting out of line with the motor. Therefore, regardless of what severe service the machine undergoes, the maximum power will, because of this constant perfect alignment, never rack any working parts nor cause undue wear on the gear teeth.

The two crawlers that are attached to the power plant are independently flexible to conform to variations in the ground. This crawler flexibility, com-

Through the bottom of the motor, the pistons and connecting rods may be easily taken out without removing the motor from the tractor.

The water is circulated with a centrifugal pump. Ignition is by means of a high tension magneto and no batteries. The governor is fly ball type.

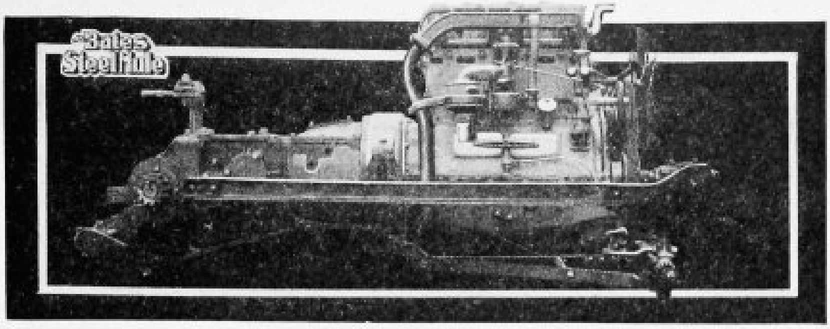
Air is cleaned by means of a centrifugal air cleaner which is well known to be under all conditions the most reliable of any type of cleaner, and requires very little attention.

The Clutch

The clutch is an enclosed dry plate disc type, very quickly adjusted and very reliable. Our seven years' experience with this clutch has demonstrated its unusual dependability.

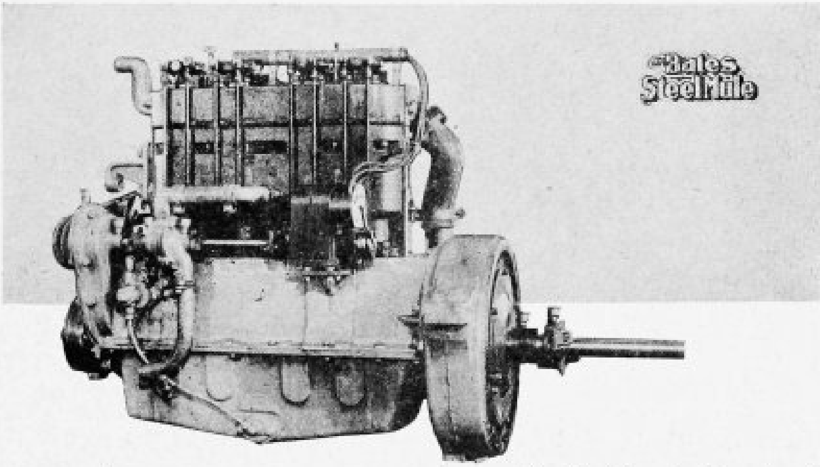
The Transmission

The transmission consists of hardened cut steel



gears running on shafts, mounted on Timken nickel steel roller bearings. All gears both in transmission and main drive are enclosed in dust-proof housings and run in oil baths.

The gears are unusually wide and big stub teeth easily resist the wear the heavy tractor work imposes. Two forward speeds are 2 1/3 miles per hour and 3½ miles per hour. Reverse is approximately two miles per hour.



The Crawler

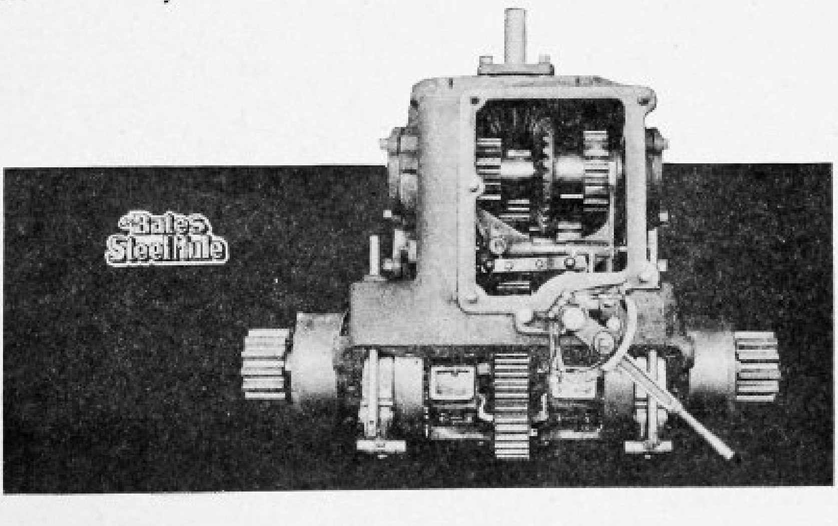
The Crawler on the Bates Steel Mule is a product of seven years' experience in the field with thousands of tractors working on every conceivable kind of soil. It is extremely durable because of its simplicity and made so that it will last indefinitely.

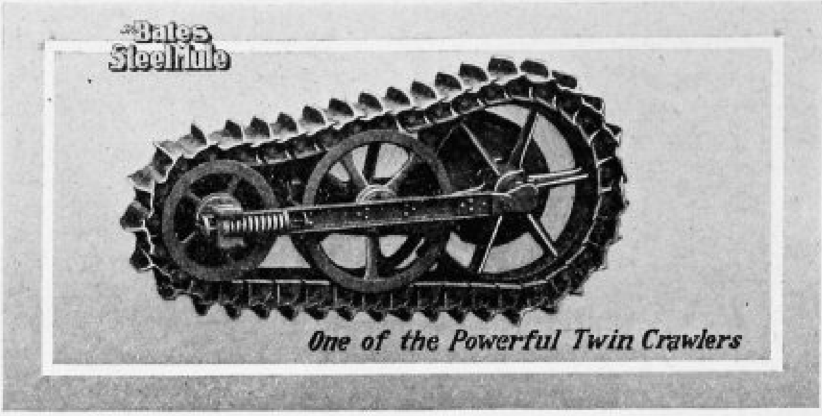
Some people have an idea that there is a great deal of wear on a crawler, but as a matter of fact the wear of a properly made crawler is very slight. Some of our early crawlers which were not nearly so durable as our present design have been in service for six years and are still doing work every day.

The crawler link itself has practically no more wear on it than the top of a railroad rail. Made of crucible steel and very rugged in design, there is no chance for it either to bend or to break.

The joints which fasten one shoe to the next are the only parts where any movement takes place. These joints are made with renewable bearings.

Into the crawler shoe is lightly pressed a thick hardened steel cylindrical bushing. A large hardened

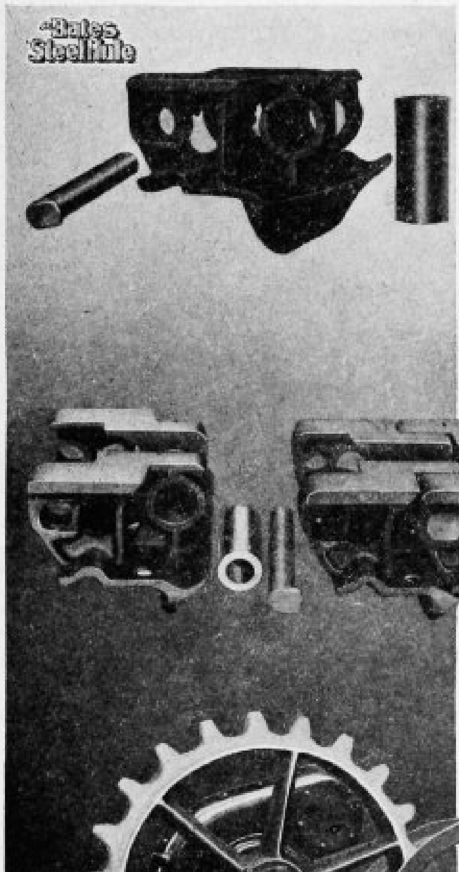


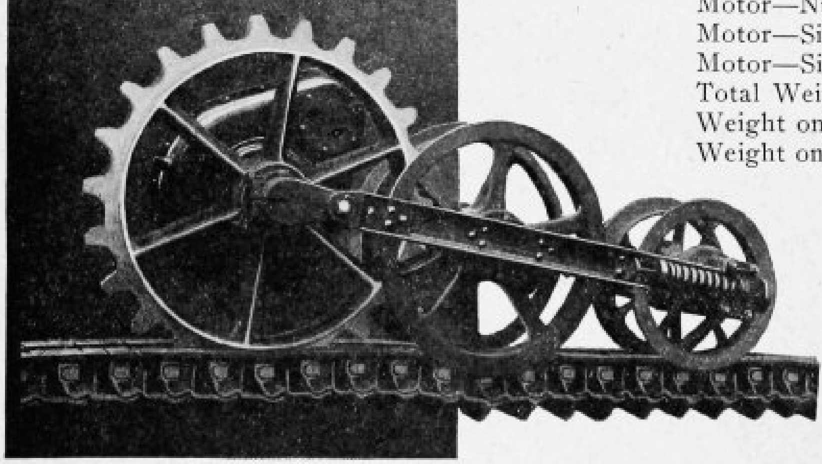


One of the Powerful Twin Crawlers

steel crawler connecting pin passes through this bushing as well as through the adjoining shoe. The pin has a key head so it cannot rotate in the shoe and makes all movement come inside of the hardened bushing.

Both pin and bushing are very large in proportion to their work and the resultant wear is therefore very slight. If after several year's service it is desirable to renew the crawler wearing parts, new bushings and pins can be purchased at a nominal price and inserted very easily.





The oscillating truck which travels over the crawler tread is connected to the tractor body through a spring mounting. The truck consists of a sprocket or hard alloy steel and four flanged steel wheels that have a face similar to a freight car wheel.

The fact that no one has ever worn out one of these wheels to date will indicate what slight wear takes place in the truck.

All bearings are dust proof and run in oil baths.

The main drive gear which fastens to the drive sprocket is an external gear and is thoroughly housed in a dust-proof case and runs in an oil bath.

Specifications

*Class Rating	15-22
Drawbar horse power, over	18
Power as Stationary Plant, over	25
Length Over-all	105 in.
Width Over-all	62½ in.
Height Over-all	58 in.
Width of Space to make Complete Turn	16 ft.
Speed High Gear—Miles per Hour (easy plowing)	3.5 to 4.5
Speed Low Gear—Miles per Hour (hard plowing)	2.33 to 3
Motor—Number of Cylinders	4
Motor—Size of Cylinders—Bore	4 in.
Motor—Size of Cylinders—Stroke	6 in.
Total Weight of Tractor	4600 lbs.
Weight on each Front Wheel	265 lbs.
Weight on Crawlers	4070 lbs.
Width of Crawlers	10 in.
Pressure per Square Inch on Tread	3.5 lbs.
Fuel used by Motor	Kerosene or Distillate
Diameter Belt Pulley	12 in.
Face Belt Pulley	8½ in.
Pulley Operating Speed	725 R. P. M.

ALLIS-CHALMERS GENERAL PURPOSE FARM TRACTOR

It was with the idea of making agricultural efficiency and prosperity more widespread that the great Allis-Chalmers Organization bent its full effort toward the production of a really satisfactory general purpose tractor at a popular price.

With an Allis-Chalmers General Purpose Tractor you can do practically **all** the work, on your farm—cultivating, discing, dragging, drilling, mowing, raking planting, listing harvesting, hauling, plowing, and belt work. It will make any farm a bigger paying investment and it is sold at a price every farmer can afford to pay.

In some localities disc plows are used exclusively. The Allis-Chalmers General Purpose Tractor will pull 2-22 in. discs without trouble. Outfit pictured opposite can be backed with ease.

Plowing requires more power than any other operation performed on the farm. The Allis-Chalmers General Purpose Farm Tractor will pull a 12-inch plow without difficulty, and will do a cleaner job of plowing than can be done with horses. The plow is hitched directly to the tractor and the two form one compact unit.

The implement is hitched directly to the tractor, and the operator rides on the seat of the implement, where he can watch the work that is being done and where he has perfect control of both tractor and implement.

The General Purpose Tractor is easily changed from one implement to the other.

Hitches are furnished for different tools at small cost and are easily attached.

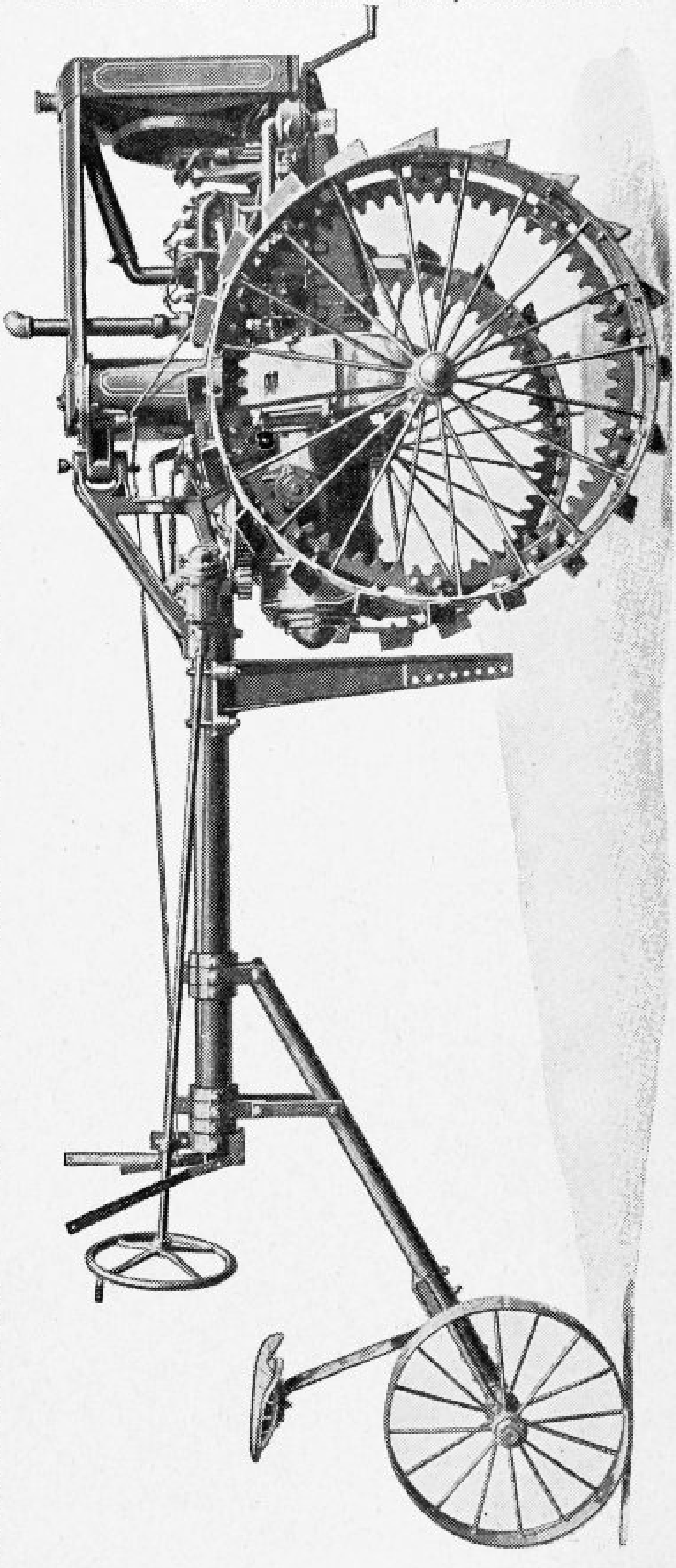
The exceptionally high clearance—28 inches—makes the Allis-Chalmers General Purpose Farm Tractor a perfect power plant for cultivating. It is so light as to travel and do its work readily on soft ground, yet is heavy enough to secure good traction. It can be used with either a single or two-row cultivator.

At harvest time the Allis-Chalmers General Purpose Farm Tractor is invaluable. The grain is harvested at the most trying time of the year for horses. The heat is usually intense and the flies maddening. But the Allis-Chalmers General Purpose moves along ceaselessly, tirelessly, finishing the job while the grain and the weather are just right.

TRACTOR SPECIFICATIONS

General

Drawbar and belt H. P. ratings..............6-12
Plows recommended ....2—12 inch
Normal drawbar pull................1000 pounds
Total width, inches ....54 inches
Is drawbar swiveled? ....No
Clearance at lowest point, inches..........28 inches
Net weight of tractor..........................2300
Domestic shipping weight 2300
TRACTION—Type of Traction...............Wheel
Number of wheels or crawlers................. 2
Number of traction members.................. 2
Diameter of drive wheels ....48 inches
Face of drive wheels or crawlers...........6 inches
BELT PULLEY—Diameter of Pulley in..........10



Face of Pulley, inches	5½
Type of Drive	Direct
CLUTCHES—Make of Transmission clutch	Borg & Beck
Type of Transmission clutch	Dry Plate
TRANSMISSION—Make of Transmission system	Own
Open or enclosed	Enclosed
Number of speeds	Variable
Range of speeds, miles per hour	1½ 2.8
Make of differential	Own
Differential	Enclosed
Final Drive, open	Bull gear
Bull gear	Sections
Engine	
Engine make	Le Roi
Number of cylinders	4
Bore and stroke	3⅛ x 4½
Normal revolutions per min	1000
Type of engine	Vert.
Valve arrangement	LH
Cylinders, how cast	Block
Number of crankshaft bearings	2
Make of Governor	Own
Type of Governor	Centrifugal
Governor	Enclosed
IGNITION—Method of Ignition	Magneto
Type of system	High Tension
Spark plug, regular, size	⅞ inch
FUEL—Fuel recommended	Gasoline
Type, fuel feed	Gravity
Number fuel tanks	1
Air cleaner, make	Bennett
Type of Air cleaner	Dry
Capacity Gasoline Tank	8½ Gals.
LUBRICATION—Lubrication method	Splash
Cooling—Make of radiator	Own
Type of Radiator	Fin & Tube
Cooling fluid	Water
Air circulated by?	Fan
Fan make	Oakes
Type of fan drive	Belt

ALLIS-CHALMERS 18-30 FARM TRACTOR

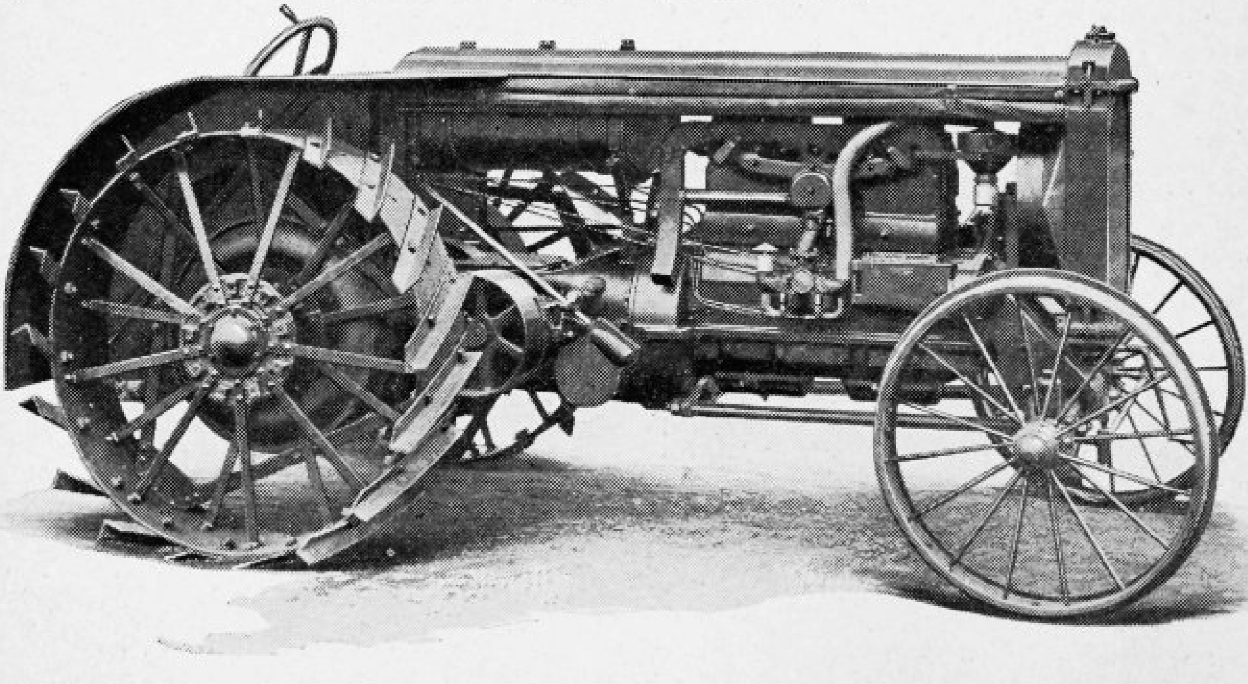
Anticipating several years ago the need of the farmer for a light, strong and durable tractor, we charged our Engineers with the task of building a machine embodying all the above mentioned features and in addition a tractor with sufficient power to pull four plows under average conditions, disc harrows, drag harrows, roller crushers, pulverizers, drills, binders, wagons, road graders, etc., and being fitted with a pulley to do the threshing, pumping, silo filling, corn shelling and all kinds of belt work anywhere you want to use it. In plowing it takes the place of eight horses and the motor being specially designed for this tractor, has great power for its weight and uses either gasoline or kerosene.

Allis-Chalmers Manufacturing Company are offering this tractor to the farmer only after careful study of the tractors previously manufactured and intimate familiarity of what the farmer requires.

The Allis-Chalmers 18-30 Tractor is designed to pull four plows at normal speed with sufficient surplus to insure the maximum life of the machine.

The Motor

The power plant of the Allis-Chalmers 18-30 Farm Tractor consists of a four cylinder vertical, valve-in-head engine of our own manufacture, and is designed especially for kerosene. The engine and transmission case are bolted together in one unit, forming what would otherwise be a frame. The entire transmission, including the final drive is enclosed and runs in oil. The motor has a bore and stroke of 4¾ x 6½, with a normal speed of 830 R. P. M. The cylinders are cast in block.



The motor is equipped with a Kingston double bowl carburetor being fed by gravity and a high tension Eiseman Magneto with an impulse starter.

Power is transmitted through an expanding clutch of our own make, which is simple and easy of adjustment. The drive wheels are 50 inches in diameter with a 12 inch face. The wheel hubs are mounted on plain bearings on the axle shaft, but shaft itself is carried on Hyatt roller bearings.

Referring to Page No. 1, the reader will note the very neat, clean cut appearance and yet sturdy general line of construction.

Complete Specifications

GENERAL—
- Trade name of tractor 18-30
- Drawbar and belt H. P. ratings............ 18-30
- Numbers of plows recommended .... 3-4-14 in.
- Normal drawbar pull, pounds, 3000 lbs. at low speed
- Total width, inches .... 66 in.
- Is drawbar swiveled? ....Yes
- Wheelbase, inches .... 81 in.
- Clearance at lowest point, inches.......... 14 in.
- Net weight of tractor 6150
- Domestic shipping weight 6150

TRACTION—Type of Traction ....Wheel
- Location of traction members...............Rear
- Number of wheels or crawlers................ 4
- Number of traction members................. 2
- Diameter of drive wheels 50
- Face of drive wheels or crawlers............. 12
- Face non-Drive wheels 6

ENGINE—Engine make .... Own
- Number of cylinders 4
- Bore and stroke 4¾x6½
- Normal revolutions per minute.............. 830
- Type of engine ....Vert.
- Valve arrangement .... VH
- Cylinders, how cast ....Block
- Number of crankshaft bearings 3
- Make of Governor .... Own
- Type of Governor ....Centrifugal
- Governor, open or enclosed .... Enclosed

FUEL—Fuel recommended .... Gasoline or Kerosene
- Type, fuel feed .... Gravity
- Water injected with fuel?.................. Yes
- Number fuel tanks 1
- Air cleaner, make ....Bennett
- Type of Air cleaner ....Dry

LUBRICATION—Lubrication method ....Force feed

COOLING—Make of radiator .... Own
- Type of Radiator .... Fin and Tube
- Cooling fluid ....Water
- Air circulated by? ....Fan
- Fan make .... Own
- Type of fan drive .... Belt

IGNITION—Method of Ignition .... Magneto
- Type of system ....High Tension
- Spark plug, regular or extension.............. R
- Spark plug, size .... ⅞

BELT PULLEY—Diameter of Pulley, inches..15 in.
- Face of Pulley, inches.....................7½ in.
- Type of Drive ....Gear
- Equipped with independent clutch?........... No
- Equipped with brake .... Yes

CLUTCHES—Make of Transmission clutch.....Own
- Type of Transmission clutch............Exp. Shoe

TRANSMISSION—Make of Transmission system .... Own
- Open or enclosed .... Enclosed
- Number of speeds 2
- Range of speeds, miles per hour............2.3 2.8
- Make of differential .... Own
- Open or enclosed differential .... Enclosed
- Does differential lock? .... No
- Type of Final Drive ....Bull gear
- Final Drive, open or enclosed.......... Enclosed
- Bull gear .... One piece

FRAME AND AXLE—Drive wheel axle.......Dead
- Front axle, type ....Cast
- Front axle, make .... Own
- Type of Steering .... Knuckle

FRAME .... None
- Type of frame ....
- Capacity Kerosene Tank .... 25 Gallons
- Capacity Gasoline Tank ....7¾ Gallons
- Capacity Water Tank ....7¾ Gallons

THE MINNEAPOLIS LINE

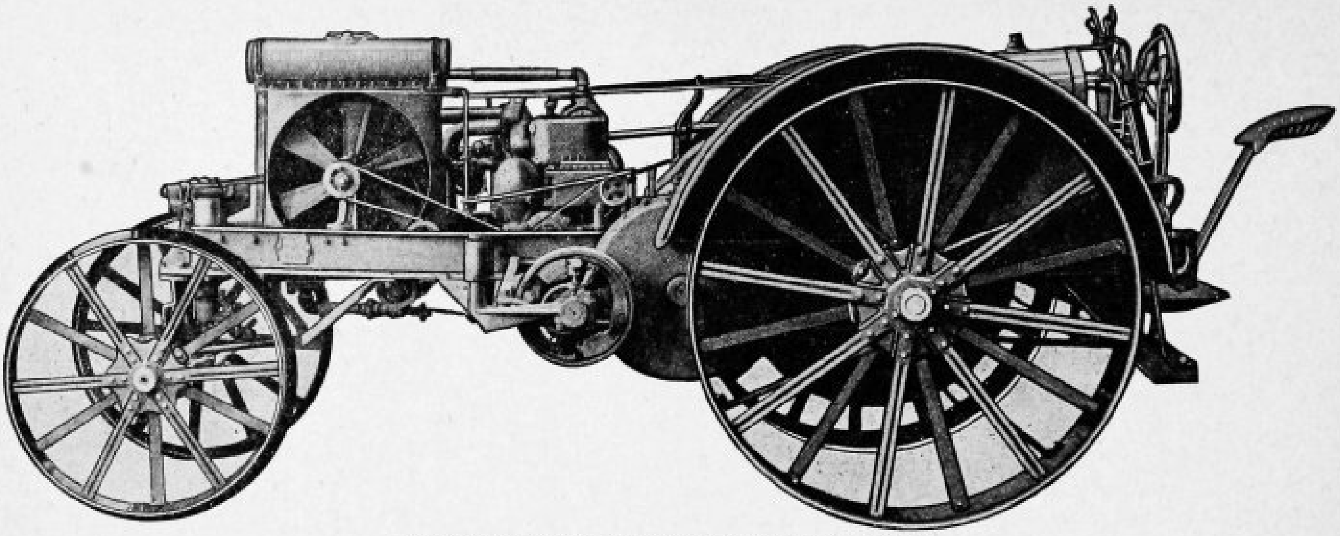
The Minneapolis 15 H. P. 4 cylinder farm motor has been designed to meet the rapidly increasing demand for a thoroughly reliable, light weight tractor suitable for performing general farm work in a satisfactory and economical manner.

There is no longer a doubt as to the small tractor being practical for general farm work, and the farmer can safely invest if he makes a wise selection.

There are many things to be considered, however, in making your selection. Don't buy one too small to meet all your requirements, too cheap to be good and durable, or too freaky in construction to be practicable and serviceable.

Frame. Made of 6-inch channels reinforced with heavy angles and corner brace plates all securely riveted together. A rigid, compact frame is one of the prime essentials of a good tractor, and in this respect "The Minneapolis" has stood up under every test and at all kinds of work.

Crank Case. Is constructed to carry the crank and cam shafts, each fitted with three wide heavy bearings. This base rests on, and is securely bolted to, the frame in six places. To the bottom of the crank case is bolted a pan, cast in such shape as to carry oil pockets, from which each connecting rod dips oil when the motor is in operation. This pan can be easily and quickly removed, giving easy access to crank and cam shafts, as well as their bearings and connecting rod bearings. There is ample space for the

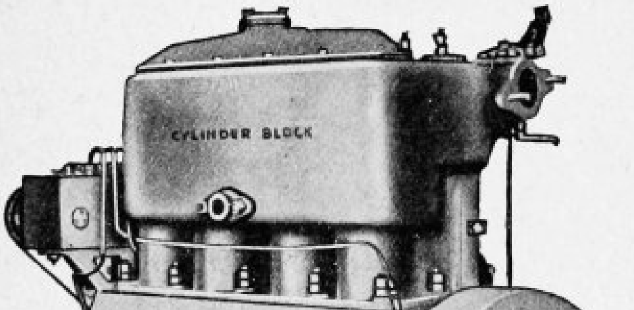


The Minneapolis 15-30 Four Cylinder Farm Motor

removal of pistons from cylinders when this pan is removed.

Cylinders. 4½-inch bore, 7-inch stroke, cast en bloc and fastened to the crank case by ten bolts. (See page 5). The cylinders are tested by hydraulic pressure for the purpose of detecting any flaws or imperfections, and after being bored are ground to perfect smoothness.

Motor Speed. 750 R. P. M. giving a road travel of three miles per hour on high gear, 2½ miles per hour on low gear, and a backup of 2 1-5 miles per hour. The above given motor speed is maintained uniform by an automatic throttling governor, of the fly-ball type, driven from the cam shaft by machine-cut gears, and these gears as well as the governor are completely enclosed, running in a bath of oil.



15-30 Motor

Oiling. The motor parts are oiled by a 7-feed mechanical oiler, oil reservoirs in bottom of Crank Case Pan and the splash system. This mechanical oiler is driven from the cam shaft, forcing oil through tubes to the several working parts, also helping to keep oil reservoirs supplied with fresh oil.

Cooling. There is ample space surrounding cylinders and combustion chambers through which water is circulated by means of a circulating pump; water being drawn by this pump from the bottom part of radiator, forced through the water spaces of the motor and back to the top part of radiator. The heated water delivered at the top of radiator is cooled in its downward course by a fan which forces cold air through the radiator cells. This cooling fan, as well as the circulating water pump, are belt-driven from the crank shaft.

Crank Shaft and Cam Shaft are both drop forgings of liberal dimensions and are each fitted to three wide babbitt bearings.

Connecting Rods. These are drop forged and fitted at the crank end with wrist boxes of bronze-backed babbitt bearings and at the upper end with solid bronze bearings.

Belt Pulley is 15 inches in diameter, 6½-inch face, having a speed of 750 R. P. M.

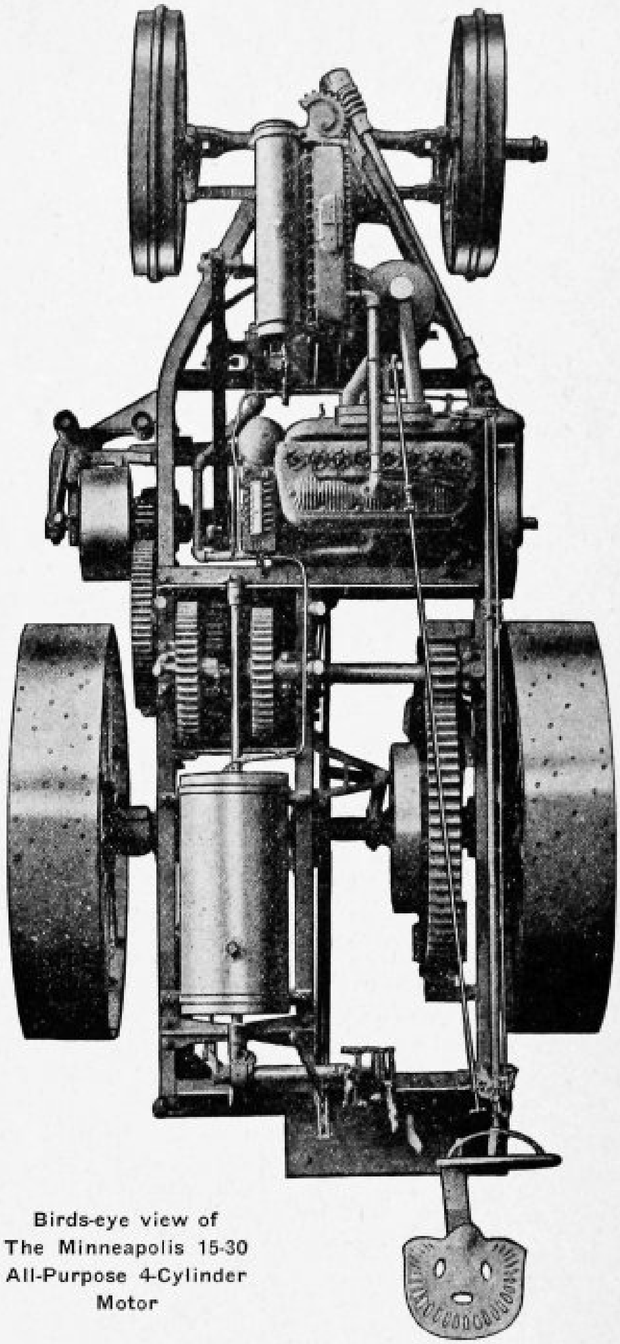
Power is transmitted from the motor to the drive wheels by a pinion on motor shaft engaging gear wheel on transmission gear shaft. These two gears are of steel, having machine-cut cogs and are completely enclosed, running in oil. The large gear on the transmission gear shaft drives the bull pinion through the transmission or speed-changing gears, and these transmission or speed-changing gears, as well as the backup pinion, are all steel spur gears completely enclosed, and operate in an oil bath. The bull pinion engages the large spur gear of the differential, furnishing direct drive to the traction wheels through the differential or compensating gears. These gears are also enclosed, running in oil, and are made entirely of steel with the single exception of the large spur gear, which is of semi steel. We have designed and attached a clutch to this differential gear for the sole purpose of locking the drive wheels together when one drive wheel slips on low or soft ground. Under such conditions the engaging of this clutch locks the drivers together, enabling the motor to pull itself out of almost any difficulty. The drive wheels should not be locked together by means of this clutch except in emergency cases.

Magneto. A high tension magneto with impulse is furnished on our tractors and has been found to be starter (doing away with the necessity of batteries) highly satisfactory in every respect.

Carburetor is of well known make, designed particularly to use kerosene, gasoline or distillate. This carburetor has been on our tractors of all sizes for a number of years, and we feel there is nothing better on the market at this time.

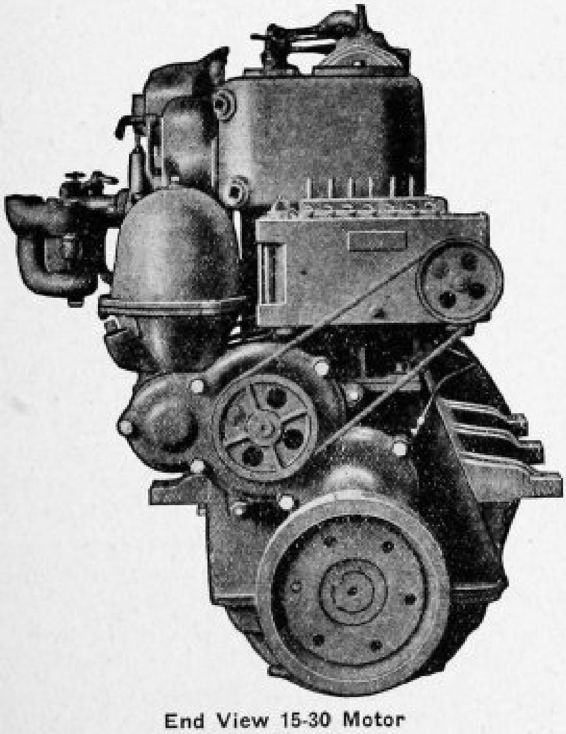
Air Cleaner. After considerable experimenting we have decided on an air cleaner for our tractor and have selected the one giving the best results after a series of tests. This cleaner is designed for the purpose of eliminating all dust and dirt from the air that might be drawn into the cylinders through the carburetor air intake.

Transmission Gear Lever shifts the gears to their different working positions. Lever in the front notch of quadrant gives slow speed ahead, while in the back notch, gears are shifted for high speed ahead. When lever is in the center notch of quadrant gears are disengaged or in a neutral position. With transmission gear lever in center notch of quadrant the reverse lever can be thrown forward, thus lifting reverse pinion into mesh with transmission gear, giving backup travel to tractor.



Birds-eye view of
The Minneapolis 15-30
All-Purpose 4-Cylinder
Motor

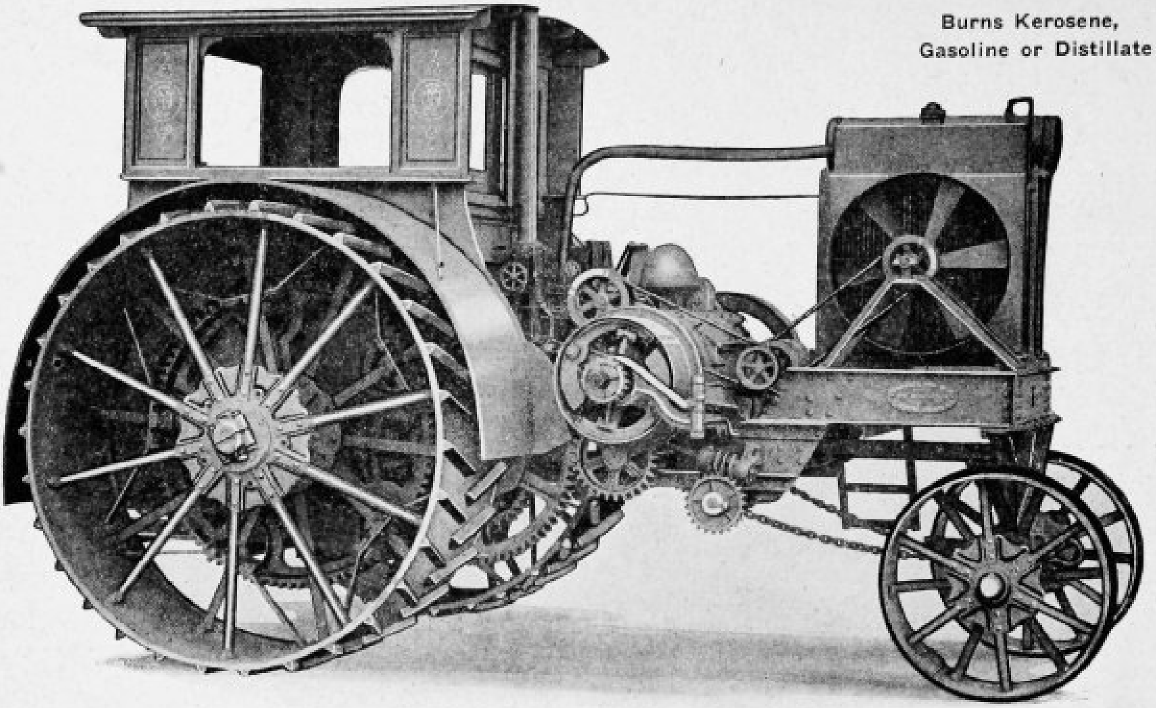
Note the simple and durable construction designed to meet the hard usage a farm tractor must receive



End View 15-30 Motor

Transmission gear lever should always be in neutral position before reverse lever is thrown forward for backing up, but there is no danger of breakage from clashing of gears since the reverse pinion cannot be shifted to proper position if the other gears are engaged.

Clutch in belt pulley must always be disengaged when the transmission gear of reverse levers are being used. Careful study of indexed outline view of



The Minneapolis 40-80 Four Cylinder Valve in Head (Horizontal) Farm Motor

tractor on page 6 will give an excellent idea of the general construction and handling of our tractor.

Drive Wheels are 56 inches high, 12 inches wide, and regularly equipped with angle iron cleats bolted to the rims of the drivers. These cleats are so made and the rims drilled in such manner that the outer row of cleats may be extended about 4 inches past the rim, thus giving additional tractive power where it is required.

Front Wheels are 36 inches high and are 6 inches wide.

Length over all 13 feet 10 inches.
Width over all 7 feet 1½ inches.
Extreme Height 5 feet 3 inches.
Capacity gasoline tank 3 gallons.
Capacity kerosene tank 18½ gallons.
Water Capacity of cooling system 7 gallons.
Approximate weight 6600 pounds.

THE NILSON TRACTOR

In buying a tractor, the first thing you want to know is, **what will it do?** All other information is of secondary importance. The Nilson Junior Tractor will pull with ease a 3-bottom 14-inch stubble plow in average soil at a speed of 2¼ to 2½ miles per hour, with ample power to spare. The Nilson is a tractor of light weight depending on its pull and not on its weight for traction. This remarkable feature is demonstrated to you in the Nilson Junior by the fact that it pulls from the drawbar 3,000 pounds at plowing speed. Nilson Tractors weigh less per drawbar horsepower. They also give wider and better contact surface between driving wheels and ground than any other tractors of the same power and can be used for Spring work, where other tractors fail because of their excessive weight and lack of grip on the ground.

Specifications, Nilson Junior

Motor—Waukesha, Type RU4R Unit power plant.

Horse Power—30 at 1,000 R.P.M. 36 at 1,200 R.P.M.

Cylinders—4¼-inch bore by 5¾-inch stroke.

Cylinders and pistons of the best semi-steel, tested five times during manufacture for imperfections.

Connecting Rods—40-50 high carbon steel, drop forged, heat treated.

Connecting Rod Bearings.—Reinforced back with Fahrig metal lining.

Crank Shaft—45 carbon heat treated, ground, 145,000 per sq. in tensile strength, 118,000 elastic limit.

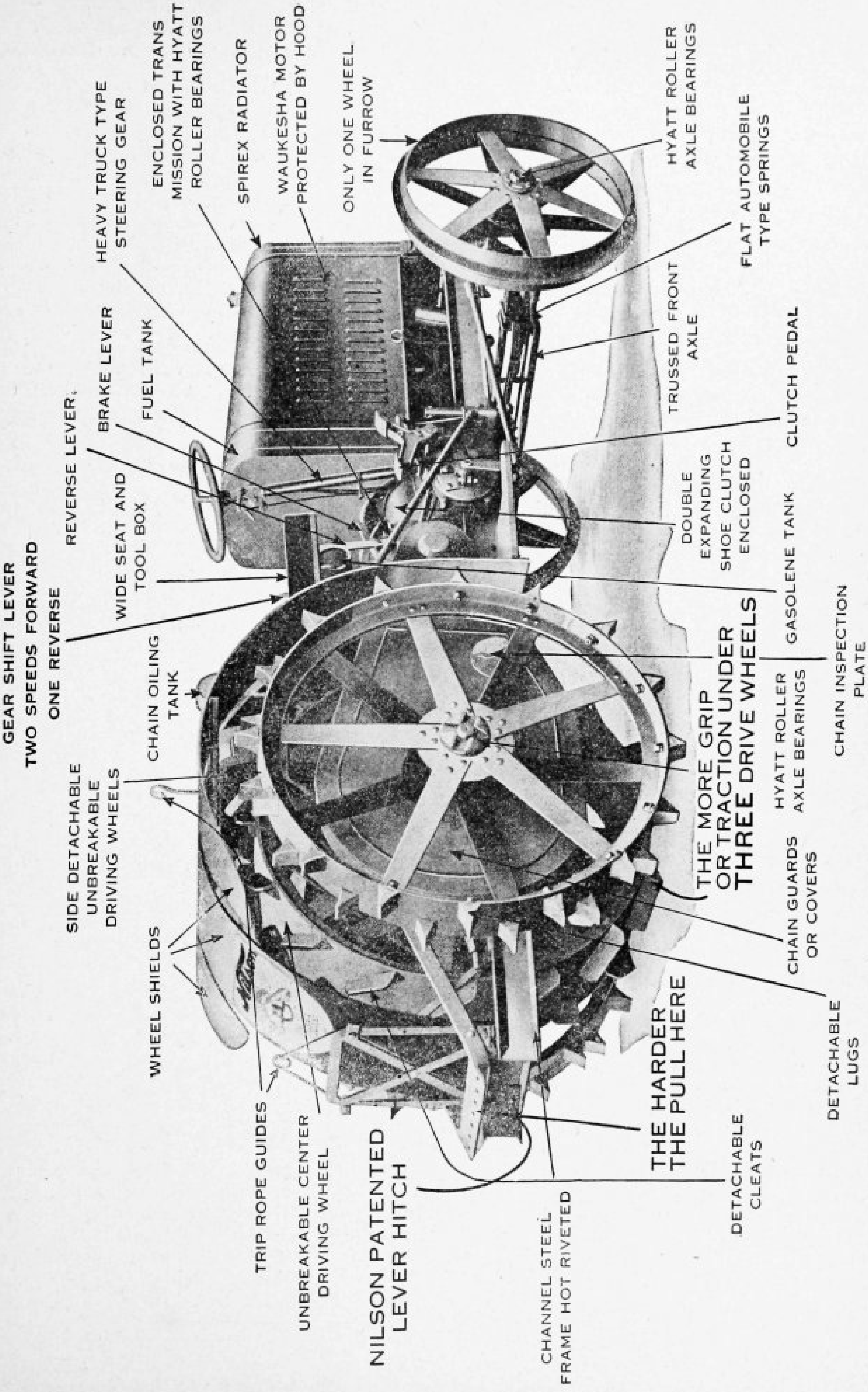
Cooling System—Centrifugal water pump, large shaft and bearings, four-blade, pressed steel fan, driven by felt from magneto shaft. Special **Nilson-Perfex** or Spirex Radiator having ample cooling capacity.

Oiling System—Waukesha constant level automatic splash system fed under pressure by positive circulating pump through filtering screen.

Governor—Waukesha Patented Governor, adjustable for speed, sealed, self-lubricating, non-hunting.

Ignition—K-W High Tension Magneto, with impulse starter, eliminating use of batteries.

Carburetor—Kingston, Model L, single adjustment for Gasoline, or Kingston Dual Carburetor for Kerosene. Bennett Air Cleaner.


GEAR SHIFT LEVER
TWO SPEEDS FORWARD
ONE REVERSE
REVERSE LEVER
BRAKE LEVER
HEAVY TRUCK TYPE
STEERING GEAR
ENCLOSED TRANS
MISSION WITH HYATT
ROLLER BEARINGS
SPIREX RADIATOR
WAUKESHA MOTOR
PROTECTED BY HOOD
ONLY ONE WHEEL
IN FURROW
HYATT ROLLER
AXLE BEARINGS
FLAT AUTOMOBILE
TYPE SPRINGS
TRUSSED FRONT
AXLE
CLUTCH PEDAL
FUEL TANK
WIDE SEAT AND
TOOL BOX
DOUBLE
EXPANDING
SHOE CLUTCH
ENCLOSED
GASOLENE TANK
CHAIN OILING
TANK
SIDE DETACHABLE
UNBREAKABLE
DRIVING WHEELS
THE MORE GRIP
OR TRACTION UNDER
THREE DRIVE WHEELS
HYATT ROLLER
AXLE BEARINGS
CHAIN INSPECTION
PLATE
WHEEL SHIELDS
CHAIN GUARDS
OR COVERS
DETACHABLE
LUGS
THE HARDER
THE PULL HERE
TRIP ROPE GUIDES
UNBREAKABLE CENTER
DRIVING WHEEL
NILSON PATENTED
LEVER HITCH
CHANNEL STEEL
FRAME HOT RIVETED
DETACHABLE
CLEATS

The Nilson

Fuel Tank—Capacity, 18 gallons.

Clutch—Double expansion shoe, 3-inch face, completely enclosed. Mounted in fly wheel on Hyatt Roller Bearings.

Steering Gear—Heavy auto truck type. Control levers for gas and spark on wheel post.

Draw Bar Pull

Draw Bar Pull—3,000 lbs. at plowing speed.

Belt Horse Power—25 H. P. at 900 Motor R.P.M. Will operate 24-inch cylinder separator fully equipped.

Belt Pulley—20 in diameter, 6 in. face; speed 360 R.P.M. (motor 900); 400 R.P.M. (motor 1,000)

Belt Speed—From 1,900 to 2,100 feet per minute.

Transmission (Nilson Special)

Mounted three-point suspension, two speeds forward, one reverse. Selective type, one lever control, using heavy duty type Hyatt Roller Bearings throughout.

Gears—High carbon steel, cut and hardened, enclosed running in oil.

Shafts—High carbon steel, splined for gears.

Speeds—2¼ to 4½ miles per hour using 10 tooth sprocket as standard equipment. Speed of 2½ to 5 miles per hour using 11 tooth sprocket. Speed of 2¾ to 5½ miles per hour using 12 tooth sprocket.

These sprockets furnished as extra equipment.

Chains—Two 1½-inch pitch standard roller chains. Shock absorbing and equalizing devices embodied in rear-drive sprockets.

Frame and Springs

Heavy 5-inch channel iron, mounted on semi-elliptic oil tempered springs, with adjustment and equalizing features.

Front Axle—Built up and forged steel construction.

Wheels—Angle iron rims with flat tapered spokes. Hyatt roller bearings on all wheel bearings.

General Dimensions

Length over all—12 feet 3 inches.
Width over all—6 feet 8 inches.
Height over all—5 feet 2 inches.
Width Rear Wheels over all—4 feet.
Wheel Base—7 feet 5 inches.
Rear Axle—High carbon steel.
Front Wheels—32 inches diameter, 6¼ inches wide.
Drive Wheel—50 inches diameter, 16 inches wide.
Side Wheels—50 inches diameter, 7 inches wide.
Short Turning Radius—16 feet.

Weight—About 4,300 lbs.; complete with side wheels about 5,000 lbs.

Standard Equipment—Includes one set tools, one pair of side wheels with lugs, one set of cleats for main drive wheel.

Road Rims—Furnished, where desired, at additional cost.

MODEL B-19 UNCLE SAM 20-30 OIL TRACTOR BUILT ESPECIALLY FOR KEROSENE

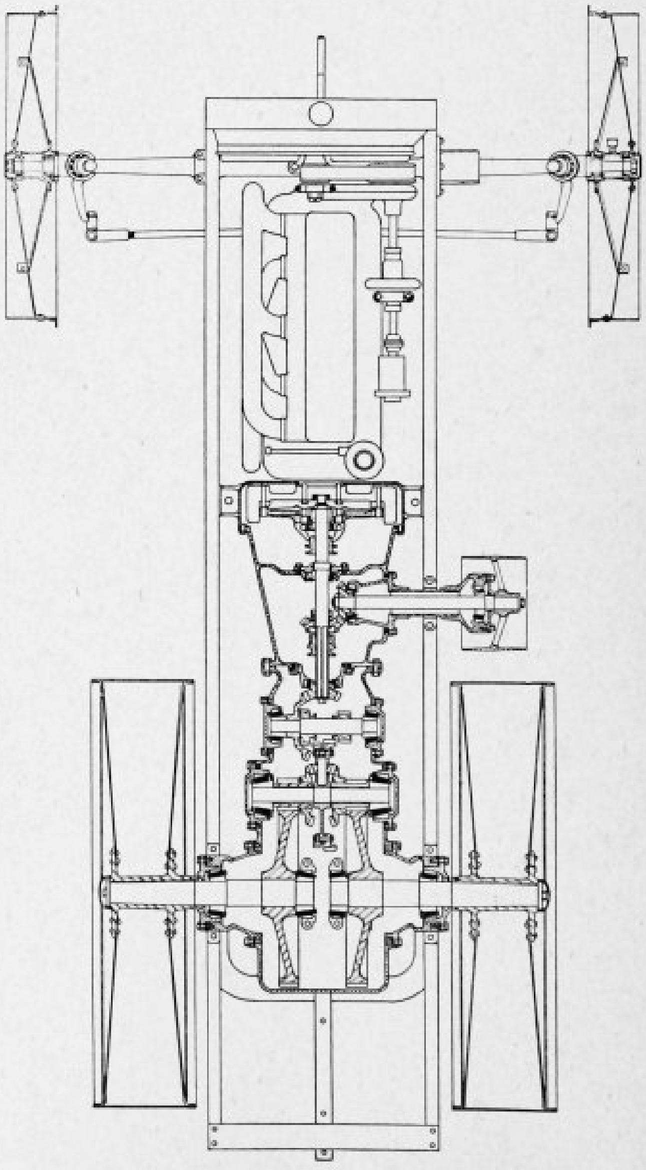
Type and General Features

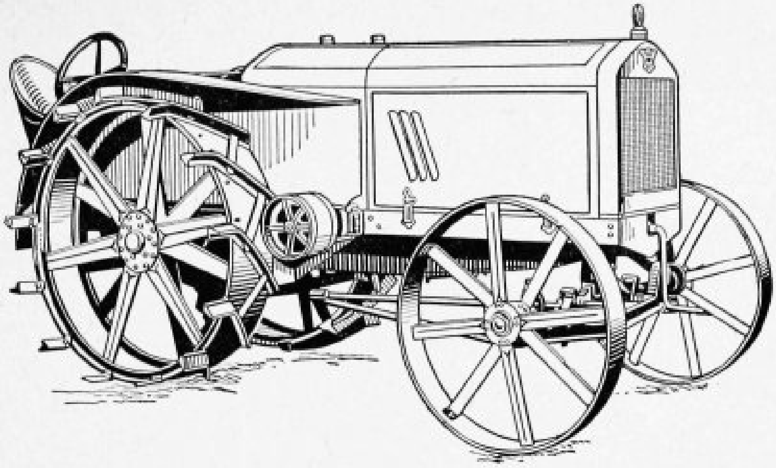
The Uncle Sam 20-30 Farm Tractor is a high type of Mechanical Perfection along modern lines of tractor construction. The Uncle Sam has a live axle drive which does away with the cumbersome and usually exposed gears and sprockets, all gears and working parts are entirely enclosed and operate in bath of oil or grease. Constructed of the finest grade of steel and by Master workmanship, the Uncle Sam is an example of strength and dependability yet light in weight, easy and comfortable to operate and complete to the last detail.

DETAILED SPECIFICATIONS AND RATINGS "UNCLE SAM" TRACTOR—MODEL B-19

TYPE—Standard Four Wheel, two drive wheels rear.

LENGTH—143 inches over all.





WIDTH—Front, 74 inches over all; Rear, 54 inches over all.

WHEELBASE—85 inches.

TREAD—Rear, 42 inches, Front, 68 inches.

WIDTH OF DRIVE WHEELS—12 inches.

DIAMETER OF DRIVE WHEELS—50 inches.

WIDTH FRONT WHEELS—6 inches.

DIAMETER OF FRONT WHEELS—36 inches.

MOTOR—Type—four cylinder, overhead valve, extra heavy duty, designed especially for tractor service and particularly for kerosene fuel.

Size—4¾-inch bore by 6-inch stroke.

Normal speed—900 R. P. M.

Carburetor—Bennett Producer type kerosene.

Air Cleaner—Bennett Centrifugal (no water).

Oiling—Force Feed and Splash.

Ignition—Dixie High Tension Magneto with impulse starter.

Governor—Duplex.

Water Circulation—Centrifugal pump.

TRANSMISSION—U. S.-Nuttal, Live axle gear set in dustproof housing. All gears and bearings running in bath of oil.

Gears—Made by Nuttall of Pittsburg—All gears are machine cut from forged steel blanks, heat-treated and sand-blasted.

Bearings—Timken adjustable roller bearings throughout.

Axle (Rear)—Nickel Steel, 3-inch diameter.

BELT PULLEY—Pressed steel—11-inch diameter, 7-inch face, 900 R. P. M. Belt speed 2600 feet per minute (S. A. E. recommendation). Belt pulley is located in a convenient position ahead of the drive-wheel with ample clearance for the belt.

FRONT AXLE—I-beam steel with auto type knuckles, Timken roller-bearings in knuckle and front wheels, front axle is suspended from half elliptic spring, patented self-steering feature is embodied in the front axle construction.

RADIATOR—Perfex "Cellular" type core.

STEERING GEAR—Heavy worm and sector with 17-inch wood rim steering wheel.

FUEL TANK—Bulkhead type made of heavy steel, electric welded, 22-gallons kerosene, 4 gallons gasoline.

FRAME—4-inch steel channel.

WEIGHT—4,000 pounds.

SPEEDS—Two forward and one reverse.

Normal or plowing speed, 2½ miles per hour.

High, 3¾ miles per hour.

Reverse, 1¾ miles per hour.

RATING—Belt H. P. 30.

Draw-bar pull in pounds, at 2½ miles per hour, 3,000.

Pulls three 14-inch plows in heavy soil or four 14-inch plows in light soil.

HEIDER TRACTORS 12-20 9-16

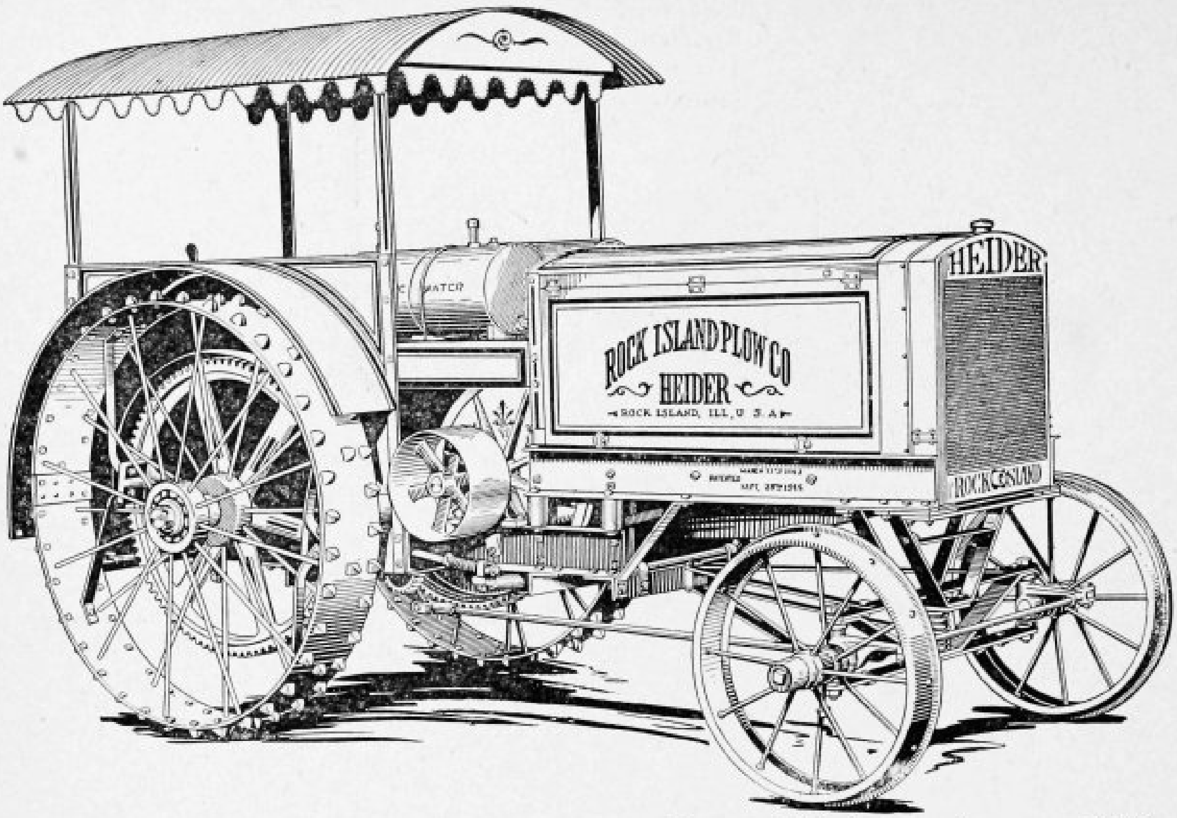
SEVEN SPEEDS FORWARD AND SEVEN REVERSE WITH ONE LEVER

One of the most popular features of the Heider Special Friction Transmission is the unusually large variety of speeds it permits—7 forward and 7 reverse. Think of it, 7 speeds forward and 7 reverse—all with one motor speed—**the right speed for every kind of work.**

The speed change lever has seven notches, and each notch represents a different speed. Any desired speed can be had while the tractor is pulling a load and it is not even necessary to come to a stop to change speeds. Just pull the lever and secure the desired speed.

Now notice the illustration on the opposite page, you can readily see the contact which drives the Heider forward or reverse. Notice how the fibre is attached to the fly-wheel of the motor, so that power is transmitted from this fibre to either one of the large metal discs on the belt wheel shaft.

When the lever at the right of the steering wheel is shoved forward the left hand disc comes in contact with the fibre wheel and the Heider goes forward. When the lever is pulled back, the right hand disc is brought in contact with the fibre and the tractor moves backward. When the lever is in the center neither disc touches the fibre wheel and the tractor stands still. The belt or drive pulley is con-



trolled in exactly the same way. Nothing could be more powerful, more simple or more economical.

No Gears to Strip

No gears to strip is another big feature made possible by the Heider Patented Friction Drive. The fibre does the driving and the discs pass the power to the drive wheels or belt pulley. The friction type eliminates clutch, bevel gears and transmission gears. **All three units are in one.** No transmission gears to put in mesh—none to strip.

Absolute Control With One Lever

With the Heider Friction Transmission no brakes are necessary. If you are driving down a grade you have absolute control of the machine, because you can throw it from high speed into reverse instantly, if necessary, without the slightest injury to any part of the machine.

Steadier Power Means More Power

The friction type of transmission is not only easy to control and very simple, but it delivers a steadier power to the drive wheels. In other words, the power is delivered with the same steady power as if it were driven by electric current. This means that heavier loads can be pulled with less lug equipment, because the footing is not destroyed by the jumping of the motor.

15 to 20 Per Cent Fewer Parts

Another big advantage of the Heider Special Friction Transmission is that it does away with a lot of gears and other parts. This can be plainly seen in the illustration on page 7. Less gears means less trouble, easier operation and your repair expense cut to minimum. This feature alone saves Heider owners thousands of dollars every year.

Turn to page 8 and see how these few gears are enclosed in an oil tight case.

THE CASE 10-18 KEROSENE TRACTOR

This is the smallest size Case kerosene tractor. It is a "handy" machine for use on small or large farms. Some farmers use two or more on the same farm, simultaneously doing different kinds of work.

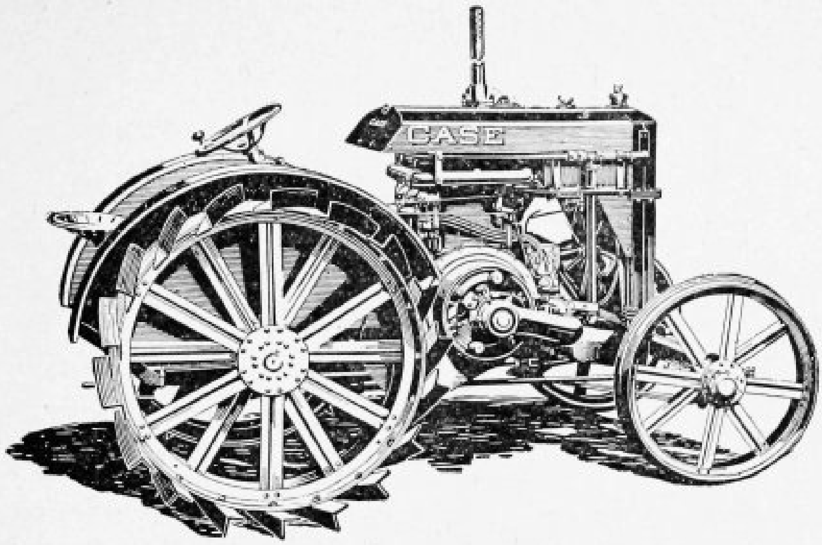
The Case 10-18 weighs about 3500 lbs.; a little more than a team of horses. It is compact and built low down; over all dimensions being, length 102 inches; width 56 inches, and height 54½ inches. It has a short wheel-base, 65 inches—and turns in a circle 22 ft. in diameter. This tractor has two speeds, 2¼ and 3½ miles per hour.

As a kerosene burner this tractor is unequalled. We refer to economy tests made during the 1918 national tractor demonstration at Salina, Kansas, July 26th to 29th.

In the field the Case 10-18 will pull an 8 ft. double action disc harrow or 5 section spike tooth harrow. It will handle a 22 shoe grain drill, two seven foot binders, the largest manure spreader, etc.

Because of its light weight, this oil tractor will travel over plowed fields, without unduly packing the soil, so it is just the thing for seeding and discing. For haying and harvesting it is unexcelled.

At general hauling this Case 10-18 will pull from 5 to 10 tons, depending upon grades and footing. It is also practical for pulling a Case No. 3 road grader



or a pair of road drags. This tractor readily does a variety of work that ordinarily requires from 4 to 6 horses.

The belt pulley on the Case 10-18 is conveniently located on the crank shaft, on the same side as the steering wheel so the tractor is easily "lined up" for a belt job. It will readily drive a Case 20x28 thresher with feeder and wind stacker; a Case No. 12 silo filler, baling press, small sized corn husker, sheller, feed mill, etc. Will also run a wood saw, a small rock crusher, concrete mixer, an air compressor for rock drills or any other machinery requiring power within its capacity.

Read the following technical description. You will find this tractor simple of design—rigidly constructed of the best materials—with all parts easily accessible for inspection or adjusting. It is a masterpiece of tractor design and construction.

CASE 10-18 CONSTRUCTION DETAILS

The frame of the Case 10-18 kerosene tractor is a one-piece casting.

This type of frame construction has proven to be the best possible for small tractors. The frame casting includes the main part of the crankcase and the transmission case. It also constitutes the housing for the rear axle and bull pinion shaft and the bearings for these parts.

The advantages of this type of frame make themselves more apparent every day the tractor is in use. If anyone interested in tractors could see one of these frames being made, he would understand readily how this frame prevents a variety of troubles experienced with some tractors.

The whole frame is made of the best grade of cylinder iron. The holes into which are fitted the bearings for the transmission, rear axle and crankshaft, are all accurately machined into this casting so that all the shafts remain permanently in line.

The holes on each side of the frame into which bearings are fitted are bored in one operation on a special machine which is wonderfully accurate. After the bearings are once set in place, they cannot move out of their original and proper position.

All the finished surfaces, such as bearing ends and the top and bottom of the transmission and crank case, are accurately milled in the same way on another special machine. This means that all frames are exact duplicates.

It will be seen from this that there is no possibility of any of the shafts getting out of line. This means that the gears will always mesh properly, eliminating undue wear.

No matter how much this tractor may be driven over rough and uneven ground, the frame cannot twist and throw the working parts out of line.

The frame and other parts are protected from twisting strains by the three point suspension which is provided by the front axle being pivoted in the center at the front of the frame. The shaft on which this axle is pivoted extends back to the bracket to which the front axle brace rods are anchored, so that the axle and brace rods are connected to one shaft. The brace rods are adjustable so that the front axle may be kept in proper position at all times.

The Steel Front Axle is of the automobile type, with ground and hardened steel spindles for the wheels.

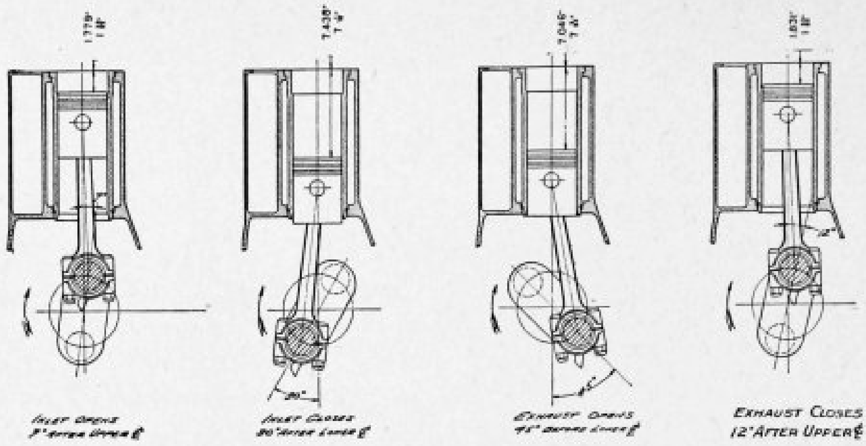
The Drawbar is attached to the frame casting under the center of the rear axle and may be locked in any position or left to swing. This construction insures easy manipulation of the tractor.

The Transmission is contained in an oil-tight and dust-proof housing, the main part of which is a part of the frame casting.

The top cover for the transmission case fits onto carefully machined surfaces.

The Case Motor built by us for this tractor is made specially for tractor work and is of the right proportions and design to stand the hard service to which tractor motors are subjected.

This motor is of the valve-in-head type which, after



ORDER OF FIRING - 1-3-4-2

years of experimenting and field experience, we have found to be the most economical and powerful.

Cylinder Block and Head

The vertical cylinder block contains four cylinders with 3⅞ inch bore and 5 inch stroke. The head of the motor is removable, giving easy access to the cylinders and valves when it is desired to remove the carbon from the combustion chamber or regrind the valves.

The Valves are all contained in the removable head, therefore regrinding of same is very easily accomplished. The head can be removed from the motor and placed on a bench, or in some other convenient place, where the work is conveniently done. This eliminates the necessity of climbing over the tractor and standing in awkward, uncomfortable positions while grinding in the valves.

This head has ample cooling capacity, keeping the valves in the best possible condition and protecting them from the warping effects of overheating.

Kerosene Burning Motor

The Case 10-18 motor is specially designed to burn kerosene very efficiently and deliver full power on this fuel.

The Valve Rocker Arms are contained in two assemblies which are bolted to the cylinder head and are very easily removed. In fact all parts of the Case motor are very accessible for adjustment.

A Pressed Steel Cover over motor head protects the valve stems, rocker arms, etc., from dust and dirt. These parts are oiled by an oil spray which comes from the crank case and provides ample and efficient lubrication for these parts.

The Water Jacket is of ample size, providing free passage for the cooling water. It is provided with hand hole plates through which all sediment may be removed.

Crank Case

The main part of the crank case is a part of the main frame and the cylinder block is bolted solidly to a carefully machined surface, assuring a good foundation for the motor. The bearings for the crankshaft are also contained in the main frame. The bearing caps are on top of the shaft giving easy access for adjustment. This construction provides the strongest and most rigid support for the crankshaft.

Ignition

The Ignition is taken care of by a high tension magneto provided with an impulse starter coupling. This coupling provides a hot spark when the motor is turned by hand, eliminating the necessity of dry cells or battery for starting. This magneto is dust proof, insuring long life and few adjustments.

The base for this magneto is fastened to a carefully machined surface on the main tractor frame casting, and is thus protected from any damage it might receive from vibration if placed in a less solid position.

Governor

The governor is of the flyball type and is entirely enclosed. A cover, the full size of the governor case, is easily removed, giving ready access to the governor. The wearing surfaces of the governor are Case hardened.

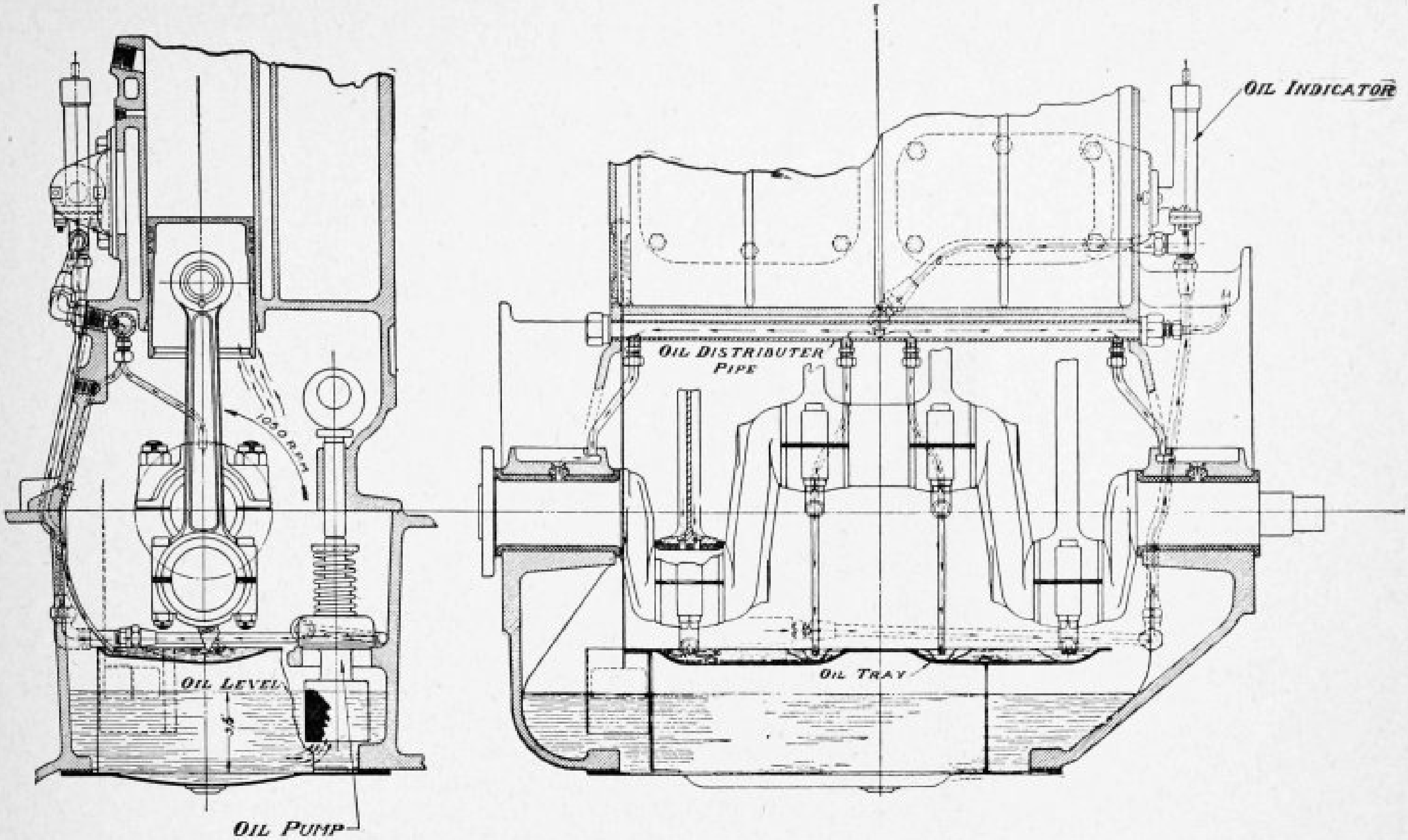
Lubrication

Lubrication is provided by means of a combination pump and splash system. A plunger pump supplies oil, first direct to the main bearings and from these it overflows to splash trays located directly underneath each crank pin, from where it is splashed to lubricate the cylinders and other working parts contained in the crank case. An indicator provided and located directly in front of the operator enables him to see whether the oil is being properly circulated at all times. A gauge is placed on the corner of the crankcase and indicates the height of the oil level in the oil reservoir.

Cooling

The cooling system used on this motor is of the forced circulation type, the circulation being by means of a centrifugal pump.

The Radiator made in our own shops is of the tube and fin type, with a cast iron frame. This cast iron



frame is very rigid and protects the tubes and joints from twisting strains.

The Fan which is driven by a friction collar at its hub, circulates air thru the radiator. This friction drive allows the fan to pick up its speed gradually, preventing damage to the enclosed helical cut gears which drive the fan shaft. The fan shaft runs on ball bearings.

A Sylphon Thermostat governs the circulation of cooling water thru the radiator. This keeps the engine at a uniform temperature and makes it very efficient as a kerosene burning motor. The Thermostatic device works automatically and requires very little attention. It reduces to a minimum the chances for raw fuel passing by the pistons and diluting the oil in the crank case.

When the motor is cool, as in starting or under light loads in cool weather, the valve in the thermostatic unit remains closed, allowing water to circulate only thru pump and around the cylinders. This results in water rising quickly to a temperature of from 160 to 180 degrees (Fahrenheit) when the valve opens and allows full circulation thru the Radiator. This device keeps the motor hot enough to vaporize kerosene under all loads and cause motor to operate successfully on kerosene in less time after starting than if the entire cooling system were in circulation all the time.

Transmission

The transmission, our own make, is composed entirely of spur gears. These gears are all enclosed in a dust-proof and oil-tight housing. By removing the transmission case cover all the transmission gears can easily be reached.

The Clutch Pinion is a steel forging with cut teeth, and meshes into a cut-steel gear keyed to the first shaft of the transmission. This shaft operates in two heavy duty Hyatt roller bearings and is provided with six splines on which the two change-speed pinions are mounted. These pinions are drop forged and are cut and hardened. Two speeds are provided. Low gear at 2¼ miles and high gear at 3½ miles per hour.

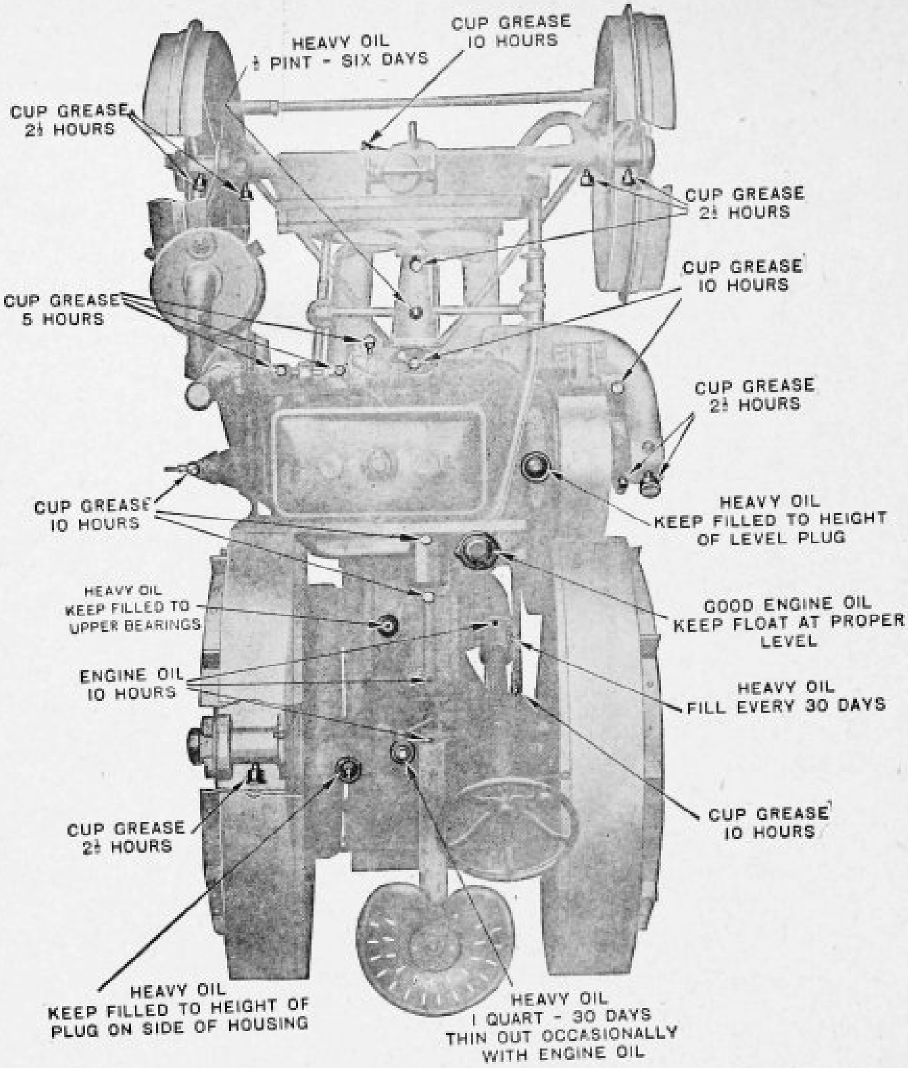
The gears on the second transmission shaft are drop forgings, cut and hardened. The bull pinion is mounted on the same shaft as these gears. This shaft too is supported by two heavy duty Hyatt roller bearings.

The Housings for the bearings in the transmission are contained in the main frame casting, giving positive alignment.

The Bull Pinion is made of a drop forging, teeth cut and hardened.

The Master Gear is a high grade .35 to .45 carbon steel forging. It is machined all over, has cut teeth with 2 15/16 inch face. This gear is hardened and oil tempered.

The Differential Gears and Pinions are made entirely from steel. They operate in a dust-proof housing which encloses the whole compensating device, the



bull pinion and master gear. The illustration shown on this page clearly illustrates this housing which is oil tight.

The Rear Axle is made of high carbon steel and operates on two big Hyatt roller bearings. The housing for the axle is a part of the main frame casting. A locking device is provided for the rear axle so that for certain conditions, should slippage occur, both rear wheels can be locked to the axle. The operator must not however attempt to make a turn with both wheels locked.

Steering Gear is enclosed. It has a drop forged and machined worm and worm wheel made of .15 to .25 carbon steel and hardened. Steering knuckles are cast steel.

Front Wheels have 6 inch face and 30 inch diameter. They have eight ⅛ inch x 2½ inch spokes riveted to the hubs and felloes.

The Spokes are ribbed to add strength and the felloes consist of angle irons riveted to the tires.

The Hubs are of malleable iron and fitted with removable bushings. A grease cup in the center is convenient for lubrication. Felt washers and dust caps are provided to keep dirt and grit out of the hub bearings.

Drive Wheels

The drive wheels are of very rigid construction. The tires are boiler plate, ¼ inch thick, and are carried by 12 flat spokes ⅛ inch x 3 inches which are not bent but are riveted, two rivets are used at the felloes and four at the hub. These wheels are 42 inches in diameter and the tires are punched to accommodate different styles of grouters. Power is applied to both rear wheels which are controlled by the differential so that both wheels exert an even pull, eliminating all twisting strains when turning corners.

CASE 15-27 KEROSENE TRACTOR

This Case 15-27 kerosene tractor is a very practical size for the needs of the average farmer. This size has all the features and qualities of a smaller Case tractor, plus the greater capacity made possible by its extra power.

The weight is about 5600 pounds (as regularly equipped), which is light weight as compared to the horsepower it delivers. This light weight in such a large capacity tractor is particularly advantageous when working on plowed ground. The large 52 inch diameter by 12 inch face drive wheels are regularly equipped with angle iron grouters extending six inches beyond the outer edge of tires. These drivers provide a good grip and ample bearing service to guard against undue soil packing. For this reason the 15-27 is an excellent tractor for seeding or discing, at which work it will pull a battery of grain drills or harrows.

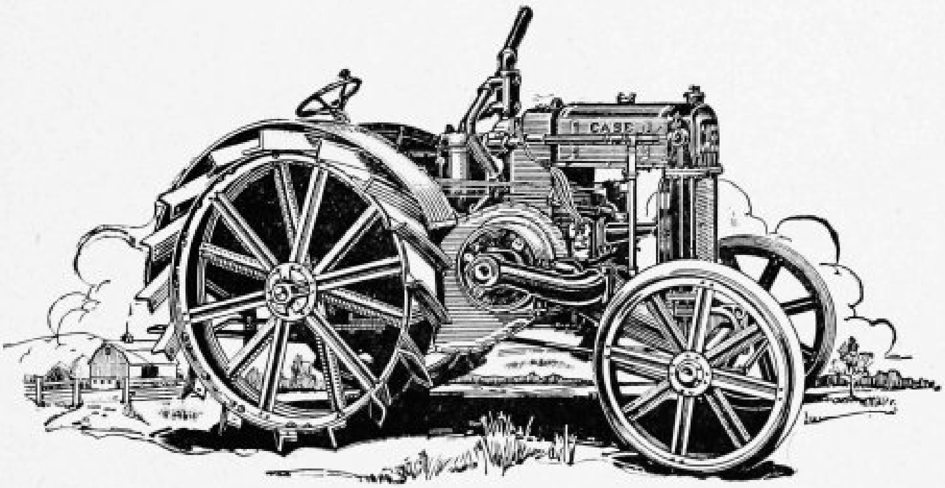
The overall dimensions of the Case 15-27 tractor are: Length 126 inches, width 72 inches and height 68 inches. The 76½ inch wheelbase permits turns in a circle 27½ feet in diameter. This tractor has two speeds, 2¼ and 3½ m. p. h.

The Case 15-27 operates on kerosene, developing full power on that fuel, and burning same very economically. There is ample reserve power so that in developing the full rated horse power the tractor does so without straining or overheating any part.

When plowing, all four wheels of the 15-27 travel on unplowed soil. It pulls three 14-inch plows in tough soil or on grades or four plows under favorable conditions. Naturally this tractor will do any other drawbar work requiring similar power. At general hauling it will pull from 10 to 15 tons, depending upon grades and footing.

The belt pulley is in the most practical location, being mounted on the crank shaft on same side with the steering wheel. It is, therefore, an easy matter to "line up" for belt work. This tractor operates a Case 26x46 thresher, fully equipped, or it will readily run a No. 16 Case silo filler with 40 ft. blower, or a clover huller, corn husker, feed mill and other belt driven machines, requiring the rated horse power of this tractor.

This Case 15-27 kerosene tractor is of advanced design and one that our engineers are justly proud of. It is very simple and built extremely durable. In it is incorporated every feature proven by test to be practical. It is a **quality** tractor, carefully constructed of the best materials, so as to give to the owner years of continuous service at low fuel cost, with little or no expense for repairs if given reasonable care.



Motor

The Case Motor in the 15-27 tractor is a special tractor motor. It is built to stand the strains and hard usage found in tractor work and will like all Case motors develop more power than the rated horse power leaving a reserve to take care of a temporary load in excess of the rated horse power.

The motor is especially designed to successfully and economically operate on kerosene. It is of the four cylinder, vertical, valve-in-the-head type, bore 4½ inches and stroke 6 inches. The valve-in-head type of motor has proven to be the most desirable for power, efficiency and economy. This type is superceding all others for high duty service.

The motor is placed transversely on the frame so that spur gears may be used thruout and to make it possible to place the belt pulley on the crank shaft, thus doing away with loss of power as is the case when belt pulley is operated thru gears.

The Valve Mechanism including rocker arms, springs, valve stems and push rods is enclosed in a dust proof cover. This cover is made of a steel stamping. The lower edge where it fits to cylinder head is provided with a felt gasket sealing this point against oil leakage and against the entering of dust. On top of this cover is placed a valve to vent the crank case. This valve opens to allow pressure to escape but closes to any pressure from the outside. The air displaced in the motor crank case passes out thru this valve and this air being impregnated with oil lubricates the valve mechanism. This cover is easily removed so that operator may at any time inspect these parts.

The Cylinder Head is made removable and in it are located the valve seats, inlet and exhaust passages. The valve stem guides are made separate and can be renewed independent of main head casting. Care has been taken to see that proper water cooling extends entirely around the valve seats and valve stems.

The head is held in place to cylinder by seventeen ⅝ inch studs. By removing the cylinder head ready access can be had to the cylinders and valves facilitating the removing of carbon or re-grinding valves.

The joint between head and cylinder is made with a copper asbestos lined gasket.

The cylinder barrels are removable so that in case of wear or scoring they can be replaced readily. This is an important feature as only the barrel need be replaced instead of entire cylinder block. The barrels are made of special cylinder iron and the bore is ground.

Crank Case—The lower half of the case is a part of the main frame. This frame is bored to receive the main bearings for crank shaft as previously explained.

With this construction it is impossible for the crank shaft to get out of alignment with the transmission shafts.

Bearings for Crank Shaft:—These are located in the main frame casting with the bearing caps placed on top. Two large hand holes are provided in the cylinder block and these openings are closed by cover plates which can be easily removed. By removing the plates an examination can be made of crank shaft bearings or any other bearings inside of the crank case.

Main Bearings:—Main bearings are of the renewable shell type. They are bronze backed and babbitt lined and three in number. The total length of bearings on the crank shaft is 12⅛ inches.

Lubrication

The motor is lubricated by a combined pump and splash system. The pump is of the plunger type with a cast brass body and ball check valves and a steel plunger which is hardened and ground. This pump is located at the lowest point of the oil pan or reservoir.

The discharge side of the pump is connected to a manifold located inside of the crank case and from this manifold separate pipes carry the oil to each main bearing and to each splash tray which are located under each crank pin. Another oil pipe leads to the governor to lubricate it, as well as the gears in the front end of the motor.

The lubrication of pistons, connecting rod bearings, valve rocker arms and cam shaft is by means of splash. An oil indicator is provided and located in sight of the operator which shows when the pump is working. A tell-tale provided with a float also in sight of the operator shows at all times the oil level in the reservoir.

Oil Reservoir

The oil reservoir is made of a sheet steel stamping, its capacity being about five gallons of oil. This reservoir is easy to remove and by its removal access is gained for any adjustment which may be required on any main or crank pin bearings.

The opening in the lower half of the crank case is large. A complete piston and connecting rod can be taken out thru this opening. The oil reservoir, having large capacity and made of sheet steel makes it ideal for cooling the oil which is very important in any motor subjected to severe service.

THE GRAY TRACTOR WITH THE WIDE DRIVE DRUM

The Transmission

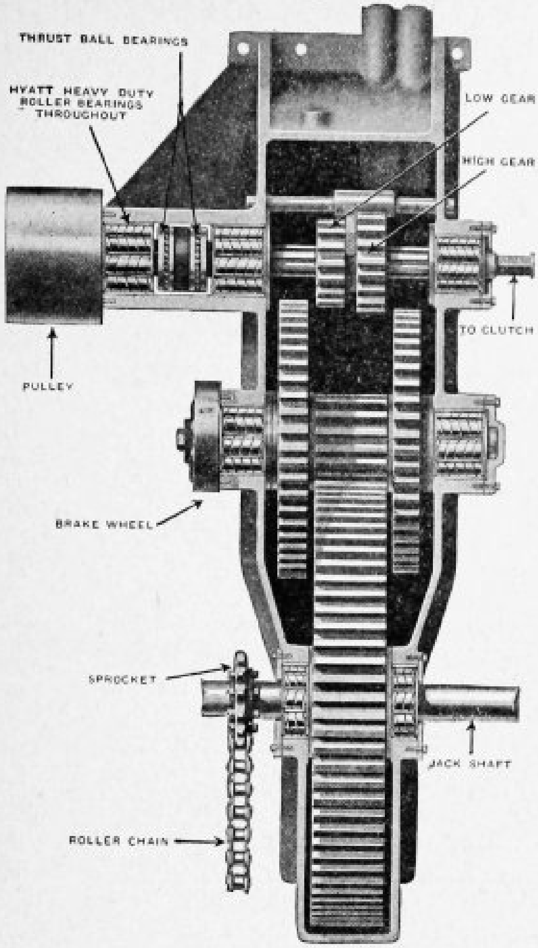
Transmission is responsible for getting the power from the motor to the drive drum. Only two features are really essential to it. First, it must transmit the power economically without big loss through friction, and secondly, it must be built to stand up year after year so it will continue to perform the same good work constantly that it did when the machine was new.

Efficiency, economy and strength are all present to a high degree in the GRAY TRACTOR transmission.

Low Gear No Harder on Motor Than High

The GRAY TRACTOR has two forward speeds and a reverse. The reverse gear is never in mesh excepting when the engine is actually reversing.

There are no more gears involved at low speed than are used at high speed. Because of this, it is as



easy on the machine to travel at one speed as the other. The motor turns the same number of revolutions per minute and develops the same amount of power at both tractor speeds and there is no danger of its overheating. The only difference is that in low you pull a heavier load slower than you do a lighter load on high.

The entire transmission is mounted in one case which absolutely insures that all gears be kept in line, that they will mesh properly and that they will transmit power with the smallest possible wear and its attendant friction loss.

A high grade automobile of the first class will stand up year after year and render good, even service. This same service will be received from the GRAY TRACTOR, because the same high class mechanical construction is used in its production.

In GRAY TRACTOR transmission all gears are mounted close together over ample bearing surfaces. There is no overhang.

Power Delivered to Drum by Roller Chain

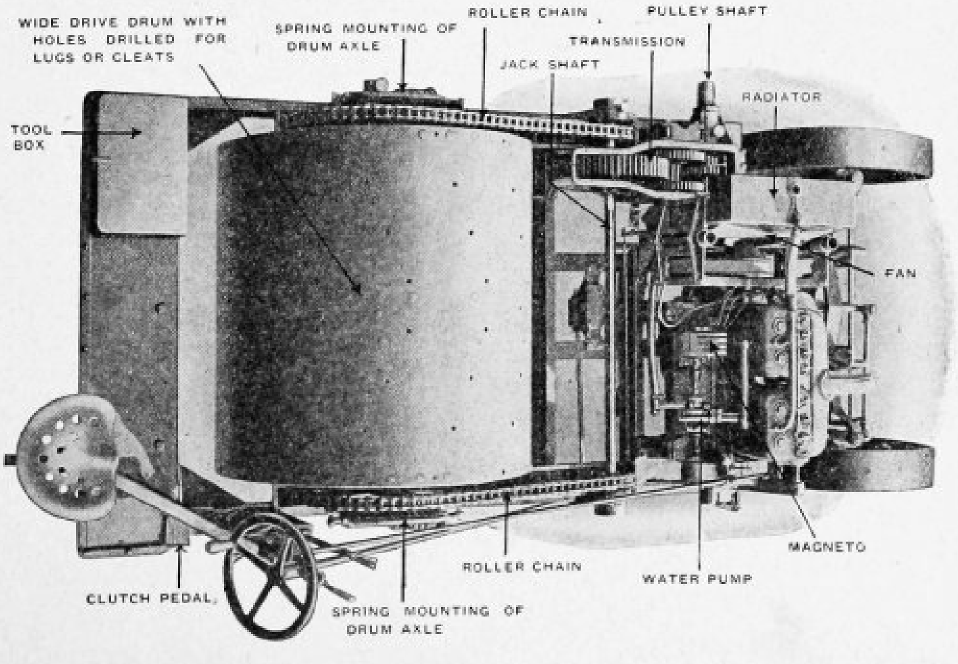
The last step in transmission of power is from the jack shaft in the drum shaft. This is accomplished by a Heavy Duty Roller Chain running in an oil bath, driven by hardened driving sprockets on both ends of the jack shaft and over cut-steel sprockets on the drive hubs, which are attached to the drum, not to the axle. The drum is driven by these two chains evenly from each side and power is transmitted to the rim through the tightly riveted and solid heads. This gives an even, clean power without twist or strain.

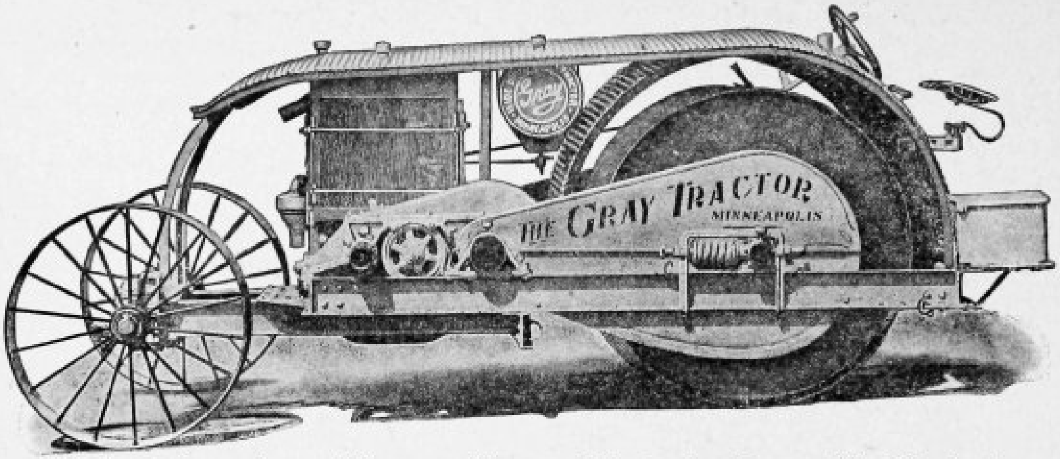
All sprockets are bolted to the hubs by steel bolts with castellated nuts. The sprockets can be easily removed and if replacements are necessary, they can be made in an extremely short time. Larger driving sprockets can be provided to increase the speed of tractor for discing, harvesting and other light work.

Roller Chain

The Roller Chain used on the Gray is of the highest type of chain construction. Users of farm machinery are thoroughly familiar with the continual trouble and annoyance that cheap chains cause when a little worn.

First of all it is made of heat treated nickel steel.





Then it is carefully fitted throughout. The two sides are drilled, and then reamed out true to size. In these sides are fitted hardened steel bushings, which are reamed and ground to size. **Hardened steel rollers run over these bushings and on the sprockets.** This construction gives a rolling contact, and reduces friction to a minimum. It also gives large bearing surface so that all danger of wear or stretch is eliminated. Through the nickel steel bushings run hardened nickel steel rivets.

The entire chain transmission is enclosed in oil tight and dust-proof cases. This thoroughly protects the chains and sprockets, keeping them in a continual bath of oil which insures their lasting throughout the entire life of the machine.

That the chains may have an even tension, the ends of the rear axle are each housed in a spring mounted cast steel bracket. These springs not only provide tension for the chains, but equalize the load so that each chain carries its half, and in addition prevents the operator from injuring his machine by jamming it into a full load with a jerk.

The chain drive of the GRAY TRACTOR is spring mounted.

Motor

The motor on the GRAY TRACTOR is the Waukesha Heavy Duty, 4-cylinder, 4-cycle Tractor Type Motor. These motors are designed, developed and built particularly for tractor service in accord with the best mechanical and scientific practice. It properly balances throughout so that it is possible to run at variable speeds without vibration. The motor is accessible, powerful and simple. The combination of nickel chrome steel and other special steel for strength, and pure aluminum for lightness, has no equal.

Oiling System. The oiling system is of the automatic splash type, the oil level being maintained automatically irrespective of the motor position. Oil is supplied by a positive driven pump, and the oil gauge shows constantly the amount of oil in the reservoir. This oiling system is not susceptible to weather changes nor has it fine pipes and valves to clog or break.

Waukesha Motor. The Waukesha governor is automatically and positively oiled by a splash system, and is enclosed in an oil-tight and dust-proof case. It is a throttle governor and responds to varying loads with the same uniform speed at all times.

Magneto. Ignition is supplied by "K. W." High Tension Magneto, equipped with a quick starting device. This magneto eliminates all batteries, coils and switches, and the quick starting device insures a fat, hot spark, and prevents "kicking," no matter how slowly the motor is turned over.

Carburetor. A special type Bennett Carburetor is used on the Gray Tractor. This type has no springs nor balls in its construction and is extremely efficient. There is but one adjustment and the use of this carburetor insures to the GRAY TRACTOR owner absolute safety from carburetor troubles.

Bennett Air Cleaner. The Bennett carburetor is also equipped with a Bennett Air Cleaner. This air cleaner, by a dry process, removes all the sand and dust from the air before it passes into the carburetor. Every experienced operator knows the effects of dust and sand on the operation and life of the motor in the field.

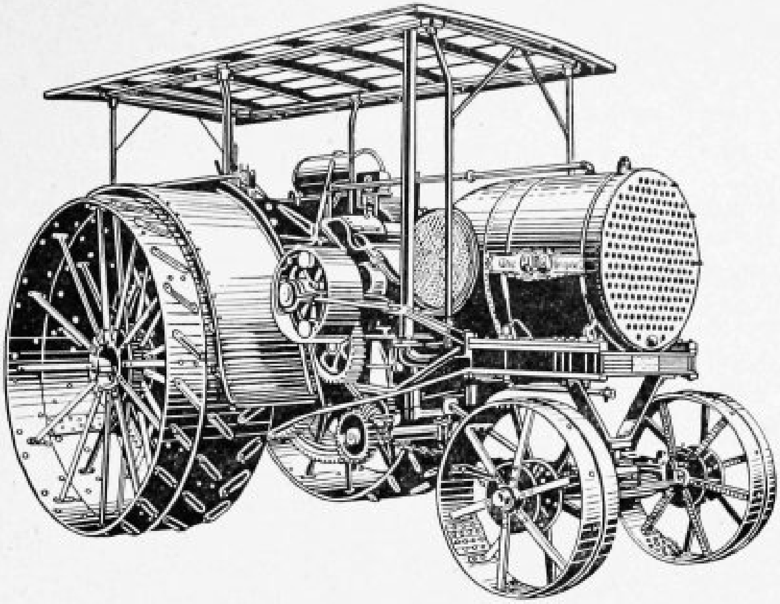
SPECIFICATIONS OF A. & T. 30-60 TRACTOR

Motor—Four cylinder, four cycle, horizontal motor. Cylinders are cast in pairs and securely bolted to a substantial crank case.

Cylinder Heads—One head for each pair of cylinders. We use a copper asbestos gasket between the head and cylinders and fasten them securely together with heavy studs. By simply removing a few nuts the heads can be removed and the carbon deposit thoroughly cleaned out. By removing the connecting rod cap, the pistons can also be taken out through the head end of cylinders.

Valves—Nickel steel valves, located in the head. The passages past the valves are large and smooth, offering the minimum resistance to the flow of the gases. The valves are accurately timed before leaving the factory and will practically never need adjustment.

Water Jackets—Surrounding the cylinder and

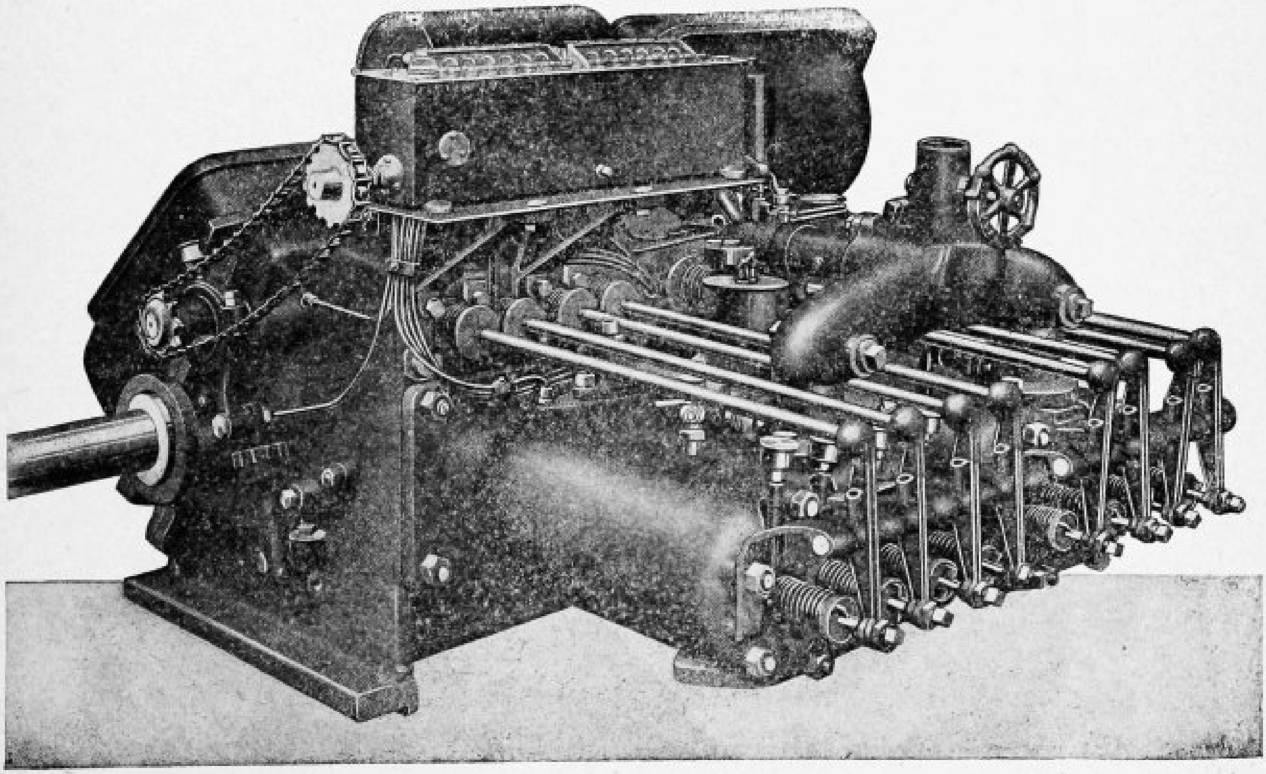


The Aultman-Tractor 30-60 Gas Tractor

head. The water spaces are large and carefully arranged so that every part of the Combustion Chamber is thoroughly cooled. Special attention has been given to the spaces around the valves so that they are always kept at an even temperature.

Pistons—Cast from the same grade of special gray iron as used in the cylinders. They are provided with five snap rings, which are made from a special mixture of hard gray iron, are re-turned and ground to the exact size of the cylinder after they are cut, which makes them fit closely and wear evenly. The piston pins are made of a high-grade steel, hardened and ground.

Motor Base or Crank Case—The use is of the most substantial design, made from the very best grade of cast iron. The bearings for the crank shaft and cam shaft are cast as a part of the base. The design of the case is such as to insure a perfect and permanent alignment of all bearings. Both the end and the center bearings are large in diameter and of ample length, babbitted with genuine babbitt. The case is provided with an oil-tight and dust-proof cover. This cover,



Quarter View of Power Plant—Left-Hand

when removed, permits of the removal of crank, cam shaft, connecting rods and pistons; in fact, all the interior parts of the motor can be withdrawn or adjusted without disturbing other parts.

Hand Hole Plate in Cover—This cover is provided with two large hand holes kept in place by a clamp and hand wheel. All adjustments on connecting cap, bearing caps, etc., can be made through the hand holes. It is not necessary to remove cover except when crank shaft, pistons or cam shaft is to be taken out.

Crank Shaft is extra large, of ample strength and made of a special high carbon steel, heat treated. All shafts are turned and then ground to one-thousandth of an inch.

Connecting Rod is a drop forging. The piston end of the rod is fitted with a split phosphor bronze bushing which can be adjusted by turning up a nut. This bushing can be easily removed and a new one put in place in case it is necessary to do so. The crank pin end is babbitted with genuine babbitt and the caps are secured to the rod by turned bolts. The bolts are fitted with slotted nuts, which enable the operator to get a very fine adjustment and yet be absolutely sure that the caps cannot come loose.

Motor Speed is automatically controlled by a centrifugal governor, which is driven by gears enclosed in the crank-case and absolutely protected from dust. The governor acts directly upon the throttle valve and the speed may be varied from one to five hundred revolutions by simply moving a lever which is set near the steering wheel.

Carburetor of the floating ball type; has no spring air valves; no spring adjustments and in fact requires no adjusting whatever except to change the amount of gasoline fed to the motor.

Battery and Magneto Systems are both provided for ignition.

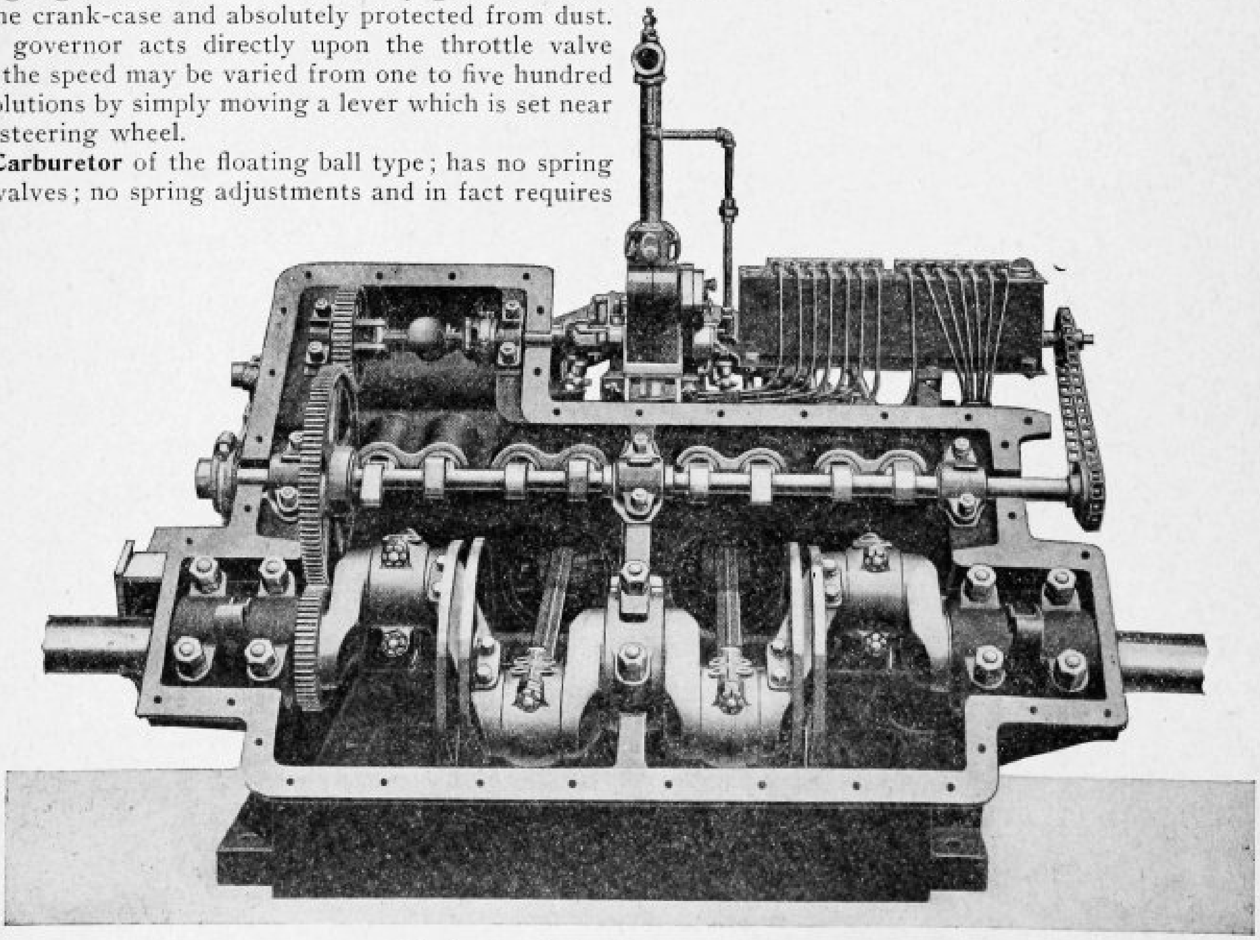
Battery consists of 10 dry cell, hermetically sealed in water-tight cases, so that there is no possibility of their becoming damaged by moisture and will last for an indefinite time when the battery is used for starting only.

Magneto of the high tension type and of the simplest construction, having no brushes or commutators to adjust. It is positively driven by cut gears direct from the cam shaft of the motor and is provided with water and dust-proof cover.

Spark Plugs are set in the head and are easily removed. Any type of standard spark plug can be used. They can always be secured from any engine dealer at a very reasonable price.

Lubrication—One of the most important features in a motor of any kind. In order to insure perfect lubrication, we provide a multiple force feed oil pump, which forces a definite amount of oil through an individual tube to each bearing and also to each cylinder.

Crank Pins are positively oiled by centrifugal oil rings fastened on the crank. These rings receive their oil from the force feed pump and force it directly to the crank pin bearings. This system insures



Motor Complete, with Cover Off—30-60

continual feeding of fresh oil to the cylinders and all the bearings.

Transmission—Note that our power is all transmitted through spur gears of simple construction, first-class material, and extra wide faces. We use no troublesome bevel gears on any of our tractors. Our differentials are all spring mounted. The gearing is subjected to exceedingly severe strains in starting heavy loads. The value of large springs to absorb this shock is apparent to any one who gives the subject a moment of serious thought.

Bull Pinions are steel, 5½-inch face, 2¼-inch pitch.

Bull Gears are semi-steel, provided with hubs and spokes to insure centering. They have heavy adjustable torsion rods by which they are securely fastened to the rims of the drivers and take up all of the driving strain.

Gear Oiling—The gearing is oiled by a multiple force feed pump, which drives a definite amount of oil to each gear and is positively driven from the countershaft so that it operates only when the engine is traveling. This system has every advantage over the gravity system, which provides no positive feed of oil. The old method did not feed at all in cold weather and must be operated by the engineer whenever the engine is in operation.

Controlling Mechanism is very simple. The forward and backward movement of the engine, also the belt pulley, is controlled by two clutches which are operated by one lever. The forward traction clutch is of the universal controlling type, and is provided with three shoes which are interchangeable and may be replaced in a very few minutes. The clutch is very easily adjusted, always under entire control of the operator, enabling him to move the engine any desired distance he chooses. The clutch is self-locking so that it requires no effort to hold the clutch in or out.

Backing Up Gear and the belt pulley are operated by the same clutch, which is of the internal expanding type and clutches directly on the inner side of the pulley rim. This clutch is provided with extra wide hardwood shoes and is easily adjustable. **This method of controlling both clutches and the belt pulley with one lever is protected to Aultman-Taylor Gasoline Engines by patents.**

Frame of locomotive truss type, built of heavy steel bars and channels. The heavy steel bars provide plenty of stock for receiving the bolts, preventing them from shaking loose, or wearing in the holes, as is often found in channel iron. The truss construction makes the frame very rigid and permits of **no vibration of the engine when in operation.**

Wheels—Rear wheels of the built-up steel type, have extra heavy steel rims; hubs, with heavy flat steel spokes, double riveted; outer end of spoke is shouldered against the rim. Inner end of spoke fits in a pocket in the hub to which it is firmly riveted. No shearing of rivets or loose spokes can ever result from this method of construction. The wheels are 90 inches in diameter, 24-inch face, with malleable cleats of the staggered type riveted on the rims. Twelve-inch extension wheels with spokes and cleats can be used.

Front wheels are 44 inches in diameter, 12-inch face. Of the built-up type and of the same rigid construction as the rear wheels.

Levers—But one lever is used for both forward and backward movement. In center position of quadrant, the lever is neutral; throwing it forward engages the clutch for the forward movement; throwing the lever back operates the mechanism for the backward movement of the engine.

Speed—The engine runs at 500 revolutions per minute. Speed on road at 500 revolutions per minute is 2.2 miles per hour.

Dimensions Over All—Extreme height of top of exhaust stack, 11 ft. 6 in. Extreme length of engine, 18 ft. 4 in. Extreme width with 24-inch drivers, 131 inches with extension.

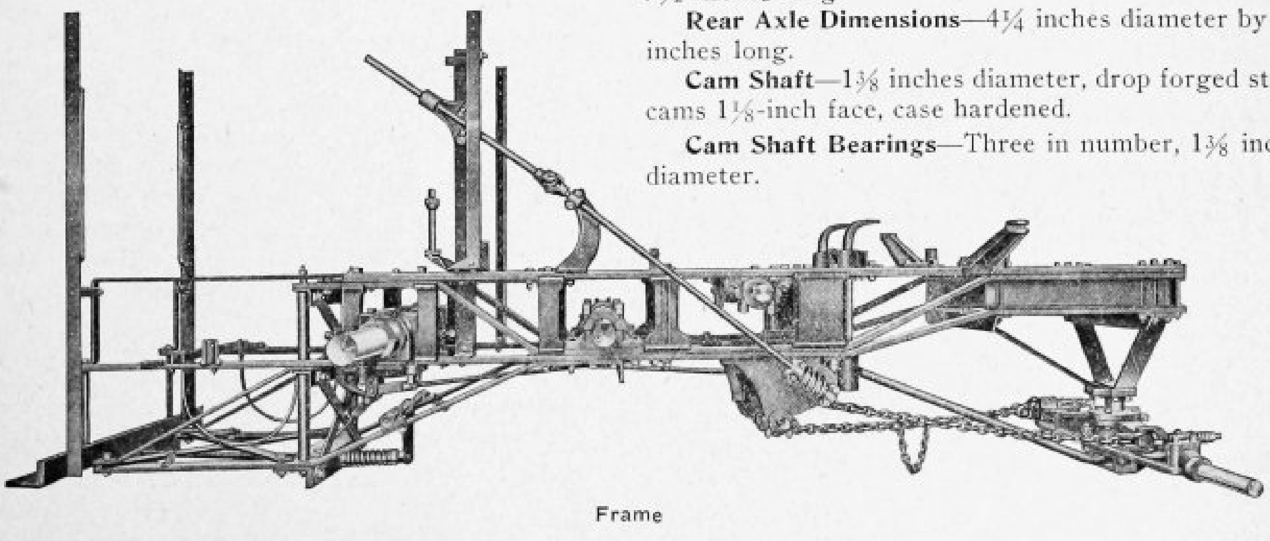
Dimensions and Measurements — Countershaft bearings, 3¾ inches diameter by 11 inches long. Crank shaft bearings, 3¼ inches diameter by 7 inches long on fly wheel side; 4½ inches diameter in center of crank case; 7 inches long on drive pulley side.

Intermediate shaft bearings, 3 inches diameter by 7½ inches long.

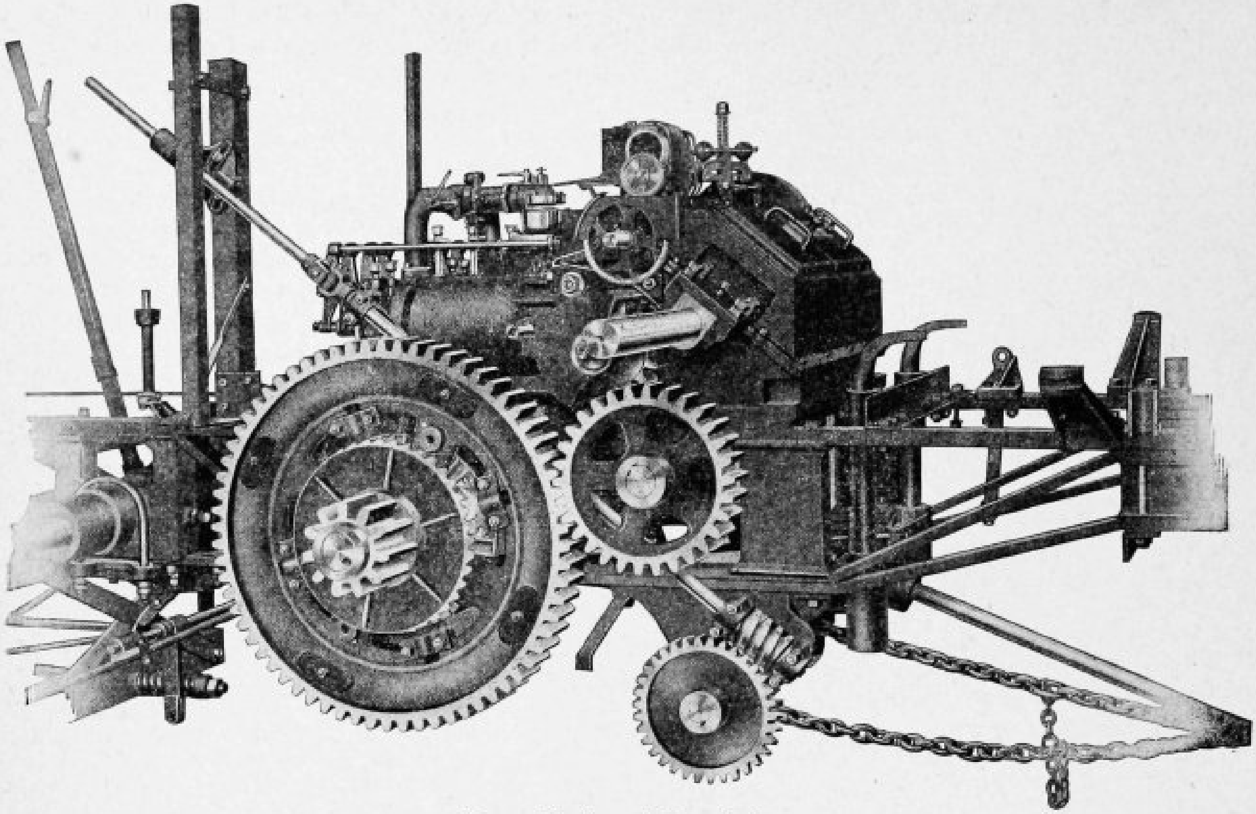
Rear Axle Dimensions—4¼ inches diameter by 103 inches long.

Cam Shaft—1⅜ inches diameter, drop forged steel; cams 1⅛-inch face, case hardened.

Cam Shaft Bearings—Three in number, 1⅜ inches diameter.



Frame



Power Plant and Tranmission

Crank Pins—Same diameter as crank shaft, 3¼ inches diameter, by 3¼ inches long.

Radiator of the tubular type, cooled by two 24-inch diameter fans, driven by ample belt. Tank is 42 inches diameter by 36 inches long, and has 196 2-inch tubes. Water capacity, 120 gallons.

Crank Shaft—High carbon steel, forged from solid piece, 3¼ inches diameter.

Cylinders—Four in number, 7x9 inches, cast in pairs, placed horizontally in the engine.

Exhaust—The exhaust gases pass out through the exhaust valves in cast-iron manifolds—these in turn discharging into one main pipe running up and discharging above canopy.

Fuel—Sixty-gallon gasoline tank placed under the platform.

Gearing—Crank shaft pinion and intermediate for forward movement are steel, 1½-inch pitch, 4½- inch face.

Crank shaft pinion for backward movement, steel. 1¾-inch pitch, 3-inch face.

Intermediate gear meshing in differential, steel, 1¾-inch pitch, 4½-inch face.

Differential gear, semi-steel, 1¾-inch pitch, 4½-inch face.

Bull pinion and bull gear, 2¼-inch pitch, 5½-inch face.

Bull pinions all of steel; bull gears semi-steel.

Drive Pulley is 24 inches diameter by 11-inch face.

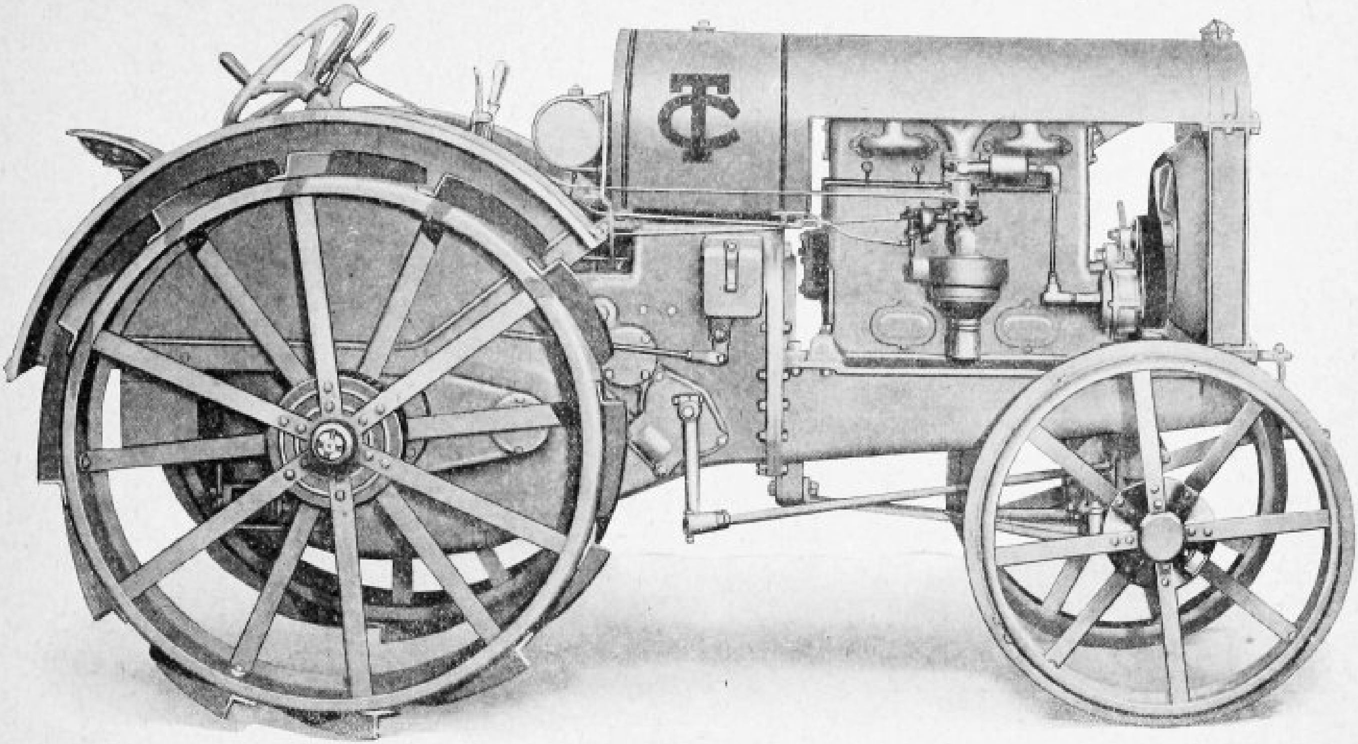
TWIN CITY KEROSENE TRACTORS

The Twin City "12-20"

This is the latest addition to the Twin City line, and, while it is a new machine on the market, you have the assurance that it is offered with the unlimited backing of our reputation and resources, as a practical power unit, thoroughly tried and proven in every phase of strenuous farm work. It is, first and last, a farm tractor. Its compact design and construction represents the latest and best that can be produced by skilled engineers with a practical knowledge of the farmers, requirements—abundance of power, endurance, simplicity in care and operation, with quick and easy accessibility.

The power plant, of supreme importance in every tractor, is a remarkable feature of the Twin City "12-20" in that it delivers 25 per cent more than its rated horse-power. This is accomplished by means of a special four-cylinder, sixteen-valve (valve in head) engine, which is applied for the first time to tractor use, and is therefore one of the several exclusive features of this "12-20." An explanation of the extraordinary power developed by this type of engine, will be found not only interesting, but really worth while to the farmer who is seeking maximum power on the lowest possible fuel cost.

The two exhaust valves take off all burnt gases so quickly that there is nothing to interfere with the quick and easy inflow of fresh fuel from the double



valve are of the two intake valves. This means that the fuel mixture in the combustion chamber is absolutely clean and that the chamber is completely filled so that the explosion naturally produces more power. It also means freedom from troubles that arise from an overheated engine, because it is the presence of burned gases in the chamber that produces this overheating and preignition.

There is no question about the unusual power of this new engine, for while the tractor is rated at "12-20," its engine actually develops 35 horse-power on kerosene, and 42 horse-power on gasoline, at one thousand revolutions per minute, which is the controlled speed of the engine.

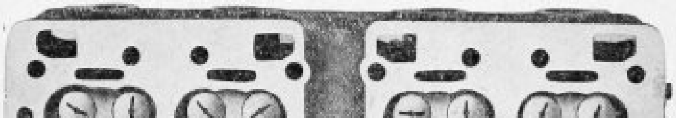
Other features of this engine are well worthy of consideration. These include a pressure-feed oiling system that automatically takes care of the lubrication of all moving parts, and a force-feed water circulation controlled by a thermostatic valve. All farmers who have used a tractor understand the value of a properly cooled engine, and what these features mean in that respect. Then, there is a sealed and enclosed governor control, that holds the engine to 1,000 R. P. M., so that no matter how quickly or how often the load is changed the engine cannot "race."

Experience has taught us that the farmer does not want complicated machinery, and we have spent time and money to make this engine simple and easy of access. For instance, it is only necessary to remove the plates on the handholes in order to test the bearings and should adjustment be necessary, it can be done simply by removing the base pan which is of pressed steel and can be handled with one hand. The cylinder head is removable so that grinding valves and cleaning the combustion chamber are simple operations. The removable cylinder sleeve and the counterbalanced crank shaft (to reduce vibration, as well as wear and tear on bearings) are among other important features. When in operation the entire engine is fully enclosed.

The general appearance of the Twin City "12-20" Tractor indicates its unusual strength and durability. Considering the history of the Twin City line, to which this tractor belongs, it is not surprising to learn that in addition to having only the best materials built into it, these materials are strengthened by heat-treating, as well as careful designing.

The transmission, which is completely enclosed, and dustproof, runs continuously in a bath of oil and is equipped with heavy-duty Hyatt roller bearings. It is simple and direct, only three gear reductions being used, irrespective of the speed, and all parts are easily accessible.

It should be noticed that in every instance the standard equipment of this "12-20" is recognized as the best on the market, including Bosch high tension magneto ignition, with impulse starter, Holley car-

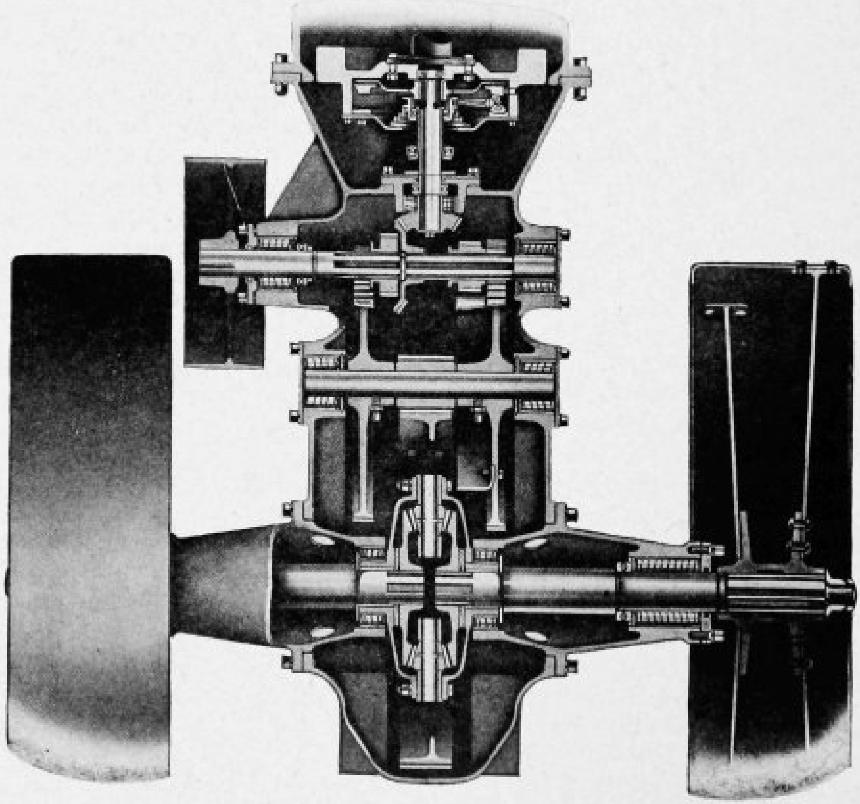


The Double Valve Area Which Means Unusual Power buretor, Sylphon thermostatic valve, Pierce governor, Fox fan Spirex radiator, etc.

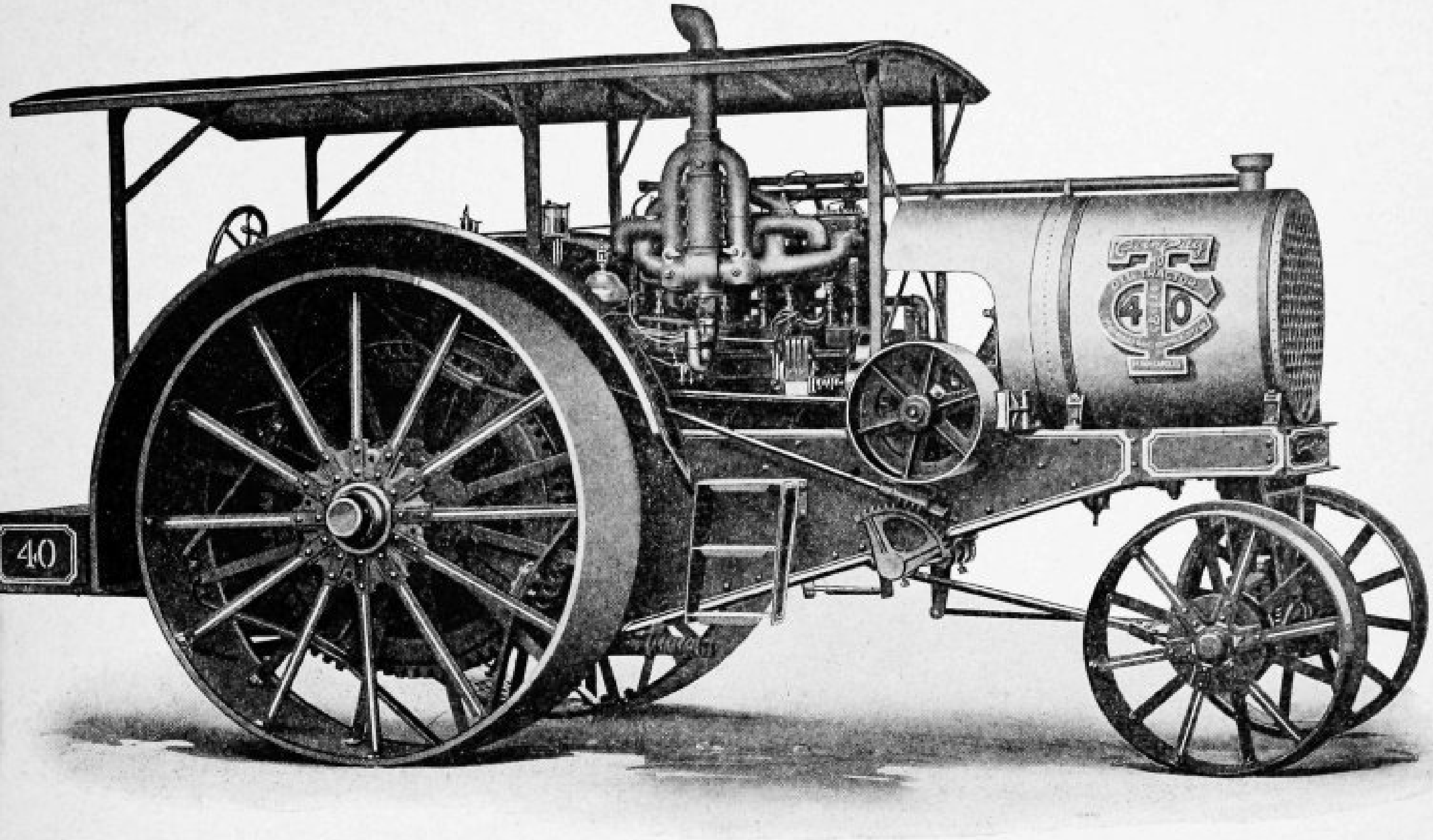
The field performance of the Twin City "12-20" tractor entitles us to claim that it is the most powerful tractor in its class and we know that your investigation will justify this claim.

Brief Specifications of Twin City "12-20"

Tractor H.-P. on Kerosene	12
Belt H.-P. on Kerosene	20
Motor—Stroke Cycle	4
Cylinders—number	4
Cast	En Bloc
Cylinder Walls	Removable Sleeves
Bore	4¼ in.
Stroke	6 in.
R. P. M.	1,000
Crankshaft	Counterbalanced
Number Main Bearings	3
Number Cam Shafts	2
Number Intake Valves	2
Number Exhaust Valves	2
Location of Valves	In Head
Cylinder Head	Removable
Oiling System	Gear Pump Pressure
Speeds—forward	2.2 and 2.9 miles per hour
Speeds—reverse	1.75 miles per hour
Weight¼withoutfuel, water or lugs	4,200 lbs.
Wheel Base	84 in.
Diameter of Drive Wheels	50 in.
Width of Drive Wheels	12 in. each
Diameter of Front Wheels	34 in.
Number of Drive Wheels	2
Diameter of Front Wheels	5¾ in. each
Type of Rear Axle	Live
Type of Front Axle	Automobile
Transmission Gears	Forged Steel, Hardened and Heat Treated
Transmission Shafts	Forged Steel, Heat Treated
Final Drive—Spur Gear, enclosed in Transmission Case	Running in Oil
Transmission—Type	Sliding Spur Gear
Number of Clutches	1
Type of Clutch	Single Disc—Dry Plate
Transmission Bearings	Hyatt High Duty
Thrust Bearings	Ball
Type of Radiator	Cellular
Radiator Construction	Truck Type Cast Tanks
Water Capacity	10 gals.
Size of Fan	10 in. diam.
Fuel Capacity—Kerosene	23 gals.
Fuel Capacity—Gasoline	3½ gals.
Diameter of Belt Pulley	16 in.
Width of Belt Pulley	6 in.
Revolutions per minute	650
Belt Speed, feet per minute	2,700
Height of Drawbar	16 in.
Total Overall Length	134 in.
Total Overall Width	63 in.
Total Overall Height	63½ in.



Transmission Showing Direct Drive



THE TWIN CITY "40-65"

The Twin City "40-65" has a four-cylinder, four-stroke cycle, vertical engine mounted lengthwise on the frame of the tractor, and just far enough forward to give the whole machine a perfect balance and distribute the load properly between the front and rear wheels. The engine is of 7¼ in. bore and 9 in. stroke.

Due to its large size and liberal proportions, the cylinders are cast singly and mounted separately on the crank case.

The crankshaft, the bearings, and the valves, are made of the very best material obtainable for these parts, are finished most accurately, and are all of generous size.

This 65 horse-power engine is perfectly governed and is built to withstand the most severe service in a satisfactory and lasting manner. It is the result of ten years of careful study and development.

In the Twin City "40-65" the power is transmitted through the fewest possible number of gears.

The main transmission of these tractors, operated by a powerful clutch in the fly wheel, is assembled complete in a single steel casting, which is in turn bolted to the tractor frame behind the motor and directly over the rear axle.

The Twin City Tractor gearing is not of the usual bevel gear type; the system of the automobile manufacturers in which the gears are cut from spherical sections of high-grade steel by special automatic bevel gear generating machines, has been adopted. This insures a perfect tooth form for these gears.

This system of cutting gears theoretically correct, produces the most efficient tractor transmission known, and answers effectively all arguments against the efficiency, or durability, of bevel gears.

Reversing is accomplished by shifting the jaw clutch from the rear to the forward bevel pinion. The bevel gears are 4½ in. face, and the main drive pinion and differential gears are 6 in. face.

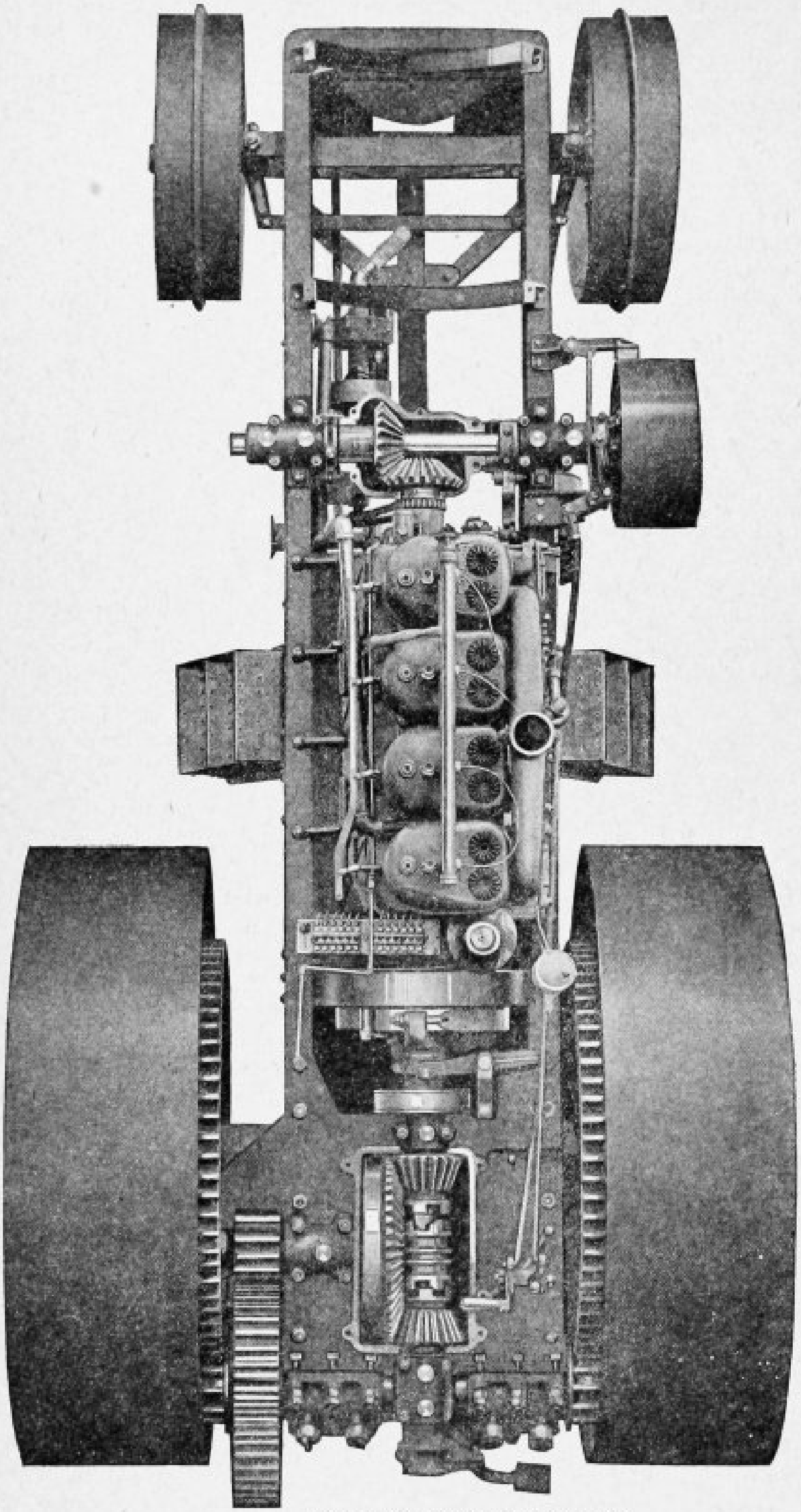
Long experience with this transmission system has proven beyond a doubt that the bevel gears show the least signs of wear, and are desirable in that they make possible a tractor of far superior design throughout, and of narrower tread.

The transmission mounted as it is in a single heavy steel casting is perfectly rigid, making it impossible for shafts to get out of alignment. All gear run in oil.

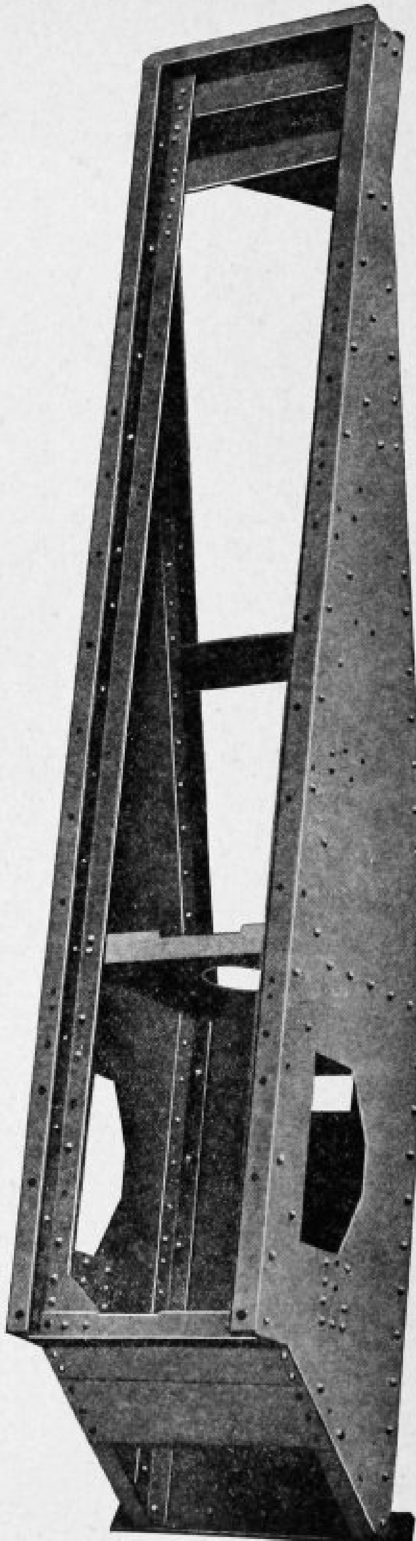
The front axle is of the knuckle type, the axle beam being a strong trussed member made of steel bars, containing the wheel knuckles at the ends and a neat spring suspension for the front end of the tractor, and also the pivot for the axle.

This type of axle has proven to be the most flexible and satisfactory steering device for automobiles, heavy trucks, and tractors, and is also the easiest and safest to handle. The front wheels turn on the ground spindles of the steel knuckles and are perfectly lubricated, the bearings being dirt-proof and grease-tight.

The belt wheel is operated from a pinion on the front end of the motor, entirely independent of the gearing which propels the tractor, so that the main



Twin City "40-65" Transmission

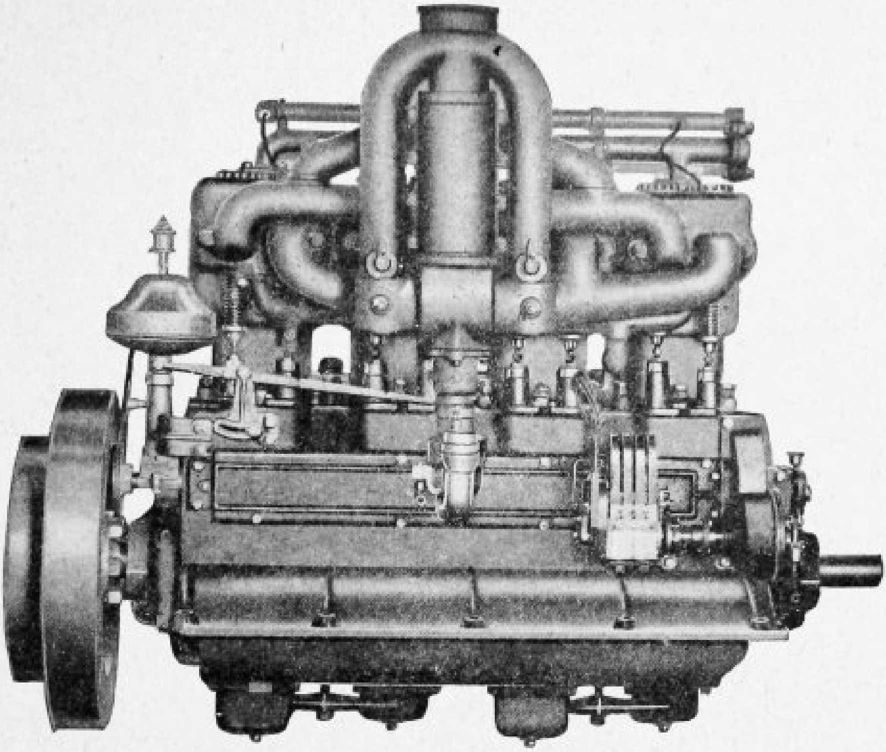


Twin City "40-65" Frame

transmission is relieved of all wear when the belt pulley only is running. These gears are 3-inch face and are cut on special machines, from the highest grade of drop forged steel.

The forward gears are thrown completely out of mesh when not in use. A brake operates on the pulley to stop its rotation when the clutch is released.

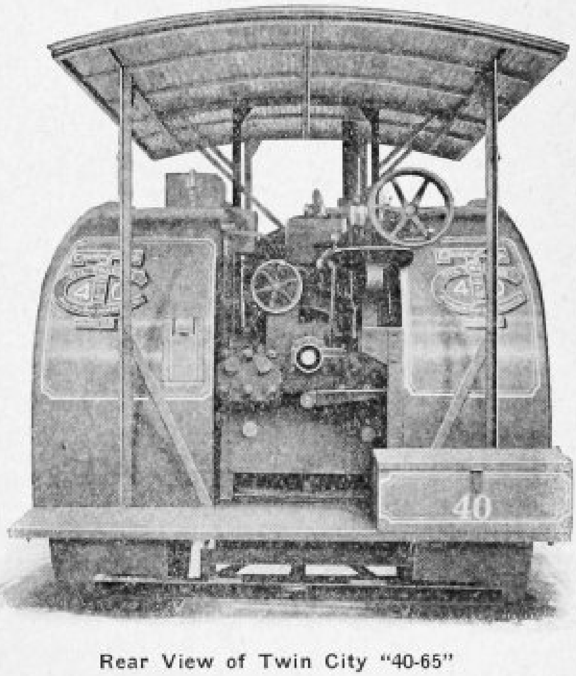
One of the unique equipments of all Twin City Tractors is the drawbar. The drawbar proper is attached to the forward cross of the frame ahead of the rear axle by a poweful but elastic coil spring suspension, thereby relieving the tractor and its transmission of the severe jerks due to varying loads.



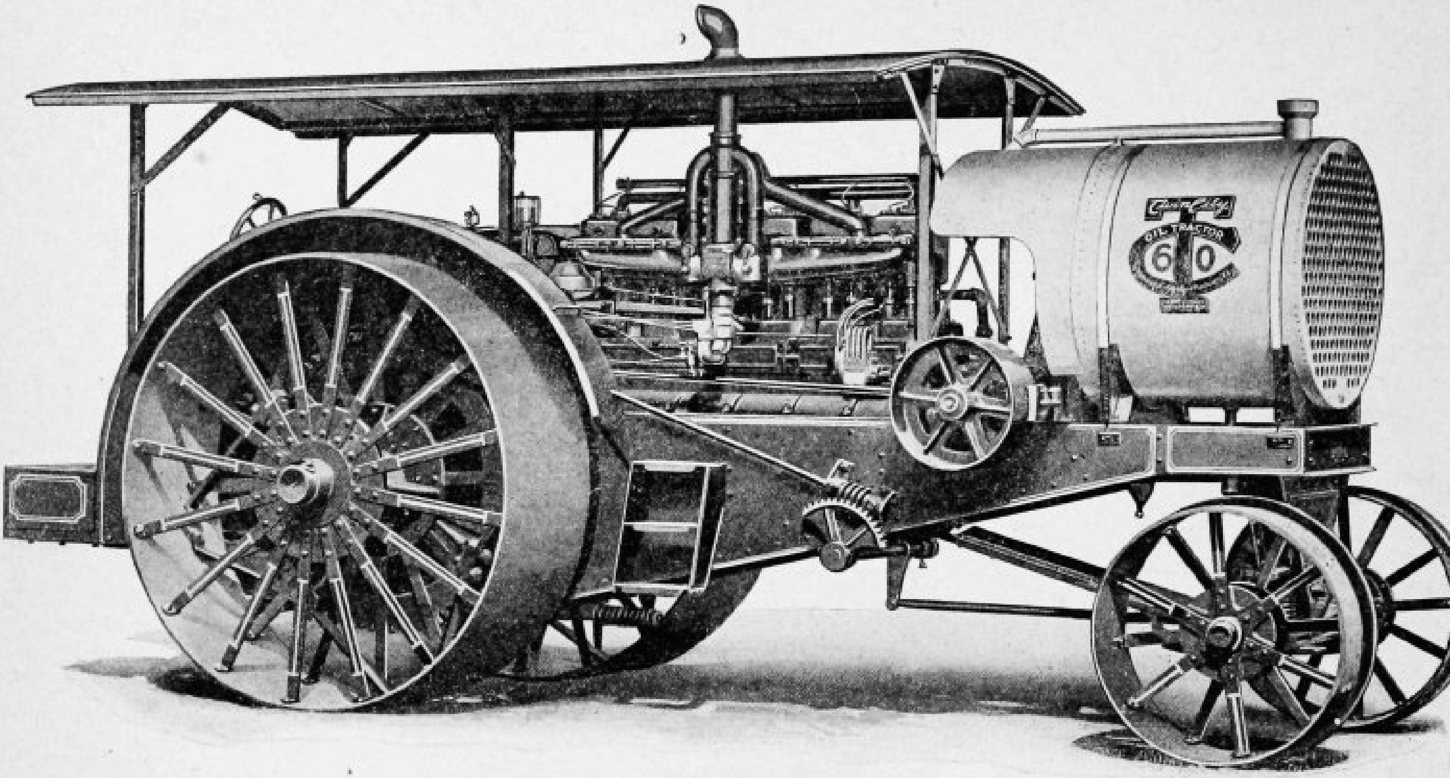
7¼x9, Four-cylinder Twin City Oil Engine, Valve Side

SPECIFICATIONS OF TWIN CITY "40-65"

Tractor H. P.	40
Belt H. P.	65
Motor—Stroke Cycle	4
Cylinders, Number	4
Cast	Separate
Bore	7¼ in.
Stroke	9 in.
R. P. M.	500
Speeds—Forward	2 M.P.H.
Reverse	2 M.P.H.
Weight, total	23,700 lbs.
Wheel base	12 ft.
Diameter drive wheels	7 ft.
Width of drive wheels	24 in.
Number of drive wheels	2
Diameter of front wheels	3 ft. 6 in.
Width of front wheels	12 in.
Number of front wheels	2
Type of rear axle	Dead
Type of front axle	Automobile
Transmission gears	Forged, steel, hardened and semi-steel
Transmission shafts	Forged steel, heat treated
Final drive	Internal gear
Bull gears	Semi-steel
Bull pinions	Forged Steel
Number of clutches	2
Type of clutches	Contracting Band
Transmission bearing	Heavy duty babbitt
Front wheel bearing	Heavy duty babbitt
Drive wheel bearing	Heavy duty babbitt
Type of radiator	Air tube
Water capacity	130 gal.
Size of fan	36½ in.
Fuel capacity—kerosene	95 gal.
gasoline	10 gal.
Diameter of belt pulley	23 in.
Width of belt pulley	10½ in.
Speed of belt pulley	500
Frame	Structural Steel
Height of draw bar	17 in.
Total over all length	20 ft.
Total over all width	8 ft. 6 in.
Total over all height	10 ft. 2 in.



Rear View of Twin City "40-65"



THE TWIN CITY "60-90"

The Twin City "60-90" is the largest and most powerful tractor built any where in the United States today.

In its arrangement it is similar to the famous Twin City "40-65," the entire tractor, of course, being built more massively to be able to transmit the enormous power of its wonderful six-cylinder engine. This engine of 7¼ in. bore and 9 inch strike is equipped with our Twin City vaporizing manifold, which enables it to operate most economically and with great flexibility on kerosene and other low-grade fuels.

It is guaranteed to develop over 90 brake horsepower continuously on the belt when operating at its proper speed of 500 R. P. M. and to deliver 60 horsepower at the draw-bar when used for drawbar work. This enormous power demands the use of high-grade materials and the most careful construction.

Few tractors built today have been given the study and engineering skill embodied in this machine, and we are proud to have the trade journals say that it is the best and most neatly designed large tractor on the market. While being essentially a large and powerful tractor, it is really a beautiful machine. Its proportions are correct throughout and the lines are clean and sensible.

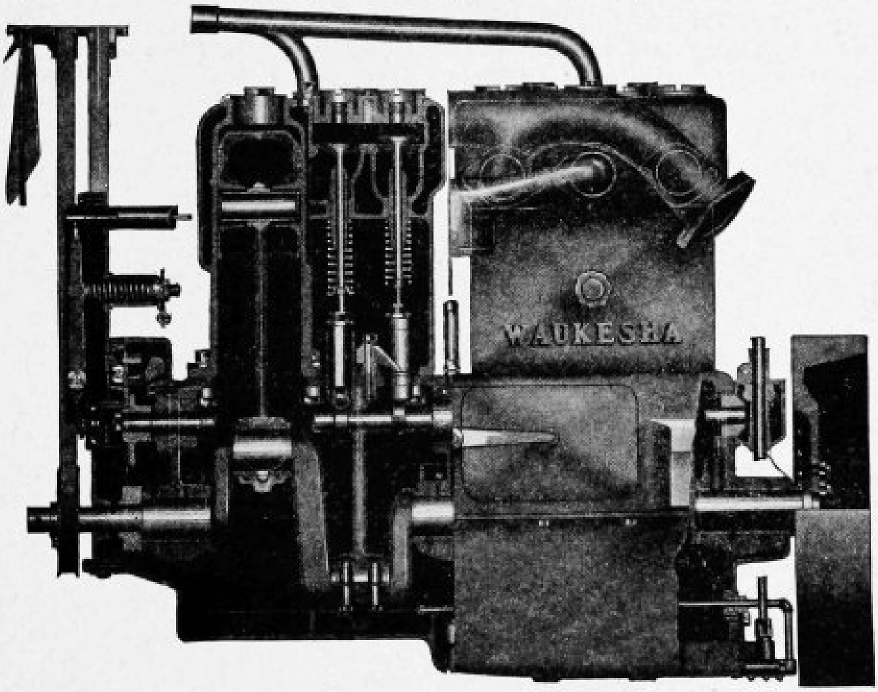
SPECIFICATIONS OF TWIN CITY "60-90"

Tractor H. P.	60
Belt H. P.	90
Motor—Stroke Cycle	4
Cylinders, Number	6
Cast	Separate
Bore	7¼ in.
Stroke	9 in.
R. P M.	500
Speeds—Forward	2 M.P.H.
Reverse	2 M.P.H.
Weight, total	28,000 lbs.
Wheel base	14 ft.
Diameter drive wheels	7 ft.
Width of drive wheels	30 in.
Number of drive wheels	2
Diameter of front wheels	3 ft. 6 in.
Width of front wheels	16 in.
Number of front wheels	two
Type of rear axle	Dead
Type of front axle	Automobile
Transmission gears	Forged, steel, hardened and semi-steel
Transmission shafts	Forged steel, heat treated
Final drive	Internal gear
Bull gears	Semi-steel
Bull pinions	Forged Steel
Number of clutches	2
Type of clutches	Contracting Band
Transmission bearing	Heavy duty babbitt
Front wheel bearing	Heavy duty babbitt
Drive wheel bearing	Heavy duty babbitt
Type of radiator	Air tube
Water capacity	116 gal.
Size of fan	43½ in.
Fuel capacity—kerosene	95 gal.
gasoline	10 gal.
Diameter of belt pulley	23 in.
Width of belt pulley	10½ in.

Speed of belt pulley	500
Frame	Structural Steel
Height of draw bar	17 in.
Total over all length	21 ft. 10 in.
Total over all width	9 ft. 6 in.
Total over all height	10 ft. 2 in.

WAUKESHA FOUR CYLINDER MOTORS FOR TRUCKS AND TRACTORS

On the following pages we show a number of illustrations that tell you the important points to remember in taking apart, putting together and adjusting Waukesha Motors. Study these illustrations carefully and become familiar with each part of the motor so you will be able to handle it intelligently and correctly. Pay close attention to the information and instructions printed under each of the illustrations. All of these points are very important and should be given very thorough attention, especially until you become completely familiar with every detail of the care and operation of **your** Waukesha Motor.



Sectional side view of Waukesha Motor, showing operation and interior construction

General Instructions

Know your motor!

Study it. Tend it carefully.

Never "tamper" with a motor, particularly a Waukesha Motor, because it is too valuable a helper to be experimented on. If trouble arises, locate the trouble and correct it. But **be sure you are right** before you go ahead.

Don't guess. If you do not **know** why your motor operates incorrectly, ask some experienced motor operator to help you out.

Eternal vigilance is the price of successful motor operation. Carelessness costs **you** money, because you lose time. Five minutes spent in looking over your motor to see that everything is O. K. **before** you start may save you **five hours'** time and a costly repair bill. Prevention is better than cure—always. The more prevention you use, the less "cure" your motor will need.

Do This Before You Start

See that the fuel tank is full.

Inspect spark plugs to see that none are cracked or loose.

Test them for sparking. If you aren't getting a good spark at every plug, look for carbon on the plugs, or trouble with the ignition.

Look at your oil glass to see that your motor won't run dry on the road or in the middle of a field. It may take an hour or two to come back and get oil that you could supply in half a minute before you started.

Be sure that the cooling system is not short of water. An over-heated motor will never give the good results that a perfectly cooled one will. Besides, if you are going where water is not right at hand, it may take you half an hour or so to get the water you need. "A stitch in time save nine."

In other words, look your motor over from stem to stern before you start, so that you can correct any troubles in the easiest and quickest manner.

A motor that is well-oiled, well-fueled seldom gives any trouble—but, neglect any one of these features, and endless troubles arise.

You can save yourself a lot of time, trouble, and expense—to say nothing of adding years to the life of your motor—by careful inspection of all parts **before** you start.

THE QUESTION OF OIL

Inasmuch as lubrication is the most important thing in the care and operation of a motor, we wish to put special emphasis upon the subject. You can realize how important this subject is when you stop to consider that without lubrication this the motor will not operate at all, while with poor oil the life of the motor is greatly shortened, and its efficiency is considerably lessened.

It is customary to use a slightly thinner oil in winter and a thicker oil in summer. The following list is of closely related oils as indicated by our experience. There are many good oils not mentioned in this list and we would be glad to investigate any oil (not listed) as to its desirability for use in Waukesha Motors if a 5 gallon sample is submitted for test, without cost to us; or we will submit a sample for your oil company to duplicate, and will check the duplication.

In Justice to all we desire that it be thoroughly understood that while we have personal preferences in oils due to extended tests which we have made, we do not advocate any particular brand of oil, and the list given is necessarily limited by our experience with the oils mentioned.

Determining which is a good oil and which is not, is difficult without accurate tests. There are no fast rules for determining the quality of a particular grade of oil, notwithstanding the fact that many men believe they can tell at a glance the difference between a good or poor grade of oil. We advise you, therefore, to use the grades and makes listed, or to send the best oil obtainable for our investigation and approval.

DO NOT UNDER ANY CIRCUMSTANCES USE THE SAME OIL, OR CONSISTENCY OF OIL, IN YOUR TRACTOR THAT YOU USE IN YOUR PLEASURE CAR. IF YOU DO THIS THE MOTOR MAY BE RUINED WITHIN A SHORT TIME.

The General Characteristic of Oils is as follows:
Pleasure Car .... Thin in consistency
Truck .... Thicker
Tractor (Gasoline) .... Thick and Heavy
Tractor (Kerosene).. .... Thicker—heaviest

In using oil be sure that it does not run as thin as water when put under a heat test; some oils do this.

RULES FOR LUBRICATING WAUKESHA MOTORS

Use a slightly thinner oil in winter and a thicker oil in summer. Special grades of oil are prepared for summer use, and different grades for use during the winter.

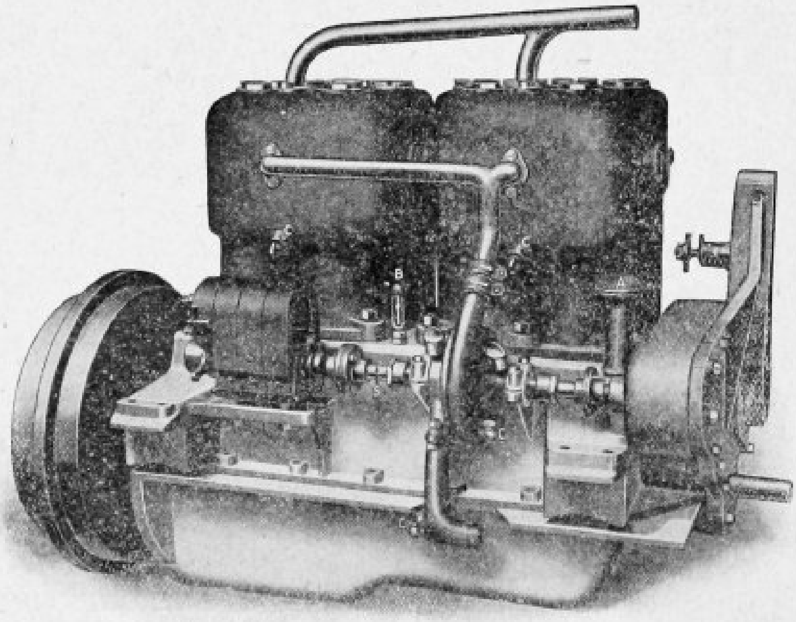
When a Motor is in continuous use the oil must be changed frequently. Conditions vary a little but it is advisable in the case of a tractor motor to change the oil completely about every TWO DAYS, and every TWO WEEKS for a truck motor. By examining the oil you draw from the crank case you can judge to what extent the oil has been diluted due to the kerosene passing into the crank case; too much kerosene in the oil would tend towards excessive wear. It is almost impossible to give a rule with regard to changing the oil in the crank case because this depends entirely upon the grade of fuel, condition of motor, etc. However, examination of the oil removed would give the best idea.

The appearance of the knob in oil guage indicates a sufficient amount of oil, but to be on the safe side it is advisable to keep the knob high up in the glass.

In case there is much blue smoke from the exhaust it indicates that the oil level is too high or that piston rings are worn or stuck.

Black smoke from the exhaust indicates too rich a mixture of fuel, resulting in waste of fuel, loss of power and overheating of motor.

Other questions relating to lubrication are covered under the subject of "Common Motor Troubles and How to Remedy Them."



HOW TO PUT OIL IN MOTOR

Test oil float in glass (B) to be sure that its movement is free: then take off breather cap (A) pour oil in slowly until float needle knob comes up to within ¼-inch from the top of the glass.

The can and funnel used in supplying the Motor with oil must be clean, otherwise mud and grit will be washed into the Motor. Dirt and grit do not lubricate but cause excessive wear.

In cases where the oil pan has been removed in order to work on the bearings, etc., be sure, after you have replaced the pan, to remove the crank case doors and fill each connecting rod oil pocket to its level: this will prevent the bearings from being scored before the pump can feed the required amount of lubricant; then proceed to fill through breather according to instructions in the above paragraph.

Always, before replacing the oil pan, be sure to clean it thoroughly, particularly the oil pump screen; test the oil pump and oil feed pipe to see that the oil flows freely: this can be done by putting a little oil in the reserve section of the pan and turning the pump with a small wrench or pliers.

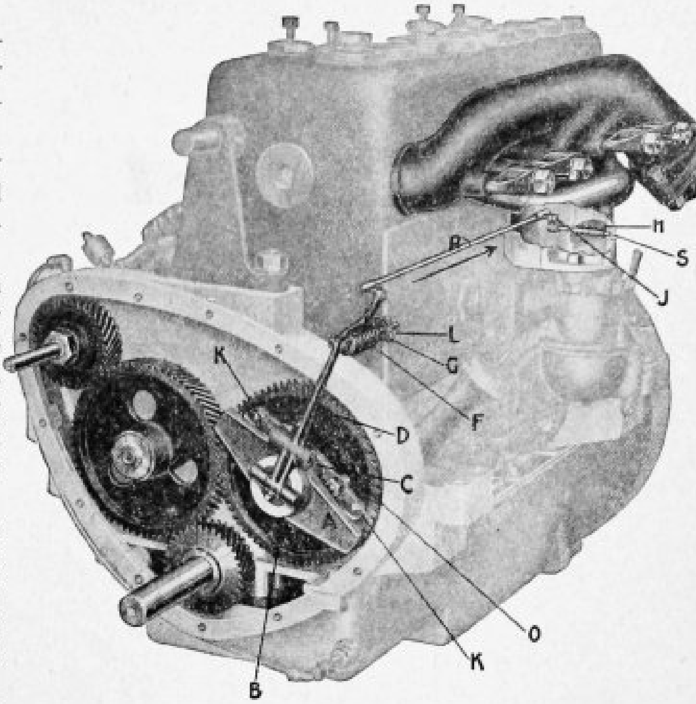
To avoid any leaks between the crank case and pan, always scrape off the old gasket, and replace it with a new one, using shellac on one side of the gasket only, and draw up the bolts before the shellac dries so as to insure an oil tight fit.

Important

Cleaning of the oil pan edge only will not suffice. You are apt to forget that the bottom edge of the crank case should be given as much attention. Also in scraping off old paper gasket care should be taken not to damage by scratching notches or grooves in the surface of the metal, as the manufacturers spends much time in having these surfaces ground in order to make them oil-tight.

Never allow any dust or dirt to collect near the breather tube. In fact anybody who wishes to preserve the life of the motor, and expects uninterrupted service from his motor, will spend at least 10 to 15 minutes a day to thoroughly clean his entire power plant. Using a small pot of kerosene and a brush will permit you to do a good job quickly.

HOW TO ADJUST GOVERNOR



The operation of the Waukesha Governor is as follows: Two circular weights back in the case behind gear "O" are held by and swivel about the two pins marked "K." These weights fly out at speed, moving part "A" outward. This action presses the ball bearing thrust contained in retainer "B" outward in proportion.

The lever "D" swivels on fulcrum "C." The movement of "A" causes a movement of rod "R" in direction indicated by arrow. The movement of rod "R" closes valve "H" which is of the butterfly type and swivels on shaft "S."

The adjustment for speed is made by turning screw "L." Turning "L" in direction indicated by arrow causes motor to speed up, while turning "L" in opposite direction causes motor to slow down.

The Governor is locked by locking nut "G." It is further possible to lock and seal the whole arrangement by passing a seal wire through hole in spring housing, and through hole in nut "G."

"F" is a spring, the tension of which governs speed of motor.

HOW TO GRIND VALVES

The time that valves will run without grinding varies with so many conditions that it is practically impossible to make a definite rule as to how often they should be ground. Generally speaking it is wise to leave the valves alone so long as the engine has good compression.

When necessary to grind them, first take out the valve chamber plugs (A) which are directly above the valves. In taking these out do not use a chisel and hammer, but use the spanner wrench that comes with the engine, otherwise you will batter up your valve chamber plugs so that they will not screw into the cylinder properly. In taking them out be careful not to spoil the copper gasket (B) that is under each plug.

With an ordinary valve lifter raise the valve spring cap (C) but be sure that you hold the valve so that it cannot raise. While the valve cap (C) is in a raised position take out the two valve spring washer retainers (D) and release the valve spring (F) so that it will go down against the push rod adjusting screw (E).

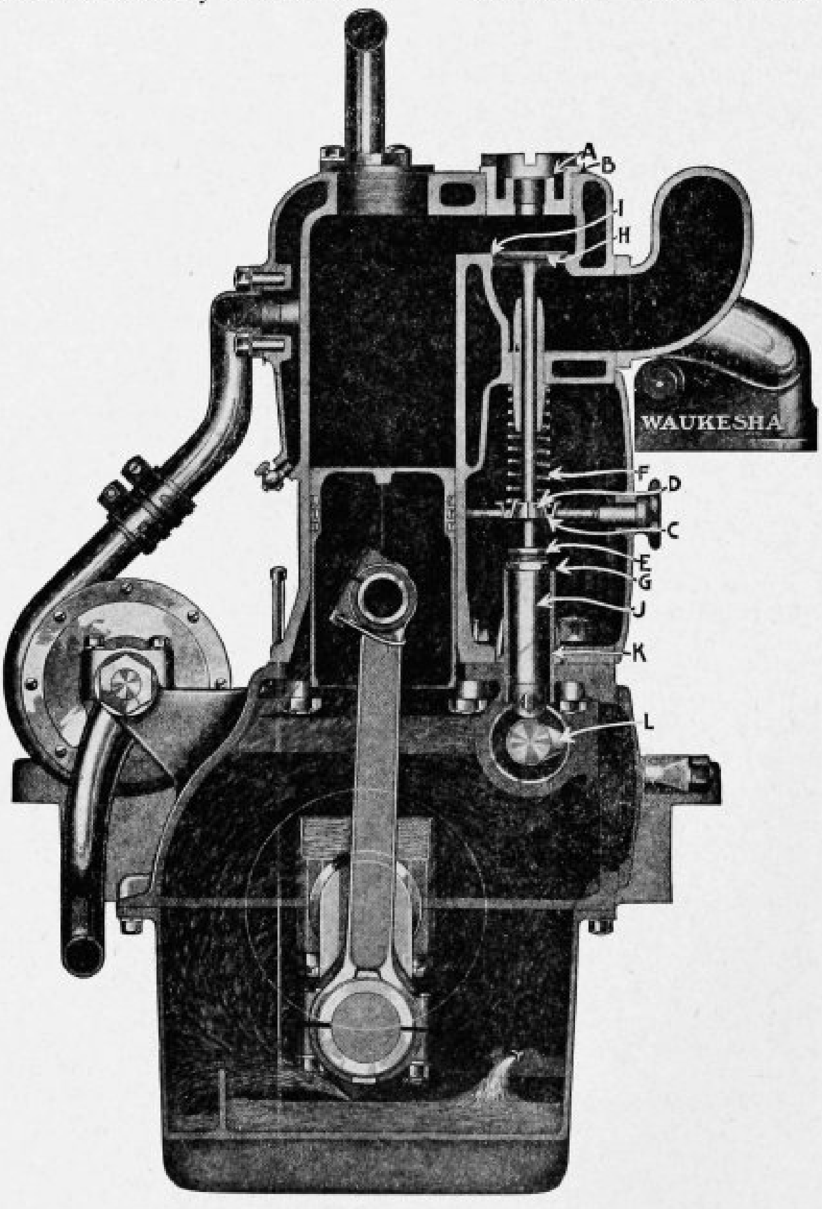
Before attempting to remove the valve spring always be sure that its corresponding push rod is in its lowest possible position as shown in cut. Now by putting a screw driver through the valve spring (F) and catching the valve spring washer retainer slot in the valve stem, the valve can be raised enough to get under it with a piece of wire and pull it out through the top of the cylinder.

Great care should be taken not to bend the stem or head of the valve while getting it out of the cylinder. With the valve out you can easily remove the valve spring (F), so it will not be in your way; then loosen the lock nut (G) on the push rod adjusting screw and run the screw (E) down so that there is no possibility of the valve stem touching it while the valve is being ground. After cleaning the valve and valve chamber thoroughly you are ready to start the actual grinding operation.

To grind the valves it is necessary to have some fine emery mixed with oil, or preferably vaseline which has been warmed, or else one of the prepared valve grinding compounds which can be bought at any auto supply house or garage. This compound, or mixture, should be smeared sparingly on the face of the valve (H), where it comes in contact with the valve seat (I) and the valve put back in the cylinder and rotated forward and backwards with a screw driver never making a full turn while grinding.

The valve should be lifted every now and then so as to get an even and smooth job of grinding. This operation should be continued until both the valve and the valve seat show a bright clean surface free from any spots.

BE SURE THAT NONE OF THE VALVE



Sectional End View of Waukesha Motor, showing Operation and Interior Construction. Note how the drip of the connecting Rods causes a spray of oil to circulate, thoroughly oiling every bearing of the Crank Shaft, the Cam Shaft the Push Rds, Pistons and Piston Pin Bushings. Note how the oil vapor circulates past the push rod and up into the Valve Case Chamber.

GRINDING COMPOUND IS LEFT IN THE VALVE CHAMBER, OR ON THE VALVE. If this compound gets into the cylinder it will cut the piston and cylinder wall, thereby causing a costly repair bill.

When replacing the valves first put on the valve springs (F) and washers (C)—then put the valve in place and be sure that the stem has been oiled and is entered in the hole in the center of the valve spring washer (C). Now adjust your valve spring lifter so as to raise the valve spring, and replace the valve spring washer retainers (D).

By putting a little grease on these retainers you can replace them one at a time and they will not fall out, the grease having a tendency to make them stick to the valve stem. Be sure that you have the small end of these retainers uppermost.

The push rod screw (E) should now be readjusted so that the valve stem will clear **the push rod adjusting screw** by about the thickness of a calling card when the push rod is in its lowest possible position.

After you have replaced the valve chamber plugs (A) using good or new baskets (B), and have pulled them down as tight as possible, run the engine without a load until it is thoroughly warmed up and then you will be able to pull these plugs still tighter while the engine is warm. The joint between the plug and cylinder must be perfect.

(J) indicates the push rod which slides up and down in the push rod guide (K). (L) indicates the cam which revolves, and lifts the push rods which in turn open the valves. When cam (L) is placed as shown in cut, the push rod is in its lowest possible position. The valves are closed automatically by the spring (F).

HOW TO ADJUST LOOSE CONNECTING RODS AND MAIN BEARINGS

Connecting rods and main bearings may be adjusted without taking the motor out of the chassis. However, this does not hold true where it is impossible to work at the motor from below.

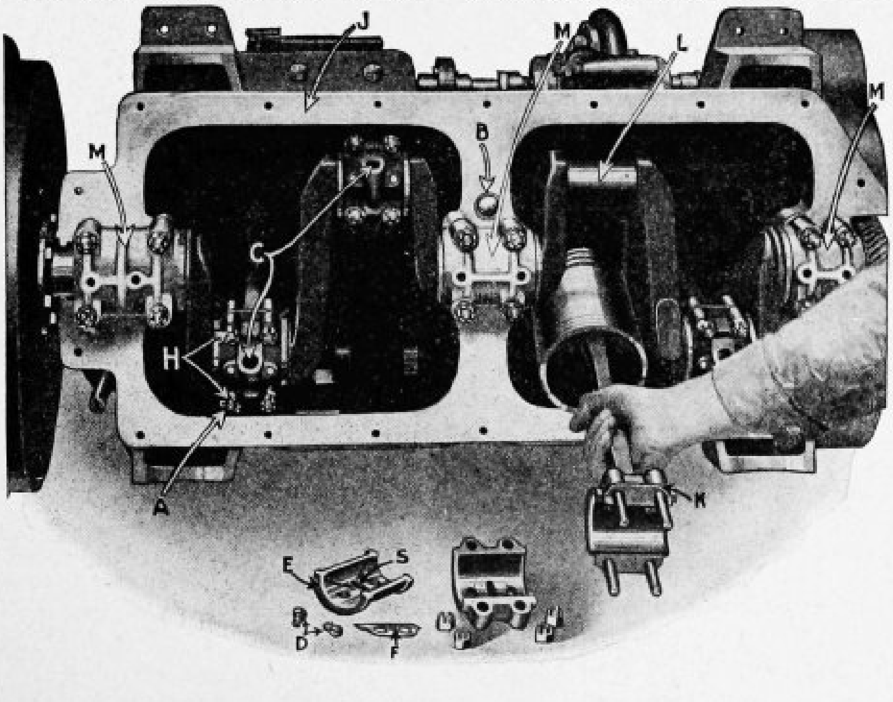
The following instructions will give you a good idea how to proceed in order to properly adjust the connecting rods and main bearings.

First—Drain off all the oil by removing the drain or pipe plugs from the bottom of the oil pan: then place a small lift jack under the pan to keep it from dropping before all the oil pan bolts that support it have been removed. It is advisable to tie up the oil float (B) as high as possible to prevent it from dropping into the oil pan while the latter is being removed (this can be done by unscrewing the holder of the oil gauge glass) and thus prevent the possibility of it being damaged or bent. This also makes it easier when you are ready to replace the oil pan. Open all four compression cups on top of cylinders.

Second—After removing pan scrape off the gasket from bottom edge (J) of crank case and clean away all dust and dirt so that it will not get into the bearings. Clean your hands and tools before working on the bearings and never use cotton waste or any rags which might leave shreds behind as these might cause serious trouble to the oiling system.

Third—When working on bearings it is a good plan to pull out the pistons and clean off the rings and piston heads. Always oil the piston rings before replacing the piston.

Fourth—Pull out the cotter pins (A) and unscrew the four nuts (H); (ALWAYS USE A SOCKET WRENCH FOR THIS OPERATION AS OPEN END WRENCHES ARE APT TO DESTROY THE NUTS) in taking off the cap be careful not to lose any shims or liners (F) and keep them in place until ready to remove them. On later motors laminated shims are used between the connecting rods and their



caps, allowing one to adjust the bearings to within two one-thousandths of an inch. Laminated shims vary in thickness, and are made up of a series of small shims—two one-thousandths of an inch in thickness—which are pressed together as one piece. In taking the loose play out of the bearings, one can peel these shims off to any amount required to have a perfect adjustment on the bearings—never peel off any more of the shims at one time than is necessary. Take out the shims to the amount you think necessary to take up the wear (being careful to remove an equal amount of shims on each side of the cap). BEFORE REPLACING THE CAP, SEE THAT THE THIN SHIMS ARE PLACED BETWEEN TWO HEAVY ONES WITH WHICH THE CONNECTING RODS ARE ALWAYS SUPPLIED. Replace the cap and draw it up as tightly as possible, using all four nuts and drawing them up evenly and firmly. Now try turning the engine over by hand in order to find out whether you have the bearings too tight or not. It should turn easily as this represents only one tight bearing; when this bearing is right loosen it, and proceed to fit the other bearings in the same manner. After each bearing has been fitted and tested draw up firmly all the nuts and use **new** cotter pins **only;** never back up the nuts to insert the cotter pins—always draw up to the next notch and never use wire in the connecting rod nuts as it will interfere with the oiling system. Have the cotter pins well bent apart—so they cannot back out when motor runs.

Fifth—Oil the bearings well by means of an oil can and turn the motor over (by using the crank handle) several revolutions before replacing the oil pan.

Sixth—Are you sure that holes (C) in all four connecting rod bearing caps are facing direction motor runs? This is important because when the motor runs oil is forced into these holes to lubricate the bearings; if one of these holes should face in opposite direction that bearing would get practically no oil, the bearing would heat up and soon cut out, resulting in a costly repair job.

Seventh—Refer to oiling system in regard to replacing pan.

HOW TO REPLACE WORN OR DAMAGED CONNECTING ROD BEARINGS

This is work for a first-class mechanic, one who is not experienced can hardly expect to do this job, and have the motor perform satisfactorily—however for emergency purposes if the following instructions are carried out, fairly good results should be obtained.

First—Remove oil pan as instructed on page 17; then take off the cap and pull out the piston as shown in cut on page 17.

Second—Take out the screws (D) in order to remove bearing (E). Be sure to fit the bearing half with the large oil hole (S) in the cap, and the other half in the connecting rod (K).

THE FOLLOWING IS VERY IMPORTANT

The back side of the bearing must have a perfect or snug fit in the connecting rod, otherwise it will be impossible to get a perfect permanent bearing on the crank pin (L). Fitting the back of the bearing is practically on the same order as fitting the bearing to the crank pin. Using Prussian blue or red lead in the rod and cap will enable you to find the high spots between the cap and the bearings; these high spots must be draw filed.

Third—Put in the screws (D) very firmly and be sure that the heads are LOWER than the bearing surface so that they do not come in contact with the crank shaft. Next draw file across the top of the cap and the rod to have the bearing flush with same.

Fourth—Without replacing the piston in the cylinder fit the bearing to the crank pin (L); if the bearing is too wide the ends will have to be draw-filed. Be careful not to file **too much** off. By applying Prussian blue or red lead to the crank pin surface it will enable you to fit the bearing to the pin to determine whether a perfect bearing surface is obtained. Remove the rod and observe whether the blue or red "spottings" indicate a bearing the full length of the cap. If they do not the babbit should be scraped until a perfect bearing surface is obtained. Adjust the bearing to the crank pin so it can be moved to and fro freely, but at the same time it must not be loose. Remove the connecting rod and replace piston and give the bearing the same adjustment as you did when the piston was out; then turn the motor over by hand several times to make sure that no binding takes place. Do not be afraid of getting the connecting rod bolts too tight as the shims under the cap will prevent the metal from being drawn into too close contact.

HOW TO REPLACE WORN OR DAMAGED MAIN BEARINGS

An expert mechanic should do this job, if one can be found.

First—Take the motor out of the tractor or chassis and before removing pan draw off all the oil.

Second—Take out all spark plugs, priming cups, etc., on top of cylinders. Now stand the motor on its head and place props under the motor arms to keep it from wabbling while work is being done.

Third—Remove the oil pan and take out all pistons and be sure that they are all marked so they will be put back into their respective places.

It is most important before removing the crank shaft to mark all the gears in accordance with instructions on page 21, otherwise there is a possibility of getting the motor out of time.

Take off the fly-wheel but be sure that you have it marked with the flange on the crank shaft, as it is very important that the fly-wheel is replaced in the same position as when you take it off.

Fourth—Take off the three main bearing caps (M, as illustrated) and remove the crank shaft. Stand the crank shaft up on end and place it safely aside as a fall might spring it out of shape and later you would wonder why the bearings could not be fitted. Remove idler gear marked A-B-C.

Take out the screws to remove the damaged bearing. Clean away all dirt and grit with gasoline; fit in one-half of the new bearing in the crank case. This operation is the same as described for replacing connecting rod bearings.

After bearing has been fitted in the crank case, replace crank shaft. Apply Prussian blue, or red lead, to the crank shaft bearing surface and scrape off the "spottings" in the same way as in fitting new connecting rod bearings. Strict attention must be paid that the new bearing does not rest too high in the case so as to throw the other two bearings out of line, nor should the bearing be too low.

Should the bearing be too high either the other two bearings will have to be raised by shimming them up, or the new bearing must be scraped until the three bearings are on the same level.

The crank shaft must fit the half of the main bearings in the crank case perfectly before you proceed to fit the caps.

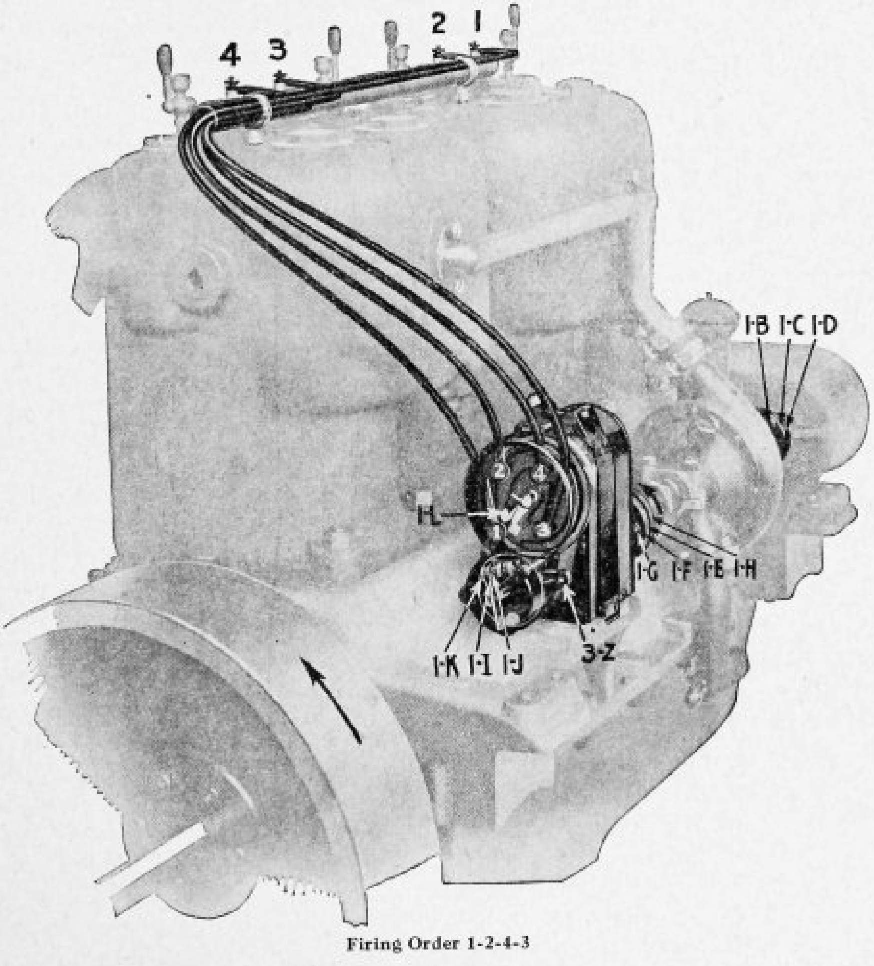
Always fit the rear main bearing cap first and tighten it up as much as possible without stripping the bolt threads. When the bearing has been properly fitted the crank shaft will permit moving with one hand. If the shaft cannot be turned with one hand the contact between the bearing surfaces is evidently too close, and the cap requires shimming. On the other hand, if the crank shaft moves too easily some shims must be removed to permit it to set closer.

After removing the cap observe whether the blue "spottings" indicate a full bearing the length of the cap. If they do not the bearing will have to be scraped. Lay the rear bearing aside and proceed to adjust the center bearing in the same manner. Repeat this operation with the front bearing, with the other two bearings laid aside.

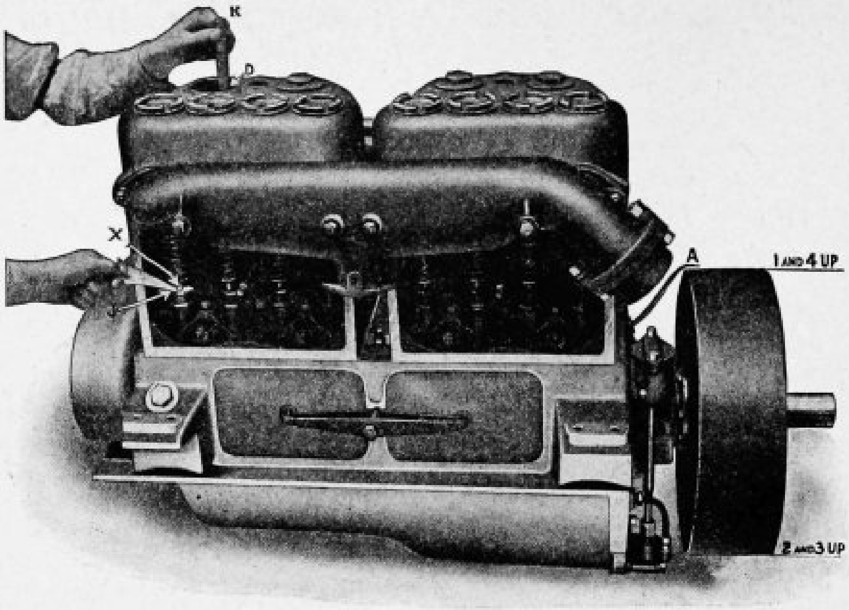
When the proper results have been obtained with the bearings replace the idler gear and be sure that the connections A-A, B-B, C-C, correspond. You can now replace the caps and insert the cotter pins, or wire. Be sure when you replace pistons that the heads and the rings are free from grit and carbon, also oil each piston ring carefully.

HOW TO TIME THE VALVES

ALL WAUKESHA MOTORS HAVE CYLINDERS NUMBERED 1-2-3-4 STARTING AT GEAR END AND READING TOWARD FLY-WHEEL END.



Firing Order 1-2-4-3



As a rule Waukesha Motors have their flywheels marked as to when the valves should open. The following method is applied in case the flywheel and the timing gears are not marked.

First—Trun the motor over until No. 1 piston is at upper dead center (refer to illustration above). In order to determine when piston is at upper dead center, remove cylinder head plug and insert a steel rule (R) or any marked stick. Rotate the crankshaft and watch while the rule (R) comes up. When it ceases to rise then the piston will be at upper dead center.

Draw two lines across the back side of the flywheel (as shown in diagram on next page); next measure off 53 degrees on each side of the center line at the lower half of the flywheel. (Refer to diagram.)

Second—On the illustration above, note the pointter (A). This pointer points to the exact top center of the flywheel. The arrow on dead center line on the diagram on next page shows where pointer (A) points looking at the back side of the flywheel. Turn the motor over slowly until the arrow (A) points directly on line No. 3 as indicated in the diagram.

Third—Remove the idler gear (A-B-C). See that the push rod (J) is in its lowest possible position. Place a thin piece of paper between the push rod (J) and the valve stem (X). Turn the cam shaft gear slowly towards the right until the paper which is placed between the push rod (J) and the valve stem (X) is held tightly. Be sure that the valve stem (X) has not raised any. Also be sure that the cam shaft gear retains its position and that the piece of paper is still held tightly between the push rod and valve stem.

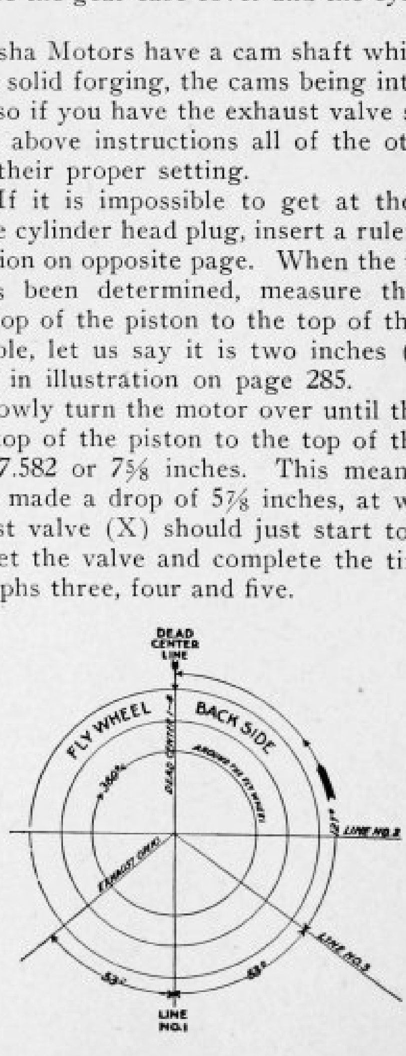
Fourth—Place a WOODEN wedge between the cam shaft gear and the case to keep this setting. This will give you the free use of both hands to replace the idler gear. Replace the idler gear.

Fifth—Give the motor a slight turn (say about one-half inch on the flywheel); now see if the exhaust valve (X) has raised any. It should if the above instructions have been carefully carried out. You can now replace the gear case cover and the cylinder head plug.

Waukesha Motors have a cam shaft which is made out of one solid forging, the cams being integral with the shaft, so if you have the exhaust valve set according to the above instructions all of the other valves will have their proper setting.

Note—If it is impossible to get at the flywheel, remove the cylinder head plug, insert a ruler as shown in illustration on opposite page. When the upper dead center has been determined, measure the distance from the top of the piston to the top of the cylinder. For example, let us say it is two inches (see arrow marked D in illustration on page 285.

Now slowly turn the motor over until the distance from the top of the piston to the top of the cylinder measures 7.582 or 7⅝ inches. This means that the piston has made a drop of 5⅞ inches, at which place the exhaust valve (X) should just start to open. In order to set the valve and complete the timing refer to paragraphs three, four and five.



This setting pertains only to Models **L**-LU4, **M**-MU4 and **P**-PU4.

For models **O**-OU4-OU4R, **S**-SU4-SU4R, **R**-RU4-RU4R, **N**-NU4-NU4R the piston should drop 4.843 or 4⅞ inches from upper dead center, that is the exhaust valve should open 50 degrees before the piston reaches the bottom dead center after the explosion has taken place.

For Models **T** and TU4, **B** and BU4 the piston should drop 4.644 or 4 11/16 inches from upper dead center; or the exhaust valve should open 45 degrees before the piston reaches the bottom dead center after the explosion has taken place.

In all events in resetting the valves, the magneto will have to be retimed.

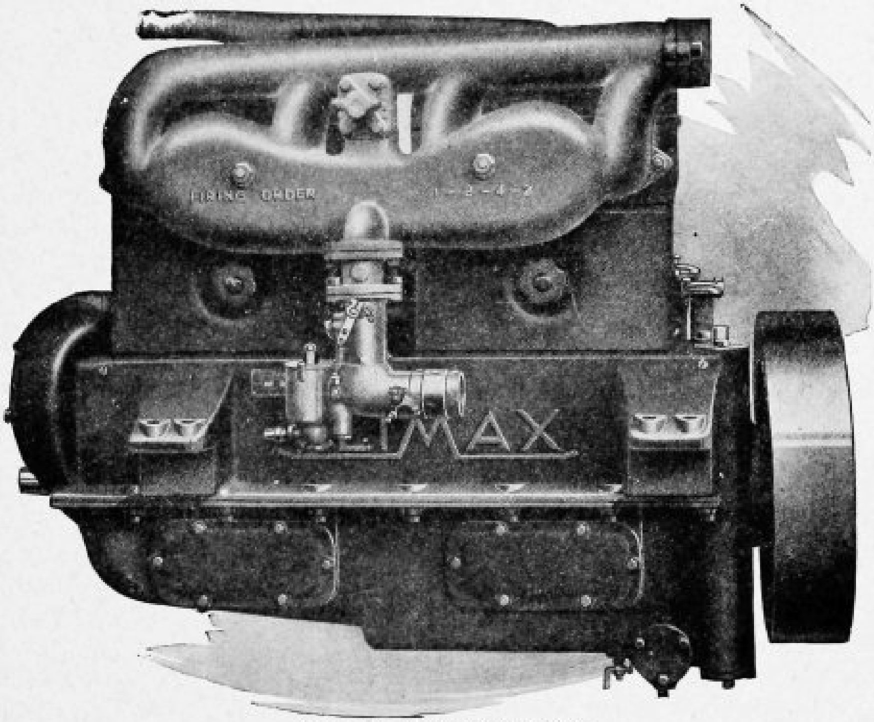
TECHNICAL DESCRIPTION OF MODELS K AND KU KEROSENE TRACTOR ENGINE

Type—Four cylinder, vertical "L" head type.
Size—Bore 5 inches, stroke 6½ inches.
Piston displacement—510.4 cubic inches.
Horse-power—Conservative rating 34 B. H. P. Maximum H. P 40
R. P. M.—800
Weight—Model K, 1110 lbs. Model KU, 1150 lbs.

DIMENSIONS

When two dimensions are given, the first is diameter.

Valve diameter	2½
Valve stem diameter	7/16
Piston pin bearing	1 23/64x2 7/16
Connecting rod bearing	2¼x3



Model K U Tractor Engine
(Carburetor Side)

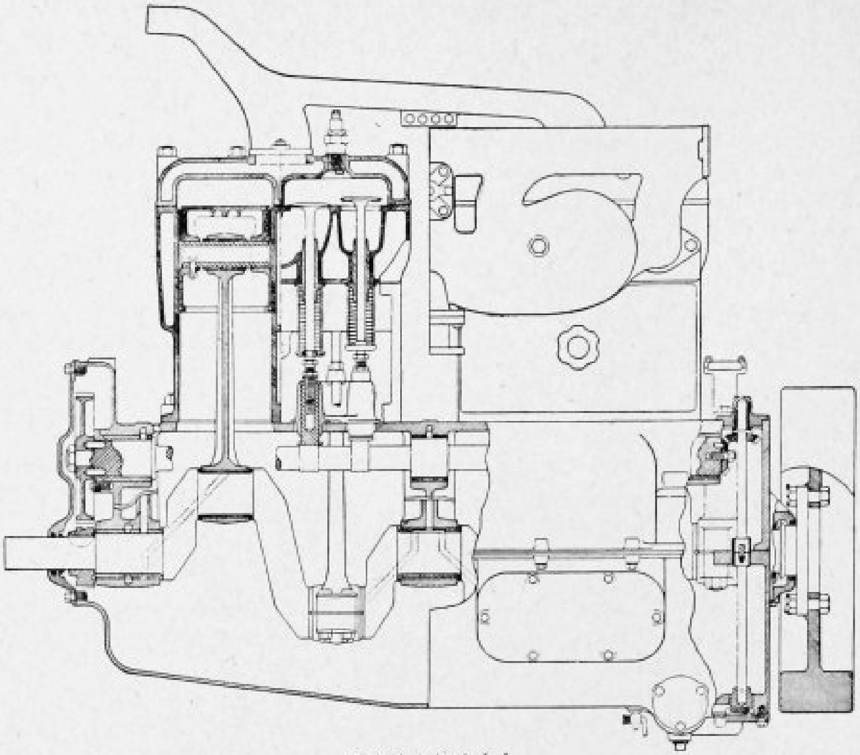
CLIMAX

MODEL KU TRACTOR ENGINE
Carburetor Side
Condensed Specifications

Bore	5 inches
Stroke	6½ inches
H. P. Rating	34 B. H. P.
Weight, Model K	1100 lbs.
Weight, Model KU	1150 lbs.

Cylinders in Pairs
Separate Heads
Large Water Jackets
Centrifugal Pump
Enclosed Governor
Dust Exclusion
Pressure Circulating
Lubrication System

Crank shaft bearing, front	2 3/16 x 3 3/4
Crank shaft bearing, center	2¼x3½
Crank shaft bearing, rear	2 5/16 x 4½
Camshaft diameter	1 5/16
Camshaft bearing, front	2x3 3/16
Camshaft bearing center	2⅛x2
Camshaft bearing, rear	2⅛x2
Flywheel diameter, Model K	17⅝
Flywheel diameter, Model KU	17
Piston length	5¾
Connecting rod length	13
Piston rings, number	3
Piston rings, width	¼
Water inlet diameter	1½
Water outlet diameter	1½
Exhaust, pipe size	2
Carburetor size	1½



CLIMAX
MODEL K TRACTOR ENGINE

Flywheel bolts diameter (6) 5/8

Cylinders. Cast in pairs, of semi-steel. Large water jackets, extending full length of piston travel, and entirely around exhaust passages and valve stem guides. Water passages to cylinder heads are large and well distributed. No steam pockets. Water jackets are accessisble for cleaning and provision is made for draining.

Cylinder Heads. These are separate from the cylinders, to which they are bolted by nine ½ inch studs in each casting. They are completely water jacketed to a depth of ¾ inch over the heads. The spark plugs are screwed into the cylinder head casting, not into valve caps. This permits thorough water cooling of the plugs. There are no sharp edges or points in the combustion chamber to heat and cause pre-ignition.

Crank Case. This is grey iron casting The greater rigidity and better ability to hold studs and threads makes this material superior to aluminum for tractor work. The crank case is divided on the centerline, the crank shaft bearings being in the upper half The bearings are well ribbed and the entire crank case is stiff and rigid and well able to withstand severe tractor service.

Crank Shaft. This is of the three bearing type, drop forged of .40 carbon open hearth steel, double heat treated. All bearings are ground to exact size. The crank webs are heavier than is the usual practice, thus strengthening them at their weakest point. The crank shaft is flanged to take the flywheel and is provided with rings to prevent oil leaking from the end bearings.

Connecting Rods. These are drop forged of .40 open hearth steel, heat treated. The connecting rod cap is attached with four 7/16 in. heat treated alloy steel bolts with castellated nuts.

Pistons. These are semi-steel castings, light and well ribbed. Three ¼-in. rings are used. The upper ring runs over the upper end of cylinder bore which is chamferred to aid in sliding pistons and rings into the cylinder. The piston is chamferred below the bottom ring and holes drilled through to prevent excess oil working up into the combustion chamber.

Piston Pins. These are hollow pins, carbonized, hardened and ground. They are secured in position by 5/16 in. cotter pins expanded inside the piston pins.

Bearings. Great care has been taken in selecting the best bearings for each purpose for which they are used. The piston pin bearing is Non-Gran bronze. For the crank pin a babbit lined bronze bearing is used, the babbit being the highest grade obtainable. The main crank shaft bearings are steel reinforced, die-cast babbit. For the oil pump shaft and the magneto shaft oilless bearings are used, doing away with the necessity for grease cups or hand oiling. The camshaft bearings are a good quality of bronze.

Camshaft. This is a low carbon drop forging, heat treated, carbonized and hardened. The cams and bearings are ground. The cams are 1-in. face by 1⅜-in. diameter.

Valve Timing. This is worked out to give exceptional power from 600 to 800 R. P. M., as it is at these speeds that the engine will operate under the most severe conditions. At the same time attention is given to the fuel economy which has proved to be remarkably low.

Camshaft Gears. The camshaft is driven through an idler gear. The crank shaft gear is a drop forging, the other gears semi-steel, all 1-in. face. The teeth are ten pitch and spiral cut. The crankshaft gear has a fit on the crank shaft of 1¾-in. diameter by 1 9/16 in. The idler gear is keyed to a shaft which runs in New Departure ball bearings. This construction is adopted to overcome the excessive wear usually found where an idler gear is used and which quickly results in noisy gears. The ball bearing construction does away entirely with any possibility of wear. The camshaft gear is doweled to a flange on the camshaft by two ⅜-in. dowels on a 1½-in. diameter circle. The gear for driving the pump shaft is taper fitted and keyed to the end of the shaft.

Valve Tappets. These are 1-in. diameter in the guide, of mushroom type, hardened and ground, and adjustable. The guides are cast in pairs and are removable with the tappets by removing one nut.

Valves. These are nickel steel, the lower end being hardened. The valve seat is 45 degrees. The valve spring is held by a pressed steel washer and slotted collar. The clear opening under the valve is 2¼-in. diameter and the lift 5/16 in.

Valve Stem Guides. These are removable and can be replaced should they wear.

Flywheel. The flywheel is bolted to the flange on the crank shaft with six ⅝-in. bolts.

Oil Pump. This is of the vane type driven by an enclosed vertical shaft at the rear of the engine. This shaft is driven by bevel gears from the camshaft. It is made in upper and lower sections so that the oil pan may be removed without breaking any connections.

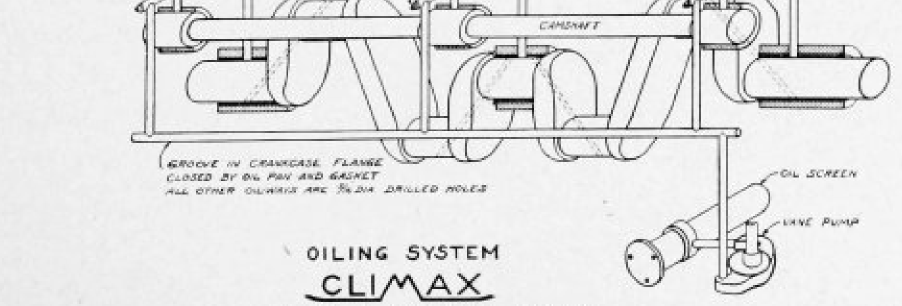
Oiling System. The entire oiling system is of the circulating force-feed type, all bearings being flooded with oil under pressure. The lower half of crank case is an oil reservoir with a capacity of three gallons of oil. From the lowest point, except for a dirt catching sump, the oil is drawn by the oil pump. It is drawn through a bronze screen, with an area of 40 square inches. This screen is easily removed for cleaning. The oil is circulated entirely through drilled passages, no piping being used. From the pump it is delivered through a vertical drilled passage to the main channel, running the entire length of the engine. From this channel, drilled holes feed the oil, under pressure, to all of the main bearings, crank pins and camshaft bearings. The excess of oil at the crank pins is thrown off as a spray, which lubricates the cylinder walls, piston pins, cams, etc. The excess of oil flows back to the oil pan where it is strained, cooled, and used again. From the highest point of the oil circulating system oil flows to the gear case on the front of the engine, thus lubricating the camshaft gears and their bearings. This system has all of the advantages of the splash system, but is without its disadvantages, particularly when kerosene is used as a fuel. Through poor adjustments, there is always a possibility of some kerosene finding its way into the base where it mixes with the lubricating oil, seriously affecting its lubricating qualities. Where the splash system is used the small amount in the troughs under the connecting rods is quickly diluted and the trouble commences. It necessarily takes a much greater amount of kerosene to have any material effect upon the large amount of oil carried in the oil reservoir.

Water Circulation. A centrifugal pump of ample capacity, gear driven, circulates the water through large free passages.

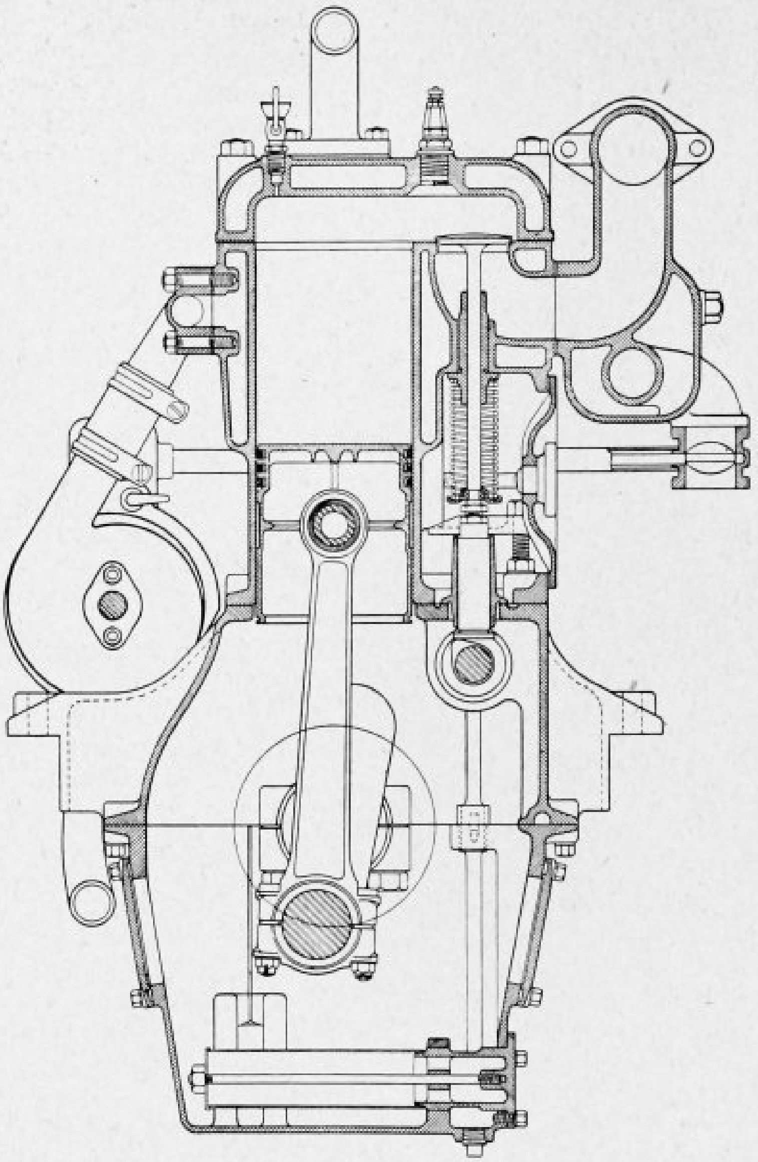
Governor. A governor of the centrifugal ball type controls a throttle valve in the intake passage independent of the carburetor throttle valve which is itself hand controlled. This governor is entirely enclosed to exclude dust and acts to prevent the engine racing if the load is suddenly thrown off.

Magneto. We recommend and will fit the Dixie magneto with impulse starter except in such instances as when the customer prefers to purchase his own equipment of this nature. The magneto together with centrifugal pump and governor are carried upon a bracket which is held by three bolts to the crank case so that it may easily be removed as a unit. The design includes the possible installation of a distributor system without changes.

Manifold. The intake and exhaust manifold is an



OILING SYSTEM
CLIMAX
MODEL K TRACTOR ENGINE



CLIMAX
MODEL K TRACTOR ENGINE

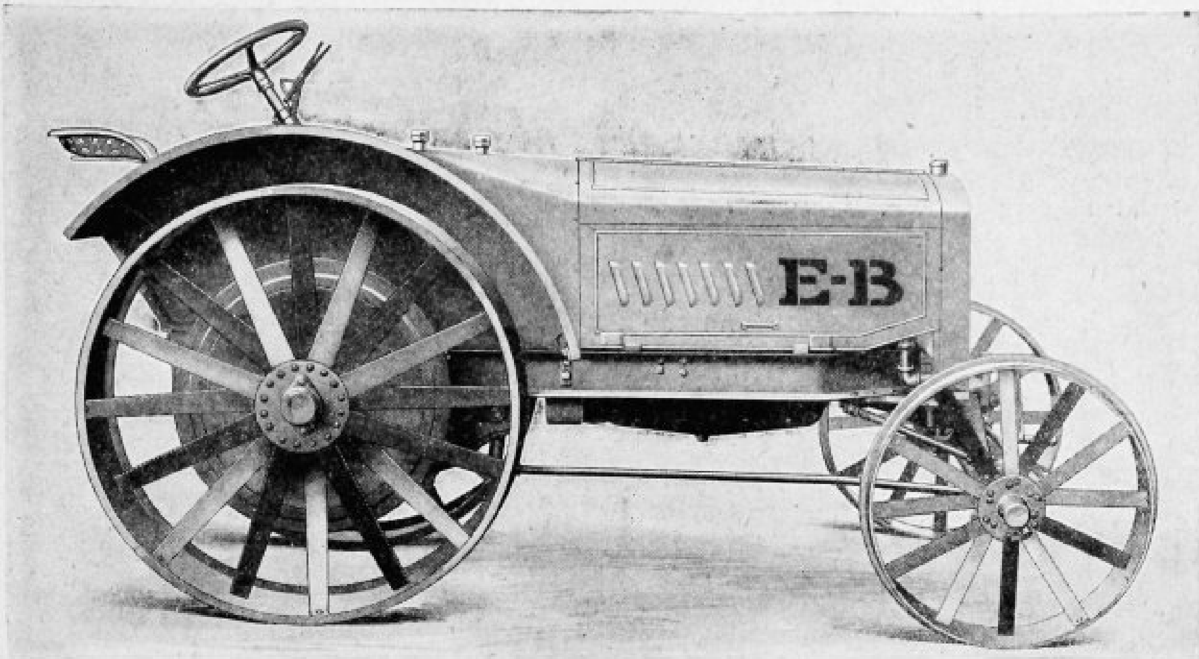
exclusive CLIMAX design and is worked out to give the best possible results when using kerosene as fuel. The kerosene become perfectly vaporized before entering the cylinders and the usual troubles attendant upon using kerosene are eliminated. Greater power and lower fuel consumption are obtained by this means.

Dust Exclusion. The protection of the working parts of the engine from the excessive amount of dust and dirt which it will encounter has been carried to an extreme. Every provision is made to keep dust out of the crank case, cylinders, and other parts. The breather on the crank case is of special design. While it relieves any pressure in the crank case, it at the same time, excludes all dust. Ample protection around the bearings is also provided. The valve mechanism is entirely covered by large plates which can be quickly removed without wrenches.

Hand Holes. The oil pan, or lower half of the crank case, is fitted with two large hand holes on each side which give easy access to the main and connecting rod bearings for inspection and adjustment. They also greatly facilitate thorough cleaning out of the oil pan when the oil supply is renewed. This is an important feature in tractor service as the oil must be changed at frequent intervals.

Oil Filler. An oil filler on one of the crank case arms is the means provided for filling the oil reservoir.

Oil Level Indicator. An indicator is provided to show the amount of oil in the oil reservoir at all times.



E-B 12-20 TRACTOR

A THREE-PLOW TRACTOR WITH POWER TO PULL FOUR PLOWS IN LOOSE SOIL

and with the endurance to keep it up 24 hours a day if necessary. It will give you the maximum power for the least money, it will pull a full 12-20 load **and still have plenty of power in reserve for an emergency.** The E-B 12-20 has been demonstrating this for two years; is doing it today; and will do it for you.

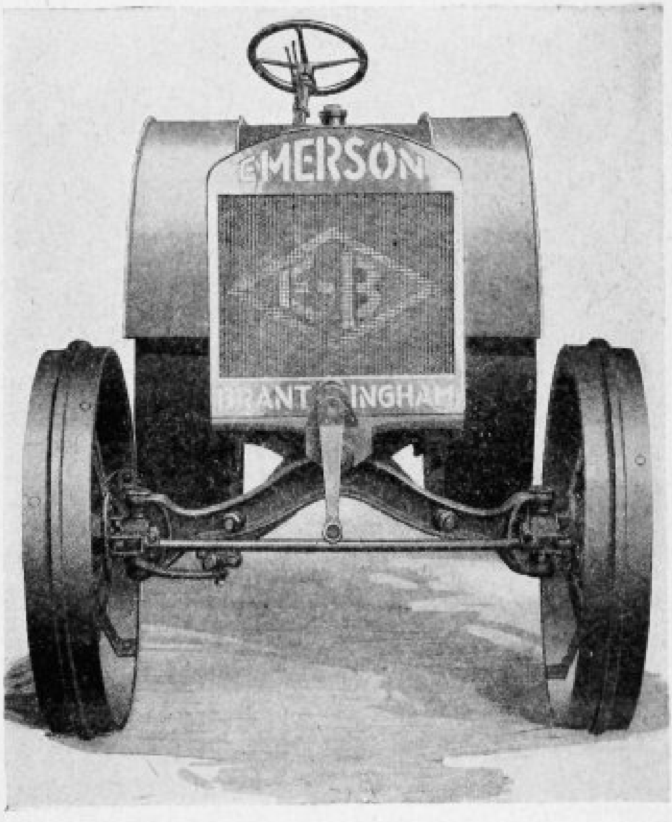
DOES BELT WORK EQUALLY AS WELL AS DRAW BAR WORK

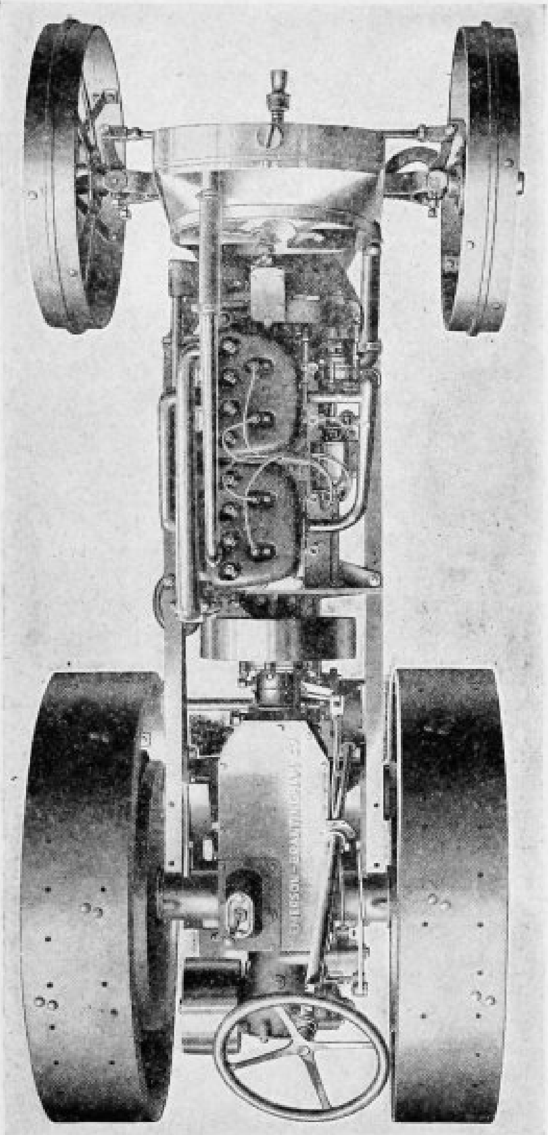
We wish you to note particularly the position of the belt pulley at the rear of the E-B 12-20 and parallel to the axle. This position has three big advantages. 1st, It makes it possible to hook up the machine being operated to the tractor draw bar and move it without taking off the belt. 2nd, It is easier to make a set. 3rd, When not in use it is entirely out of the way.

One E-B 12-20 the belt pulley shaft runs on Hyatt roller bearings so that friction is reduced to the minimum. By a simple operation it can be disconnected from the transmission so that it will not run when not needed for belt work.

SPECIFICATIONS

Drawbar H. P. 12
Belt H. P. 20
Motor—Bore—Stroke..........4¾ inches x 5 inches
Number of Cylinders.... ....4 Cylinders
Normal Speed R. P M.............................. 900
Lubrication System ....Splash with Pump
Ignition ....K. W. H. T. Magneto
Carburetor........Stromberg, Combination Manifold
Cooling System Type..........Radiator with Pump
Pulley Dia.—Face—R. P. M.....12 in.—6⅛ inch—900
Transmission Type.................Sliding Gear
Speeds Forward .... Two
Speed M. P. H......... ....Low 2.1—High 2.77
Wheels and arrangement..... 4 with 2 Rear Drivers
Dia.—Face of Drive Wheels........54-inch—12-inch
Dia.—Face of Front Wheels....... ..36-inch—6-inch
Frame Construction ....Built-Up





Wheelbase	87-inch
Total Width	55 inches
Total Length	132¾ inches
Turning Radius	12½ feet
Total Weight Less Fuel, Water, Oil and Lugs	4355 Pounds

Hyatt Heavy Duty Axle Bearings

Specially designed for heavy duty. Self cleaning and lubricating. Require no adjustment of attention.

E-B Auto Type Steering Wheel and Control

Exactly the same as an automobile. Customary spark and throttle levers. One foot pedal—combined clutch and brake.

E-B Ball and Socket Gear Shift

Similar to the high priced automobiles. Gears lock into place on each change. Easy and simple to operate.

Belt Pulley Near Control Devices

Geared directly to main drive shaft. Located at rear of tractor. Controlled by main clutch. Out of way when not in use.

E-B Enclosed Dust Proof Drive Gears

Housed in sheet steel casings. No dust or dirt can get at them. Permits gears to run in oil.

E-B Patented Transmission Saves Power

Rear axle and transmission—one unit. Compact construction—less weight. Less power required to move tractor.

Hyatts on All Drive Gear Shafts

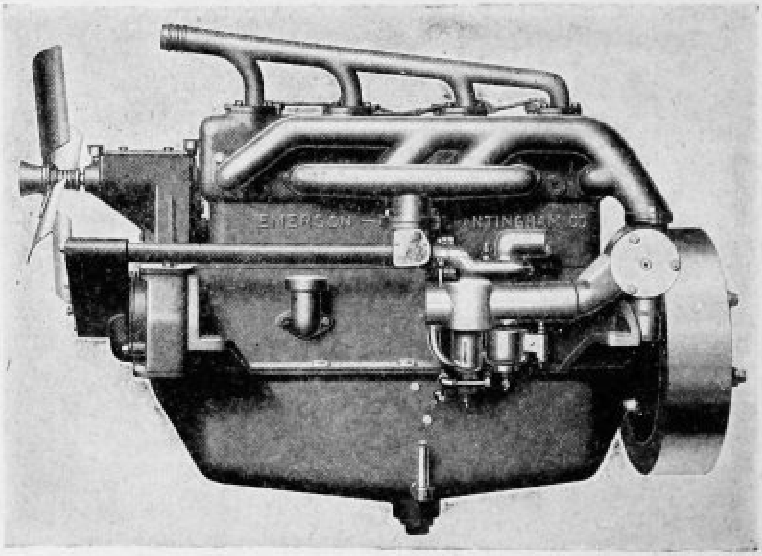
Keeps shafts and gears aligned. Protects shafts from shocks. Hyatts last longer than other types of bearings.

E-B Machine Cut Heat-Treated Transmission Gears

Made from E-B specification drop-forgings. Heat-treated to make teeth very hard and interior structure very tough. Machine cut and finished.

E-B Gears Run in Oil in Dust Tight Case

All the transmission gears and rear axle are housed



in the same oil tight, dust proof gear case. This gear case is a single rigid casting with a removable cover for inspection, so that it is absolutely impossible for any of the gears or the rear axle to get out of alignment, no matter what strain the tractor frame is subject to, as all the bearings are housed in the same casting. For ordinary purposes one oiling is sufficient for a season's run.

Stromberg Carburetor

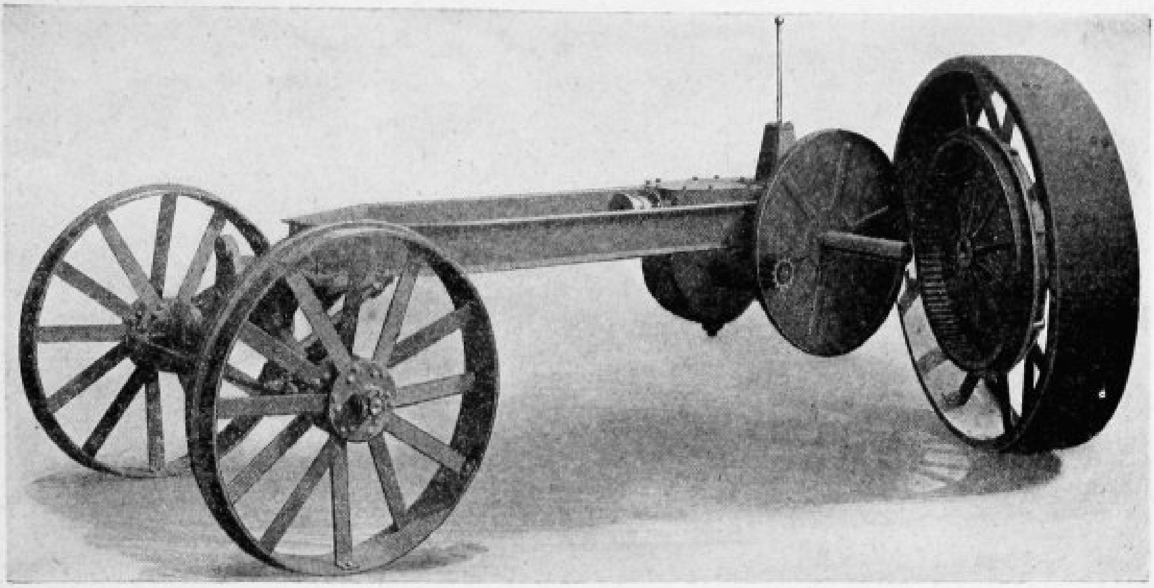
A real kerosene carburetor—vaporizes the kerosene. Cylinders get full concentrated charge.

Frame Provides for Short Turn

Two short channels of steel. Just long enough for mounting for motor. "U" shape permits turn of 12½ foot radius.

E-B Four Cylinder Motor

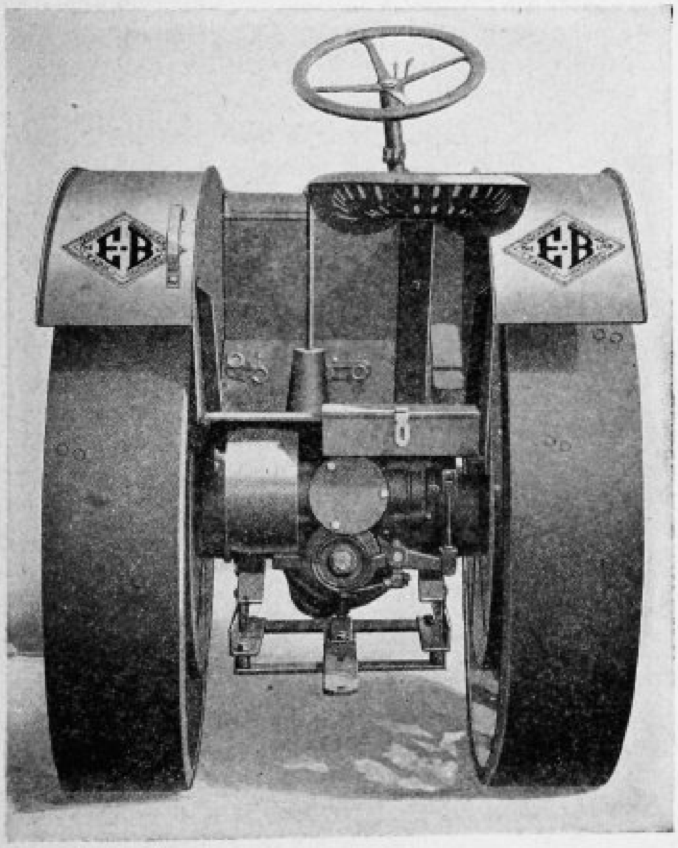
Designed to burn kerosene. A heavy duty, slow speed motor. Built for hard service. Rated at only 80 per cent of its power.



E-B Cast Steel Truck Type Axle
Front axle cast steel. Provided to front girt, allowing free movement over rough ground or obstacles.

E-B Enclosed Governor Running in Oil
Horizontal fly ball type. Controls motor speed at all times—motor cannot be raced. Located on inside of motor case—runs in oil bath.

E-B Gear Driven Fan
No belt to get loose or break. Provided with self operating clutch—no sudden change in speed can injure gears or fan.



High Grade Radiator
Large water capacity. Water circulated by gear driven centrifugal pump. Prevents motor overheating under all conditions.

K. W. Impulse Starting Magneto
Mounted on brass away from motor. Does away with batteries. Delivers hot spark at right instant. Makes starting easy.

THE AVERY TRACTORS

Built in six sizes of tractors, 8-16, 12-25, 14-28, 18-36, 25-50 and 40-80 H. P., all built alike, of the same standardized design, with low speed opposed "Draft-Horse" Motor and "Direct-Drive" Transmission.

AVERY 40-DRAWBAR, 80-BELT H. P. TRACTOR

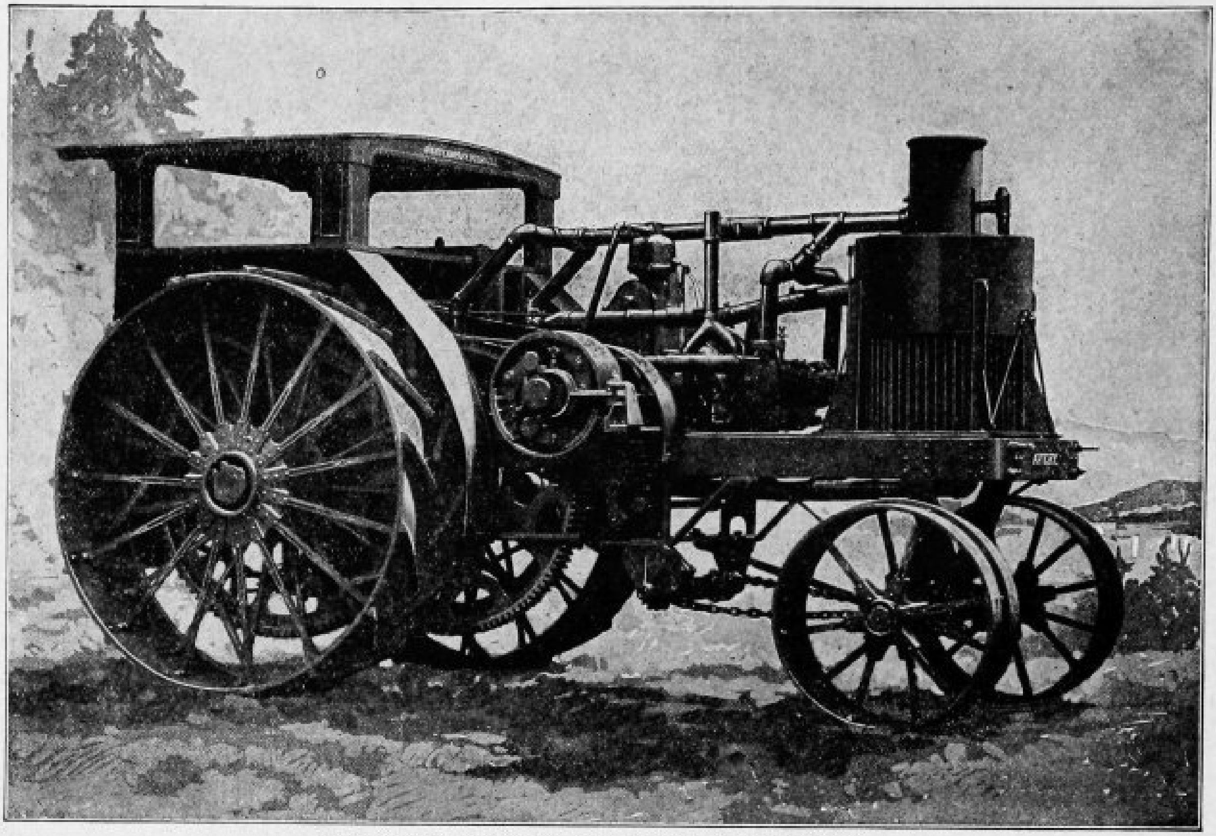
Four-Cylinder Opposed Motor

For pulling 8-10 moldboard plows, 18 disc plows—driving 32 x 54, 36 x 60-inch or larger threshers, and for other field, belt, hauling and road work.

SPECIFICATIONS:

Motor
Number of Cylinders 4
Bore of Cylinders, inches.......... 7¾
Stroke, inches 8
Revolutions per Minute, Minimum..........500
Maximum 600
Diameter of Crankshaft Bearings, inches..... 4½
Length of Crankshaft Bearings, inches......9 & 9
Diameter of Belt Pulley, inches.......... 26
Face of Belt Pulley, inches.......... 10
Fuel: Kerosene, Distillate, or Gasoline......
Capacity of Fuel Tank, two compartments, gallons ....5½ & 45

Gearing
Face of Crankshaft Pinion and Compensating Gear, inches 5



AVERY 40-DRAWBAR, 80-BELT H. P. TRACTOR

Face of Bull Gears and Pinions, inches	6
Miles per Hour, on low gear	1¾
Miles per Hour, on high gear	2 2/3
Wheels	
Front Wheels, diameter, inches	42
Front Wheels, face, inches	16
Rear Wheels, diameter, inches	87½
Rear Wheels, face, inches	24
Special Rear Wheel Extensions, inches	12
Shafting	
Rear Axle, diameter, inches	5
Front Axle, diameter, inches	3½
Countershaft, diameter, inches	4
No Intermediate Shaft used.	
Miscellaneous.	
Extreme Width, inches	111½
Extreme Length, inches	215
Extreme Height, inches	121
Shipping Weight, pounds	22,000

THE AVERY TRACTOR FUEL SYSTEM

Avery Tractors Turn Kerosene or Distillate Into Gas and Burn It All. The Patented Duplex Gasifier Does the Trick

The fuel system used on Avery Tractors from the 8-16 H. P. to the 40-80 H. P. size burns kerosene, distillate, or any other low-grade fuel more successfully than it has ever been done before.

Avery Tractors burn the kerosene that other so-called kerosene burning tractors waste They use less kerosene by gasifying all of it instead of part of it passing the pistons and being wasted on account of not being fully vaporized. With an Avery Tractor you can get as much power out of a gallon of kerosene as the old style so-called kerosene burning tractors get out of a gallon of gasoline.

Avery Tractors burn kerosene or distillate without the troubles previously experienced in burning these low-grade fuels, such as fouled spark plugs, pitted valves, carbon in the cylinder, pre-ignition, etc. They burn it so successfully that we are able to use a closed bottom crank case and gear pump oiling system which every one knows is much superior to the mechanical oilers which builders of so-called kerosene tractors are compelled to use to prevent the kerosene which passes their pistons and piston rings diluting the oil and causing the crankshaft and connecting rod bearings to be cut out. Avery Tractors also burn low-grade fuels so successfully because of the Patented Duplex Gasifier which is located on each cylinder head, that we are able to use an opposed perfectly balanced motor with a long manifold, while others are compelled to use unbalanced twin cylinder motors with short manifolds in order to use kerosene even as well as they do.

The secret of all these wonderful results is found in the Avery Fuel System, consisting of an air heater, fuel heater, double carburetor, patented duplex gasifiers, governor, cold air inlet water spray, and thermo-siphon cooling system. The combination of all these devices, which took years of experimenting to develop, makes Avery Tractors such that they do not merely **run on** kerosene, they burn **all** the kerosene, distillate, or other low-grade fuels.

The Avery Fuel System is also well built. There is not a drop of solder used in the construction of the fuel tank, nor a soldered joint in the fuel line. The fuel tank is welded and the fuel line is made of copper tubing with brass unions.

HOW AVERY TRACTORS BURN ALL THE KEROSENE OR DISTILLATE

First of all, the fuel pipe passes through the gasifier and the kerosene or distillate is heated on its way to the carburetor. This fuel heater is shown in the illustration of the gasifier at the right, and is marked "E." An air heater is also provided for heating the air as it is drawn to the carburetor whenever the weather conditions make it desirable. This air heater is equipped with a lid which can be raised or closed to let in or shut out the cold air, and when lowered the air is drawn in past the exhaust pipe and heated. The air heater is shown at the bottom of this page.

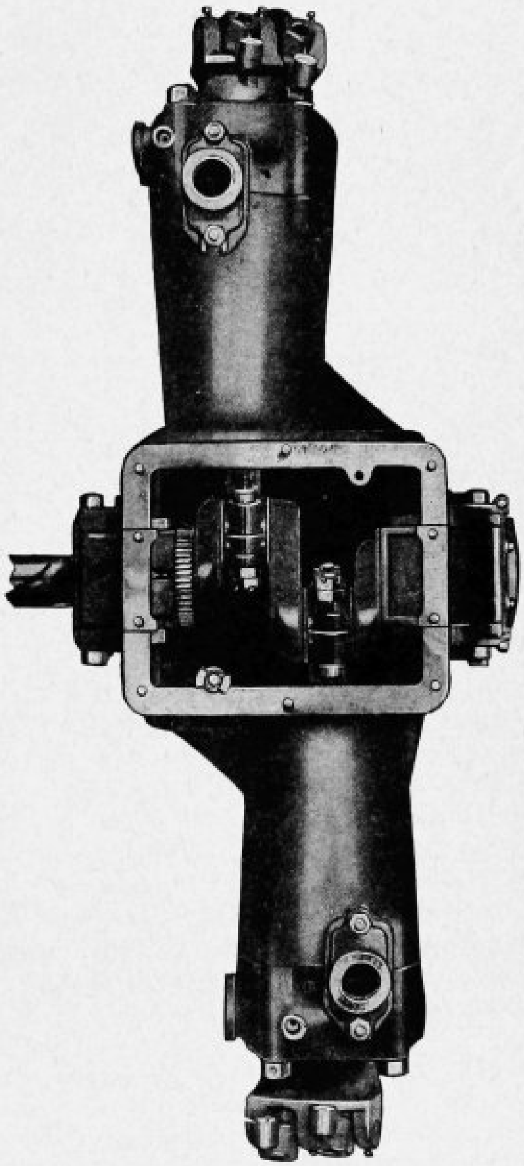
All Avery Tractors are equipped with double carburetors. One bowl is for gasoline and the other for kerosene or distillate. The motor is started on gasoline and when it warms up, you simply pull a lever and instantaneously switch over to the low-grade fuel without having to make a single adjustment of any kind. This double carburetor is one of the special features of the Avery fuel system, and is an Avery invention. See illustration at the right.

But while a carburetor will mix gasoline with air and form a gas which will explode readily in the cylinder, no carburetor has yet been designed which alone will successfully vaporize kerosene or distillate to such an extent that no fuel will be wasted. In the Avery fuel system we accordingly placed on each cylinder head our Patented Duplex Gasifier, which takes the mixture of kerosene and air as it comes from the carburetor and so reduces the particles of kerosene and mixes them with air as to form a vapor or gas that burns more successfully than kerosene or distillate has ever been burned before.

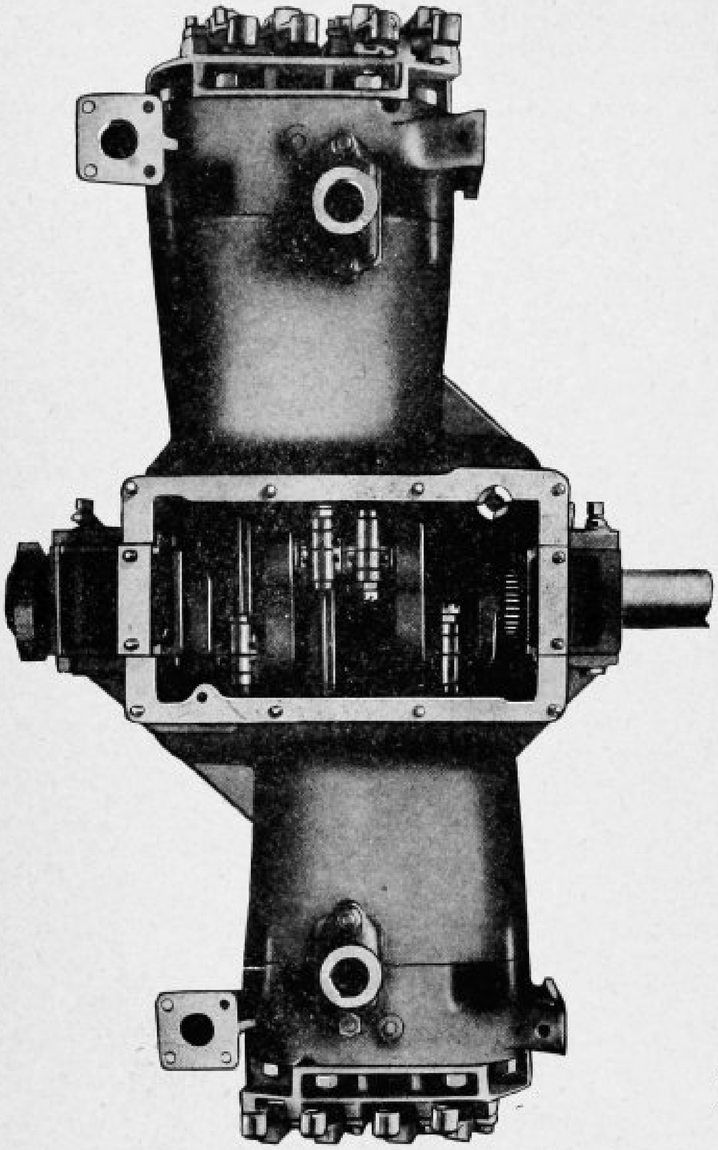
You will also see here an illustration of a cross section view of the Patented Avery Gasifier. A thin corrugated wall separates the exhaust and intake chambers, and is heated to a high degree by the exhaust. The fuel mixture received from the carburetor contains some unvaporized particles, as no carburetor will completely vaporize all of it. This mixture is drawn into the intake chamber of the gasifier, which is so shaped that, by centrifugal action, these heavier particles of fuel are dashed against the hot wall and are instantly vaporized or held in suspense until they are fully gasified when they are sucked into the cylinder. The Avery Gasifier works somewhat like a cream separator, it hrows the heavy particles of fuel to the outside as a cream separator throws cream out of the milk.

Any lack of thorough vaporizing on the part of the carburetor or any condensation in the manifold is thus taken care of by the Avery Gasifier, which is attached directly to each head of the motor and which thoroughly gasifies the mixture and delivers it immediately into the cylinder in a form that makes it possible for Avery Tractors to burn **all** the kerosene, distillate, or other low-grade fuels. The Avery Governor is also a very important part of the Avery Fuel System. By its use the quantity of fuel is regulated accurately to meet the varying conditions of traction or belt work.

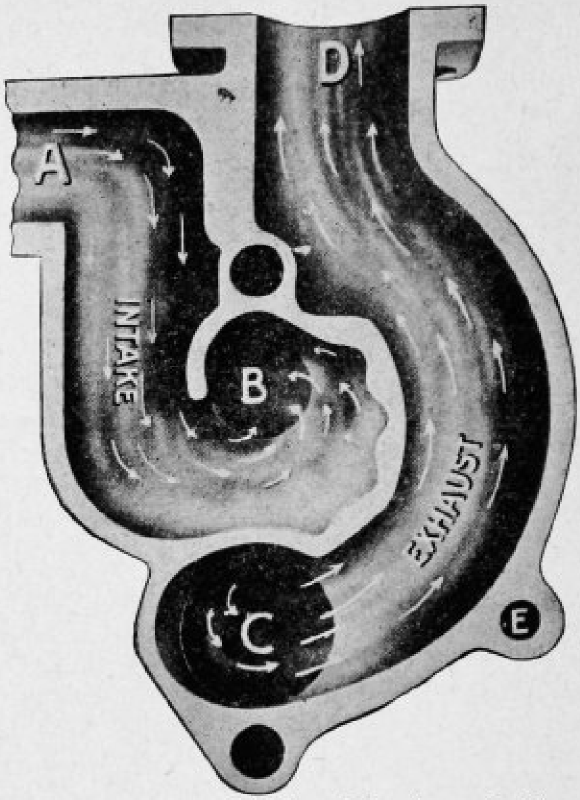
In buying a tractor remember this, that **running on** kerosene is one thing, and that **burning all** of it is an-



Top View of Two-Cylinder Avery Perfected Opposed Motor as Used in the Avery 8-16 and 12-25 H. P. Tractors.



Top View of Four-Cylinder Avery Perfected Opposed Motor as Used in the Avery 14-28, 18-36, 25-50 and 40-80 H. P. Tractors.



Cross Section of the Avery Gasifier—the Device that Does the Trick. Turns kerosene or distillate into gas and **burns it all.**

A—Fuel mixture coming from carburetor and entering gasifier.
B—Fuel mixture thoroughly gasified and entering cylinder.
C—Exhaust coming from cylinder.
D—Exhaust exit.
E—Fuel heater.

other. While it is a big step in advance from **burning** gasoline to **running on** kerosene it is even a much bigger step from **running on** kerosene (as most any tractor can do that for a little while) to **burning all** of the kerosene or distillate as do Avery Tractors.

Avery Tractors are the only make of tractors with a double carburetor and Duplex Gasifier Fuel System, and the only make of tractor that really burns **all** the kerosene, distillate, or other low-grade fuels.

THE AVERY TRACTOR COOLING SYSTEM

The cooling system used in Avery Tractors is the simplest and yet the most efficient type made. It is the thermo-siphon system in which the heat of the water causes its own circulation. No circulating water pump is used and thus all wearing and breaking of gears, packing of pumps, draining, and freezing and such other troubles as a water pump is sure to have are all done away with.

In the Avery Cooling System we have also eliminated the fan and the belts or chains required to run it. Instead, we use the exhaust of the motor to draw the cool air past the tubes. This saves all the power required to drive the fan and eliminates any breakage or other trouble with the fan, fan belts or chains. We also pipe the exhaust so that it does not blow on the driver at any time.

Probably one of the first things you will notice about an Avery Tractor is the distinctive appearance of the radiator. It is unlike that used on any other tractor. It is round and open on all sides, a feature which is very important when you consider that a tractor is used about half the time standing still doing belt work. And even when doing traction work a tractor travels but a few miles per hour so that its speed of travel does not aid in cooling the motor. In the Avery Tractor, no matter from what direction the wind is blowing, the air will strike the radiator, while with styles of radiators open only in front, the wind does not blow on the tubes unless it comes from just the right direction.

The Avery Radiator is made of copper tubes placed vertically. Not a drop of solder is used in its entire construction. Each tube is independent of the rest. It is put in by means of hollow steel plugs which are driven in either end of the tube, thus spreading them so that they cannot leak. If, however, you should chance to break a tube, all you have to do is to stop up the holes in each end until you can put in a new tube when your radiator is just as good as ever.

The illustration above of the Avery Cooling System shows everything in detail—the round tube radiator, open on all sides; the exhaust which is piped in such a way as to cause a vacuum and draw the cool air in past the vertical tubes; and the manner in which the water circulates.

THE AVERY TRACTOR OILING SYSTEM

One reason Avery Motors are long lived is because of the remarkable efficiency attained in lubricating the working parts by the Avery Oiling System. The Avery Tractor Motor is equipped with an internal gear pump oiling system. This system is very simple as well as efficient, has few parts, and the oil pipes are large. We do not use any troublesome mechanical oil pump such as is used on many tractors, which has a small pipe for each bearing and a pump for each pipe with holes so small that they clog up and cause a lot of trouble especially in cold weather. In the Avery Oiling System the oil flows instantly in cold weather as soon as the tractor starts. There is no pressure system to stop up. The oil flows through a ⅜-inch pipe so that there is practically no chance of the pipes clogging up. The Avery Oiling System works every day in the year, cold or hot, and works every minute. The oil flows the instant the motor is turned over until it stops.

The illustration here shows the Avery Oiling System in detail. The surplus oil is carried in the lower part of the crank case. It flows down through a strainer to the gear pump, which forces it up the pipe into the sight feed glass bottle. It then flows down through the pipes to the openings just above each crank, out of which it pours in a steady stream. This lubricates the crankshaft bearings, connecting rod bearings, etc., and is then thrown by the motion of the cranks into the cylinders and lubricates them.

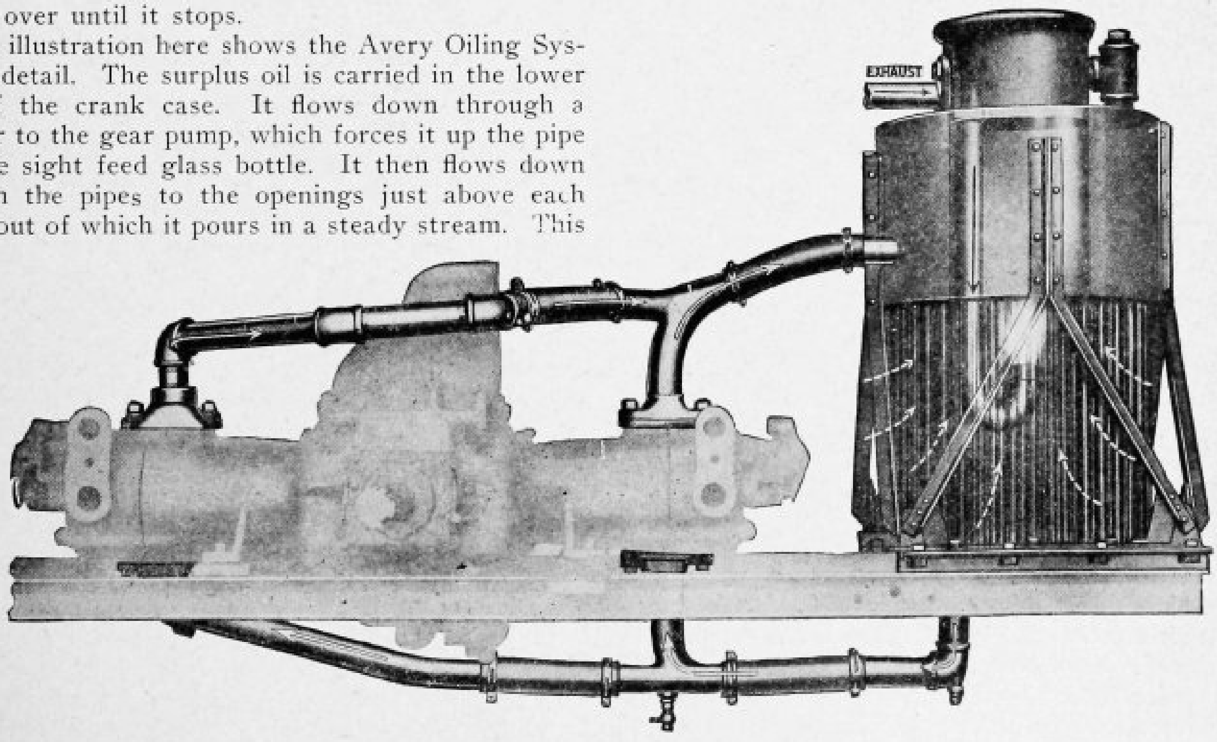
A cork gauge shows the operator the exact level of the oil in the crank case at all times and the glass sight feed enables him to be sure that there is always a constant flow of oil.

THE AVERY PATENTED SLIDING FRAME TRANSMISSION THE "DIRECT-DRIVE" TRANSMISSION

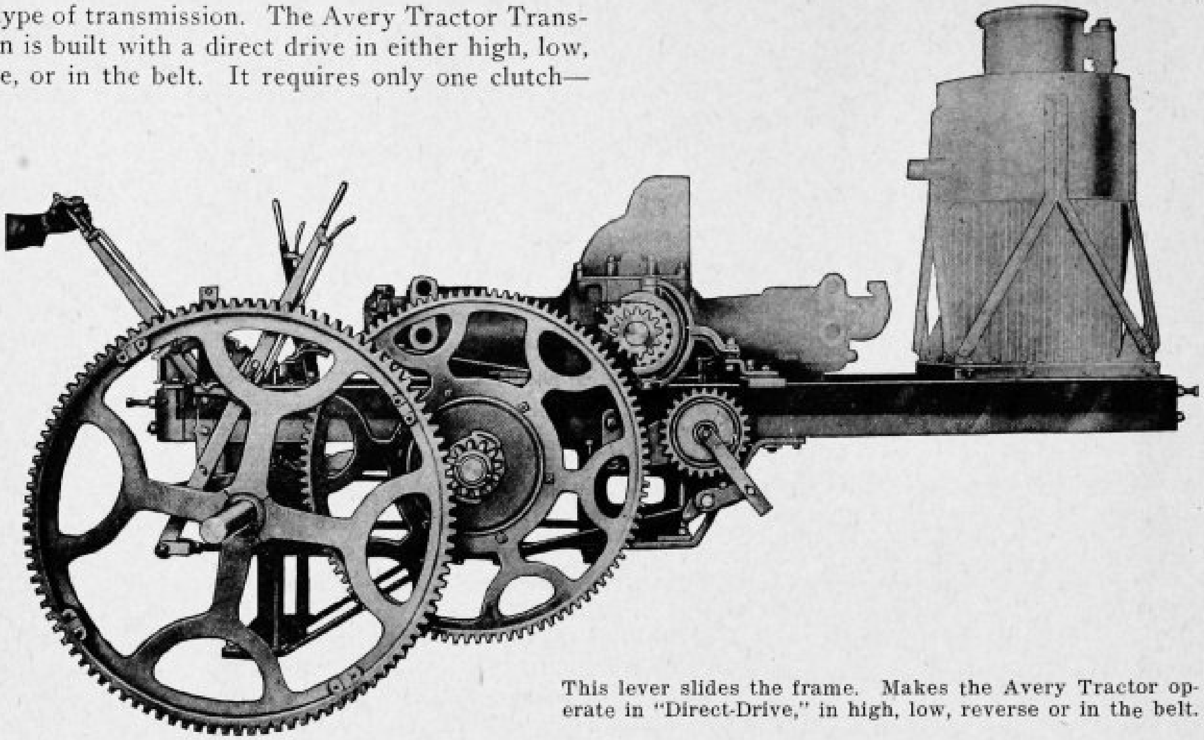
There are many different types of transmissions being experimented with by newer tractor companies, but manufacturing experience has shown that certain types of transmissions have always proved best for the conditions under which different kinds of machines operate.

On the bicycle, the bevel gear type was tried out and discarded for the chain type. On the automobile the chain type was tried out and discarded for the bevel gear. On the motor truck the chain was also tried out, but in most cases has been discarded for either the worm or internal gear. On the steam tractor, which is the machine most like the gas and oil tractor, chains, bevel gears, worm gears, and friction drives were tried out and all discarded in favor of the spur gear type which proved the most efficient. We accordingly adopted the spur gear type of transmission because of its many advantages, and then improved it as no other company has done.

The Avery Tractor Transmission is like a steam engine transmission that has been developed successfully through fifty years of test. We simply use an internal combustion motor in place of a boiler on the



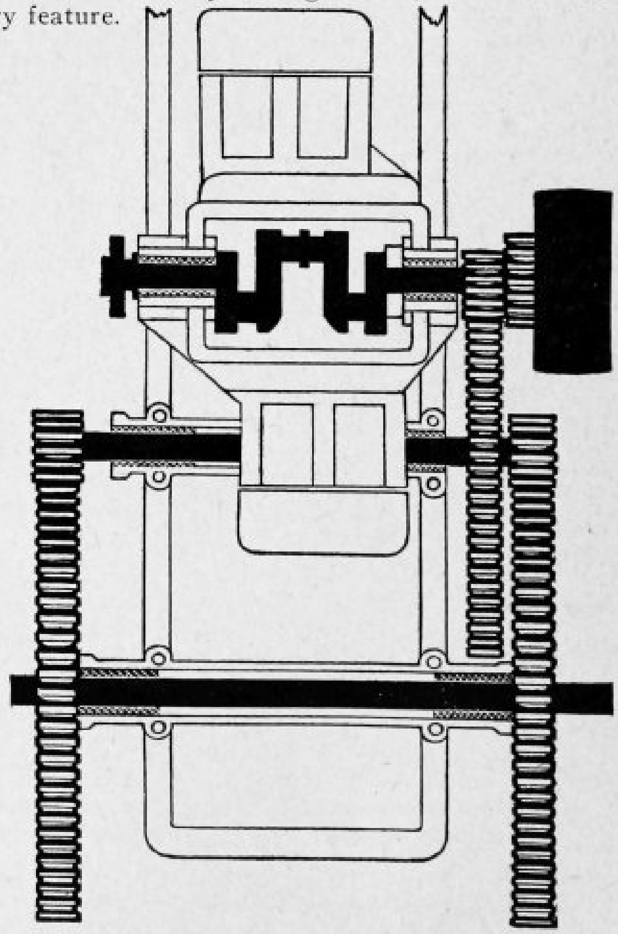
Cooling System—Solid White Arrows Show Water Circulation—Black Arrows Exhaust—Broken White Arrows Air Circulation—No Water Pump or Fan is Used same type of transmission. The Avery Tractor Transmission is built with a direct drive in either high, low, reverse, or in the belt. It requires only one clutch—only eight gears—only three shafts—and only three gear contacts between the motor and the drawbar. This Avery "Direct-Drive" Transmission is made possible because of the Patented Avery Sliding Frame. By the use of this sliding frame the high and low speed crank pinions both mesh directly into the compensating gear without using any intermediate gear. All intermediate gearing, shafting, and bearings are eliminated. This makes less gears, shafts, and bearings to wear out, and delivers more power to the drawbar because of less friction.

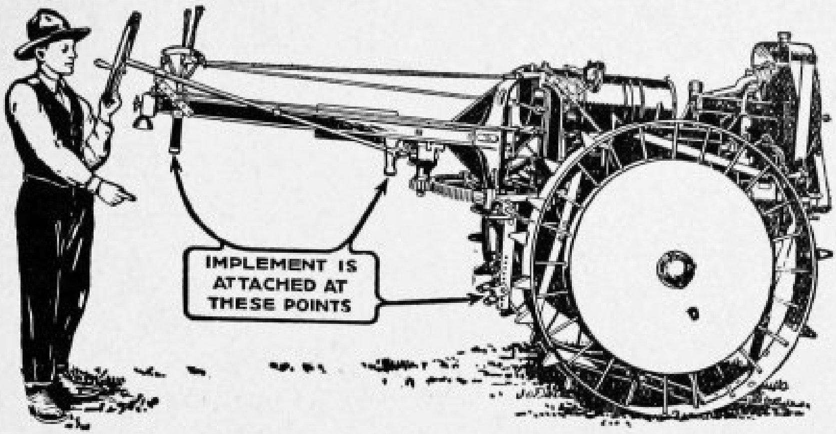


This lever slides the frame. Makes the Avery Tractor operate in "Direct-Drive," in high, low, reverse or in the belt.

We have designed the Avery Tractor Transmission in such a way that all the gears are open and located outside the frame where they are easily accessible, yet are well protected. Nothing can start to go wrong without your seeing it in time to overcome your troubles before you are broken down. All are made of steel and semi-steel, which means that they are able to stand up under the hard strains that tractor gears meet. The belt pulley is mounted directly on the end of the crankshaft. There are no bevel gears between it and the motor and no extra power of the motor is delivered directly to the belt. None is lost through extra bearings or by turning corners through bevel gears. Because the Avery "Draft-Horse" Motor runs at a low speed, we are also able to use a large belt pulley, which grips the belt better and insures better running of the machinery.

These features make the Avery Patented Sliding Frame "Direct-Drive" Transmission the simplest and most efficient tractor transmission system built. No other tractor has a combination of all these superior transmission features—direct drive from crankshaft to belt—direct drive from crankshaft through both high and low speed gears—all straight spur gears—and such a small number of gears, shafts, and gear contacts. The combination of all of these features which you get **only** in an Avery Tractor is made possible by the Patented Avery Sliding Frame, an exclusive Avery feature.





THE MOLINE-UNIVERSAL TRACTOR MODEL D

During the past three years we have been manufacturing Moline-Universal Tractors in large numbers and thousands of them are in use in all parts of the world, giving wonderful satisfaction. It has been demonstrated that the Moline-Universal two-wheel construction is the best for general farm use.

In type the Model D is the same as all former Moline-Universal Tractors, but is improved mechanically to give more speed, more power and thus more work. In brief these improvements consist of:

(1) Complete Remy electrical starting and lighting system.

(2) New electrical engine governor.

(3) Perfected overhead-valve, four-cylinder engine.

(4) Lubrication of engine under 35 pounds pressure.

(5) Special manifold construction to burn low grade gas.

(6) Crankshaft 2½ inches diameter, eliminating vibration.

(7) Complete enclosure of all parts, including final drive.

(8) Transmission gears drop forged, cut and hardened.

(9) Fifteen Hyatt roller bearings and five ball bearings.

(10) Liberal use of splines in transmission, adding strength.

(11) Differential lock doubles traction in soft ground.

(12) Pair of internal expanding brakes on differential shaft.

(13) Complete accessibility of all working parts.

(14) Large capacity through combination of light weight, power and speed which enables as much work to be done as with any ordinary three-plow outfit.

These are just a few of the improvements, all thoroughly tried and tested, but new to tractor construction, which from a mechanical point of view stamp the Moline-Universal Model D as the most advanced tractor.

And while you are studying this subject of tractors, bear in mind that no automobile, no matter how expensive, is made better than the Moline-Universal Model D. Every piece that goes into the Model D is inspected and re-inspected both for quality, workmanship and material. Drop forgings, heat-treated parts, steel cut gears and unusually large bearings add extra years of endurance to the Moline-Universal.

You get more value dollar for dollar in the Moline-Universal than any other tractor.

Judged from these standards—

(1) Ability to do all farm work,
(2) Increasing man's efforts,
(3) Economy of operation,
(4) Mechanical efficiency,
(5) Quality of construction,

You will find the Moline-Universal Model D supreme in the tractor field.

Clearance for Cultivating

Among the many things which the Moline-Universal Tractor will do is cultivating. It has ample clearance, 29½ inches, to straddle a corn row. This is more than enough, as the average cultivator has only from 29 to 30 inches arch clearance.

The Moline-Universal Tractor and the Moline-Universal Two-Row Cultivator form a unit much easier to handle than four horses and a two-row cultivator. The cultivator is so attached to the tractor that the operator sits in line with the outside of the right bull wheel of the tractor. This gives the operator a clear, unobstructed view of the rows ahead, which is essential to successful cultivation. The cultivator has many features which make its operation extremely easy and effective. All who have handled this outfit express surprise and delight at the ease and simplicity of operation.

No large amount of headland is required at the end of the field. The Remy electric governor allows the tractor to be slowed down to a "snail's pace" for turning at the end of rows. The tractor can also be stopped and backed very easily.

Until the Moline-Universal appeared it was generally believed that tractors would be limited in their uses because of the impossibility of using them to cultivate corn and other row crops. It was argued, and well to the point, that a farmer could not reduce the number of horses because he must keep the full number for properly cultivating his corn.

The greatest demand for farm power in the corn belt comes at the end of May or first of June. The corn is being cultivated and hay put up and in many cases harvesting is going on at that time. The average size farm does not have enough men or horses to carry on all operations simultaneously. As a matter of fact, every available horse and man is put to work in the corn field. Thus to be a success on the average farm, and really replace horses, the tractor must cultivate, as well as do other work. The Moline-Universal Tractor does this.

Best for Plowing

While the number of work hours demanded by cultivation will equal or exceed the number of hours required for plowing, plowing speed is the feature which governs the number of acres which can be put under cultivation. Thus with the Model D the increase in speed and power, maintained with light weight construction, gives a full capacity outfit in plowing, yet it can be used economically in the lighter field operations.

Under ordinary plowing conditions the Moline-Universal Model D will plow 9 acres in a 10-hour day. This is due to the speed of the Moline-Universal, which will pull two plow bottoms at 3½ miles per hour, and do as much in a day as the ordinary three plow tractor traveling 2¼ miles per hour. The Moline-Universal will plow efficiently at any speed from ½ to 3½ miles per hour. Thus the Moline-Universal has the advantages of a large capacity outfit and is still light enough for light work such as cultivating, mowing, etc.

Advantages of speed plowing consist of better contact of the furrow slice with the subsoil, eliminating air spaces and better pulverization through the force with which the furrow slice is deposited in the furrow.

Specifications of the Moline-Universal Tractor (Model D)

Engine—Four-cylinder, 4-cycle, perfected overhead-valve type with 3½-inch bore and 5-inch stroke. Removable head.

Valves—Large, chrome nickel steel valves, 1¾ in. in diameter, one-half diameter of cylinder bore. Double valve springs give unusually quick and quiet action. All mechanism completely enclosed and self-lubricating.

Crankshaft—Extra heavy drop forged high carbon steel, with large crank pin bearings, 2½ inches in diameter. No whip or spring at any speed. Note 2½-inch crank pin bearing with 3½-inch bore.

Connecting Rods—Drop forged, with extra large crank pin bearing, bronze backed nickel babitt, renewable. Piston pins tubular steel, hardened and ground.

Pistons—Special light weight. Gray iron, with three rings, lap jointed.

Camshaft—One-piece, drop forged, hardened and ground to exact size, with three bearings. Camshaft gears are helical for quiet running.

Lubrication—Force-feed. Oil forced by gear oil pump in constant stream through hollow crank-shaft to every crank pin and shaft bearing. Every moving part, including overhead-valve mechanism, is lubricated by an oil mist. This also lubricates all engine and belt drive gears. Every bearing floats on a film of oil under pressure.

Cooling—Thermo-syphon system with large water passages. Modine-Spirex radiator of large size. Cooling fan runs on Hyatt roller bearings. Belt equipped with easy take-up and covered.

Ignition—Special Remy ignition system with generator, distributor and Willard storage battery. Champion spark plugs.

Lighting—Electric search light, throwing powerful beam ahead, and electric light at rear of tractor over plows enables perfect work at night.

Governor—Remy electrical governor controls motor speed from control box within reach of the operator. By simply turning a dial, engine maintains any speed desired and quickly handles changes in load. All wires in armored conduits.

Storage Battery—Improved Willard six-volt of large capacity, spring mounted.

Self-Starter—Remy self-starter with Bendix drive. Operated by clutch lever from the seat.

Carburetor—Holley automatic.

Clutch—Borg & Beck, three-plate dry disc. Easy engagement and firm grip. Easy adjustment. Needs no lubrication.

Transmission—One gear ratio forward and one reverse. Cut and hardened nickel steel drive pinion slides on splined clutch shaft. Driving disc in clutch fits in splines in clutch shaft. Entire transmission mounted on Hyatt high duty roller bearings in rigid air-tight gray iron housing. Transmission runs in oil bath.

Bevel Pinions—Power is transmitted to differential shaft by bevel gears of hardened cut steel. Gears run on Hyatt high duty roller bearings and end thrust is taken on high duty ball thrust bearings, with adjustment collars. Bevel pinion integral with shaft. All shafts hardened and ground steel, running in oil bath. Clutch, transmission and differential shafts are splined.

Differential—Bevel type. Self-contained. Runs on two big Hyatt high duty roller bearings. Cut and hardened steel gears.

Differential Lock—On differential shaft, enclosed. Makes both wheels turn together. Controlled from seat. The differential lock is of great value in soft ground.

Brakes—Internal expanding differential brakes between bull pinion bearings and differential make tractor practically self-steering. Brake shoes Raybestos lined.

Final Drive—Bull gears of internal type operate within dust-proof housings. Bull pinions of cut and hardened steel on splined differential shafts. Lubricated by heavy grease through covered opening in housing.

Drive Wheels—52 inches diameter, 8-inch face. Each wheel mounted on two Hyatt roller bearings. Width to outside of drive wheels 54 inches; inside with 38 inches. Lugs or cleats furnished to meet all soil conditions. Extension rims 6 inches wide furnished as an extra.

Raising and Lowering Land Wheel—For plowing, one wheel in furrow and land wheel is raised to keep tractor level. Wheel is raised or lowered by one man with little effort without a jack.

Clearance—29½ inches, ample for cultivating.

Belt Work—A 9-inch belt pulley with 6½-inch face. Belt travels at standard tractor belt speed. Tractor develops full 18 horse-power on belt—ample power for ensilage cutters and small threshers.

Tractor Speed—From ½ to 3½ miles per hour. Will do as much in a day as the average three-plow outfit. Two plows at 3½ miles per hour will turn more soil than three plows at 2¼ miles an hour. Less slippage due to lighten draw bar pull. Moline plows are designed to operate perfectly at any speed of the tractor.

Weight—Approximately 3,380 pounds (from 1,500 to 2,000 pounds lighter than any tractor on the market with the same capacity).

Power—9 horse-power on draw bar, 18 horse-power on the belt. Pulls as much as six big horses.

Steering—Easily and accurately guided from seat of implement. Practically self-steering.

Control—All control levers within easy reach of operator, including self-starter. Control so arranged as to be accessible from seat of the implement.

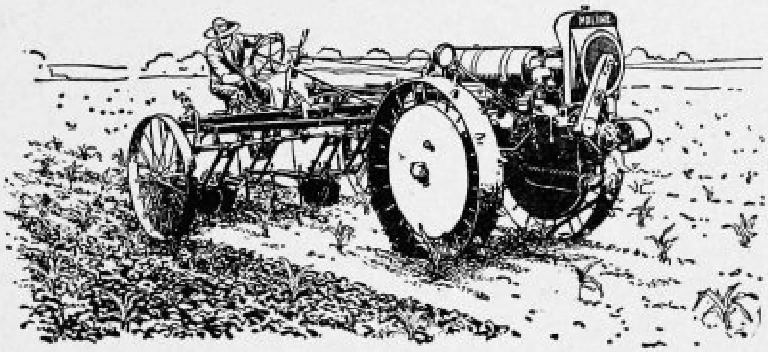
Air Cleaner—Bennett cleaner to remove dust from air.

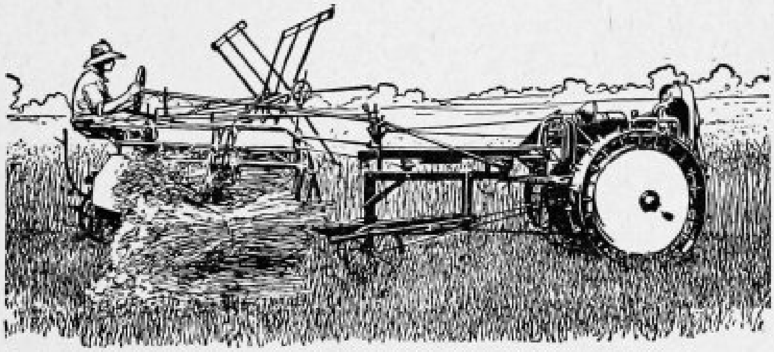
Gasoline Capacity—15 gallons.

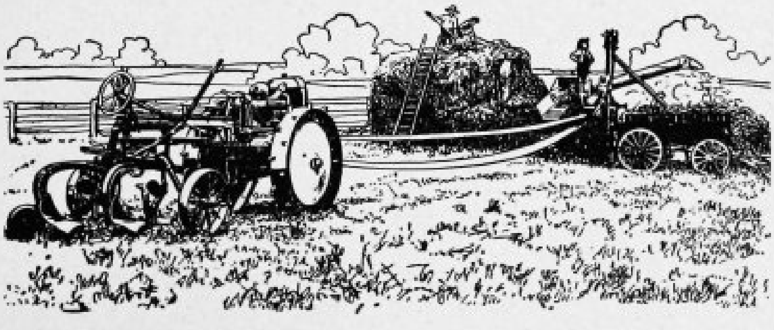
Tools—Tool roll with complete set of tools and oil can.

Standard Equipment—One 16-inch or 18-inch sulky, two-bottom 12-inch or 14-inch gang or two-disc gang, all specially designed for the Moline-Universal, with extra heavy construction, power lift, etc.

Extra Equipment—Rear carrying truck, attachments for disc harrow, grain drill, planter, lister, cultivator, mower, grain binder, corn binder, manure spreader, etc. Also a line of implements built specially for use with the Moline tractor. **Friction clutch belt pulley as an extra.**







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