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AUGUST, 1916
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Westinghouse Cross Compound Air Compressors

WESTINGHOUSE AIR BRAKE CO.
PITTSBURGH, PA.

PREFACE

The railroad employe should first determine the kind of air compressor information most essential to his particular needs.

For *enginemen*, the *first* essential is the ability to properly start, run, stop, and lubricate the compressor, and to quickly remedy such disorders as may develop on the road. It is of secondary importance that enginemen should know the internal workings of the compressor or be familiar with the movement of parts, and flow of air and steam in different chambers, ports, passages, etc. Of course, the more comprehensive the air brake education of the employe, the more valuable his service to his road. The section of this Instruction Pamphlet covered from pages 26 to 30 and pages 37 to 39 and portions of the text from pages 40 to 44 inclusive are, therefore, intended primarily for this class of employes.

For *repairmen*, or those employes who have to do primarily with the internal construction, operation and proper functioning of the moving parts of the compressor, the study of ports, passages, chambers, steam pressures, air pressures and the whys and wherefores of internal operation is of first importance. The matter covering description, etc., from pages 9 to 23 inclusive, and pages 37 to 39 and portions of the text from pages 40 to 44 inclusive, are, therefore, intended primarily for this class of railroad employes.

Round house air brake nen or those who test the compressor while on the engine to determine its condition, or *repairmen* who test the compressor to determine whether it should be returned to service after being overhauled and repaired, should be familiar with the Repair Shop and Road Tests of Steam Driven Air Compressors as specified on pages 30 to 37.

Air brake instructors, inspectors, road foremen of engines, and officials in charge of air brake operation and instruction generally should be familiar with our general recommendations as to the manipulation and specific instructions thereon as formulated and officially approved for a given road; should know the internal operation and functioning of the compressor; the maintenance of the compressor in service; and, in general, approved methods of organization and instruction for different classes of railroad employes in order to secure the largest possible practicable results for the railroad.

This instruction pamphlet has, therefore, been made sufficiently comprehensive throughout to meet all normal requirements of this class of officials. We feel very strongly that for those most concerned no effort is of greater practical benefit to the road served than that spent in the proper kind of air brake education and we are ready and willing, at all times, to assist in promoting these processes of education along practical lines in every way possible.

WESTINGHOUSE AIR BRAKE COMPANY,
Pittsburgh, Pa.

August, 1916.

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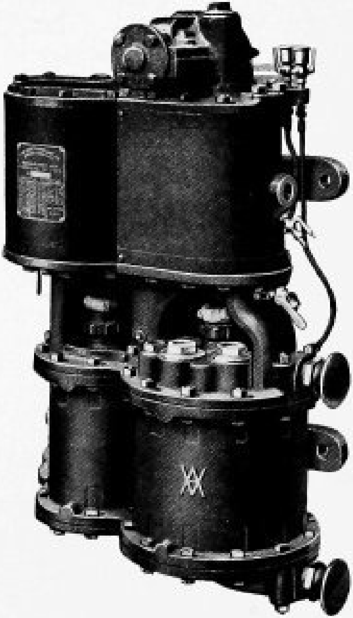

Fig. 1. 8½-Inch Cross Compound Compressor, Air Inlet Side

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8½-Inch Cross Compound Air Compressor

NOTE—The reference numbers shown herein are for convenience only and are not to be used when ordering repair parts. See Part Catalog giving piece numbers, prices, etc.

It is generally recognized that the duty imposed upon the locomotive air compressor has very largely increased from year to year, but the extent of this increase is more fully appreciated when the following factors are considered:—

(a) The development of locomotives of great weight and tractive power and in consequence longer trains of heavy, large capacity cars.

(b) The large cylinders and reservoirs required for the heavier cars, the longer brake pipe due to the longer trains hauled, and the greater number of flexible connections and fittings where leakage may

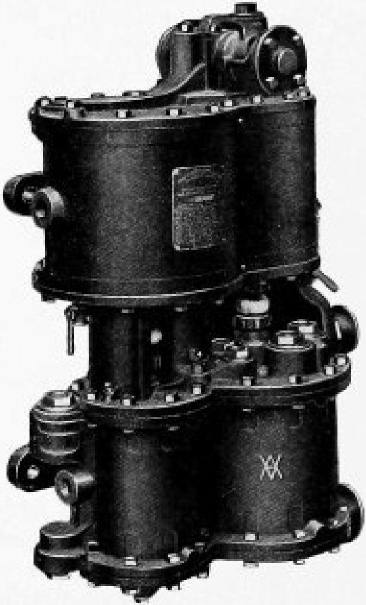


Fig. 2. 8½-Inch Cross Compound Compressor, Air Discharge Side

occur, combine to demand normally a larger volume of compressed air than ever before.

(c) The growing use of many *pneumatically* operated auxiliary appliances, such as water scoops, automatic ash pans, engine reversing appliances, Pullman water raising system, bell ringers, etc., which take their supply from the air compressor.

(d) The present practice on the part of most railroads of using practically all-air trains.

(e) The necessity of avoiding delays at terminals, where traffic tends to congest, by a prompt charging of long trains. Present day service conditions demand a compressor of ample capacity to secure maximum brake efficiency.

The great increase in compressor capacity called for in modern service has resulted in a much more careful consideration of the matter of steam consumption than formerly, and as a result the Westinghouse 8½-inch Cross Compound Compressor was developed for the specific purpose of combining maximum capacity and highest efficiency, by compounding both the steam supplied and the air compressed to the extent that, while this compressor has a capacity over three times greater than the well known 9½-inch single stage compressor, the steam consumption per 100 cubic feet of air compressed is but one-third.

The following table gives the principal dimensions, displacement, weight, etc., of the 8½-inch compressor.

GENERAL DIMENSIONS, DISPLACEMENT AND WEIGHT OF THE 8½-INCH CROSS COMPOUND COMPRESSOR.

Diameter of High Pressure Steam Cylinder	8½ in.
Diameter of Low Pressure Steam Cylinder	14½ in.
Diameter of High Pressure Air Cylinder	9 in.
Diameter of Low Pressure Air Cylinder	14½ in.
Length of Stroke	12 in.
Governor	1¼ in.
Diameter of Steam Admission Pipe	1¼ in.
Diameter of Steam Exhaust Pipe	1½ in.
*Diameter of Air Admission Pipe	2 in.
Diameter of Air Delivery Pipe	1½ in.
Designed for Steam Pressure of	200 lbs.
Working against an Air Pressure of	140 lbs.
Normal Speed, single strokes per minute, under above conditions	131
Displacement, cubic feet per minute, under above conditions	150
Overall Dimensions: Height	52 in.
(Approximate) Width	37 in.
Depth	18¾ in.
Average Net Weight	1500 lbs.
Weight, boxed for shipment	1750 lbs.
Lift of Air Valves	3/32 in.

SIZE OF GOVERNOR, STEAM VALVE AND PIPING FOR TWO COMPRESSOR INSTALLATION.

Governor	1½ in.
Steam Valve	1½ in.
Steam Admission Pipe	
Main Pipe	1½ in.
Branch Pipe	1¼ in.
Steam Exhaust Pipe	
Main Pipe	2½ in.
Branch Pipe	1½ in.
Air Admission Pipe	
Main Pipe	2½ in.
Branch Pipe	2 in.
Air Delivery Pipe	
Main Pipe	2 in.
Branch Pipe	1½ in.

*NOTE—If desired, the air inlet may be arranged as shown by the dotted lines in Fig. 21, the main inlet pipe being 2½ inches in diameter and the branch pipes 2 inches in diameter.

DESCRIPTION

As in the case of the Standard Westinghouse Single Stage Compressors, the steam cylinders are placed vertically above the air cylinders and connected by a common center piece, see exterior views, Figs. 1 and 2.

The diagrammatic views, Figs. 19 and 20, serve to illustrate the *simplicity* of this design and emphasize the fact that the cross compound compressor is a serial arrangement of two standard single stage compressors, actuated by the same controlling mechanism, and with pistons moving uniformly in opposite directions. These cuts also show the few moving parts employed, which comprise (*a*), the high pressure steam low pressure air pistons, connected by a Vanadium steel piston rod drilled for the reversing valve rod which operates the reversing valve, and which in turn moves the main piston valve controlling the admission of steam to and the exhaust from both the high and low pressure steam cylinders and, (*b*), the low pressure steam and high pressure air pistons connected by a solid Vanadium steel piston rod having no mechanical connection with the valve gear.

Figs. 6, 7, 17 and 18 are sectional views showing the ports and passages, also numbered parts which are referred to as follows: 2, top head; 3, steam cylinders; 5, air cylinders; 4, center piece forming the connection between 3 and 5; 6, lower head; 7, high pressure steam piston, $8\frac{1}{2}$-inches in diameter, and its rod; 8, low pressure steam piston, $14\frac{1}{2}$-inches in diameter; 9, low pressure air piston, $14\frac{1}{2}$-inches in diameter; 10, the high pressure air piston 9-inches in diameter (the maximum stroke of each pair of pistons is 12 inches); 11, high pressure steam piston ring; 12, low pressure steam piston ring; 13, low pressure air piston ring; 14, high pressure air piston ring; 15, piston rod nut; 16, piston rod jam nut; 17, piston rod cotter; 18, reversing valve plate; 19, reversing valve plate bolt; 21, reversing valve rod; 22, reversing valve; 23, reversing valve chamber bush; 24, reversing valve chamber cap; 25, piston valve, complete; 27, large piston valve ring; 28, exhaust piston valve ring; 29, small piston valve ring; 30, piston valve bolt, complete; 31, piston valve bolt nut; 33, large piston valve cylinder head; 34, large piston valve cylinder head cap screw; 35, small piston valve cylinder head; 36, small piston valve cylinder head cap screw; 37, upper inlet valve; 38, lower inlet valve; 39, upper intermediate valve; 40, lower intermediate valve; 41, upper discharge valve; 42, lower discharge valve; 43, upper inlet valve seat; 44, upper inlet valve chamber cap; 45, lower inlet valve cage; 46, upper intermediate valve seat; 47, upper intermediate valve cap; 48, lower intermediate valve cage; 49, upper discharge valve cap; 50, lower discharge valve cage; 53, stuffing box; 54, stuffing box nut; 55, stuffing box gland; 56, air cylinder lubricator; 57, upper steam cylinder gasket; 58, lower steam cylinder gasket; 59, upper air cylinder gasket; 60, lower air cylinder gasket; 61, small piston valve cylinder head gasket; 62, large piston valve cylinder head gasket; 63, $\frac{1}{4}$-inch drain cock; 64, $\frac{1}{2}$-inch drain cock; 65, air strainer; 67, lower head plug; 68, piston rod swab; 69, tee head bolt and nut; 71, tee head bolt and nut; 72, tee head bolt and nut; 73, tee head bolt and nut; 74, tee head bolt and nut; 75, tee head bolt and nut; 76, guard plate for upper intermediate valves; 77, lagging; 78, jacket; 79, jacket band; 86, piston rod packing; 87, reversing valve rod bush; 89, upper discharge valve seat; 91, jacket band screw; 92, tee head bolt and nut; 93, tee head bolt and nut; 94, tee head bolt and nut; 99, lubricator bracket; 100, union stud; 101, union nut; 102, union

Fig. 3. Special "Fifty-Four" Air Strainer

swivel; 103, oil pipe to low pressure air cylinder; 104, oil pipe to high pressure air cylinder; 106, piston valve bush; 107, large piston bush; 117, large piston portion; 118, exhaust piston portion; 119, small piston portion; 120, small piston valve cylinder cover bush; 123, cotter.

When a suction strainer of greater capacity and efficiency than that regularly included with the compressor is desired, the Special "Fifty-Four" Air Strainer (so-called because of its large suction area, viz., 54 square inches), Fig. 3, is used. As will be seen from Figs. 4 and 5, this is a very large double cylindrical strainer (overall dimensions approximately 10" x 14") with an inner strainer of perforated sheet steel, galvanized, and an outer strainer of coarse galvanized wire mesh, the intervening space being well packed with curled hair. A

Fig. 4. Disassembled View Special "Fifty-Four" Air Strainer

galvanized iron shell 3 encircles the strainer proper, preventing dirt, oil and water from striking directly against the strainer and thereby reducing the possibility of trouble from clogging. The presence of curled hair insures more efficient elimination of dust and dirt from the air than is possible with the ordinary form of strainer. The strainer may be quickly and conveniently taken apart without disturbing any pipe connections by removing the nuts from the four studs. This strainer should be installed vertically with the large opening downward and bolted under the running board at some protected point so as to draw reasonably clean air.

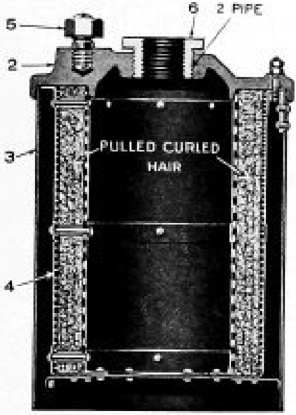


Fig. 5. Sectional View Special "Fifty-Four" Air Strainer

The drain cock 63 is intended to draw off any condensation in the steam passage *a* and should always be opened when the compressor is first started. The drain cock 64 connected to the low pressure steam cylinder is for the same purpose and should also be opened for a short time before the compressor is started so that any condensation of steam in the cylinder may be removed.

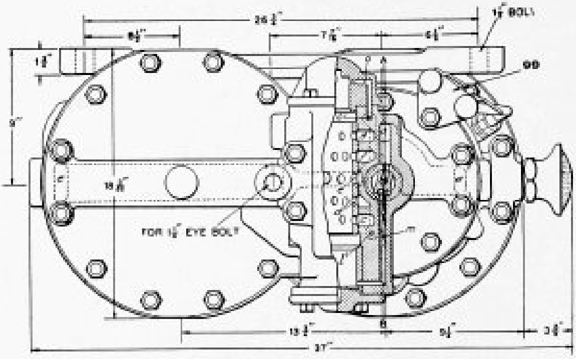


Fig. 6. Horizontal Section of Reversing Valve Chamber

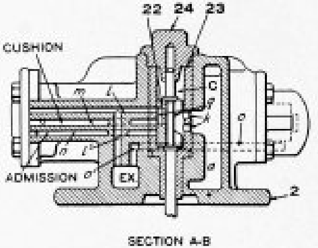


Fig. 7. Vertical Section of Reversing Valve Chamber

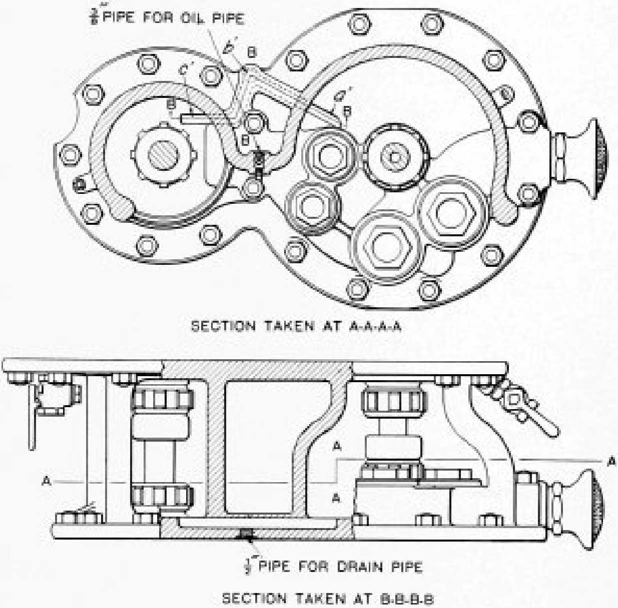


Fig. 8. Partial Sectional Views of Center Piece, showing Drainage

Fig. 8 shows partial sectional views of the center piece of the compressor, illustrating the provision made for draining off from the center piece the water which drips from the stuffing boxes. The water which thus accumulates is drained through passages *a'* and *c'* to *b'* and thence through the drain pipe connection on the lower flange to some convenient point, as between the engine frame.

The Governor is located in the piping to the steam inlet, Fig. 18. Steam entering passes through port *a* to the top head, and thence through ports *a* and *k*, Fig. 7, to the reversing valve chamber C and main valve chamber, Fig. 18; *e* is the exhaust passage leading to the steam exhaust pipe. As it is difficult to follow the ports in these cuts, we have prepared two diagrams, as shown in Figs. 19 and 20, in which the piston valve and reversing valve are turned 90 degrees horizontally from their actual position in order to make the operation more easily understood, and all ports and passages are connected in the simplest possible manner, without regard to the actual construction of the compressor.

Referring to Fig. 19, passage *a*, communicating with cavity C and the two chambers *b*, conveys the steam from the source of supply to the operating valves, of which there are two, namely: the reversing valve and the piston valve. The piston valve is a multiple piston device, consisting of a large piston at one end, a small piston at the other, with three intermediate pistons of uniform size, which will be referred to hereinafter as numbers 1, 2 and 3, numbering from the small piston end of the piston valve.

It is evident, that with five pistons mounted on a common rod and working in a cylinder, we have, including the ends, six separate chambers. In this particular construction, five of these chambers have permanent connections as follows:

The first chamber, *E*, behind the outer end of the small piston, to the atmosphere.

The second chamber, *b*, between the small and No. 1 intermediate piston, to passage *a*.

The third chamber, *i*, between the No. 1 and No. 2 intermediate pistons, to the lower end of the low pressure steam cylinder.

The fourth chamber, *k*, between the No. 2 and No. 3 intermediate pistons, to the upper end of the low pressure steam cylinder.

The fifth chamber, *y*, between the third intermediate and the inner side of large piston to passage *a*.

The reversing valve 22, moving vertically on its seat in chamber *C*, controls the admission and exhaust of steam from the cavity *D*, behind the outer end of the large piston of the piston valve, causing it to operate horizontally, the intermediate pistons moving as follows:

Intermediate piston No. 3 crosses a port connecting passage *c* controlling the flow of steam to the upper end of the high pressure steam cylinder, and also the exhaust into the upper end of the low pressure steam cylinder.

Intermediate piston No. 2 crosses a port connecting with passage *e*, controlling the exhaust of steam from either end of the low pressure steam cylinder.

Intermediate piston No. 1 crosses a port connecting with passage *g*, causing steam to be admitted to the lower end of the high pressure steam cylinder or exhausting the same from this cylinder into the lower end of the low pressure steam cylinder. A passage, *z*, leading from the upper end of the high pressure steam cylinder is the means of supplying pressure to balance the reversing valve rod.

OPERATION

When the high pressure steam piston has nearly completed its up stroke the reversing valve plate 18, comes in contact with the shoulder on the reversing rod, forcing said rod 21, to its uppermost position, carrying with it reversing valve 22, the movement of which, in turn, not only blanks port to passage *m*, thereby cutting off means of exhausting steam from cavity behind the large end of piston valve, but also opens port to passage *n*, filling this chamber, D, with live steam from passage *a*. The pressure thus exerted on the outer side of the large piston added to the pressure on the inner side of the small piston is now greater than the pressure exerted against the inner side of the large piston, and the piston valve moves toward the left, or in the direction of chamber *E*. The small piston valve cylinder head 35 is provided with a bush having six elongated grooves, three of which are shown in Fig. 17. (All of these grooves have been considered for the sake of simplicity as combined into one groove, Figs. 19 and 20.) As the piston valve moves toward the left and uncovers these grooves, live steam from chamber *b* by-passes to chamber *E* back of the small end of the main valve piston. At the instant these grooves are cut off by the further movement of the piston, port *o* leading to the exhaust is also blanked which enables the small piston to compress the steam in chamber *E*, thus providing a high cushioning pressure. This movement of the main valve piston admits steam to the upper end of the high pressure steam cylinder, starting the high pressure steam piston on its downward stroke. All parts have now assumed the position shown in Fig. 19.

A direct communication is now established whereby live steam is supplied through passage *a*, chamber *y*, and passage *c* to the upper end of the high pressure steam cylinder, forcing downward the high pressure steam piston and low pressure air piston to which it is rigidly connected by the piston rod, that is free to move in the necessary stuffing boxes. The movement of the piston valve to the left, as described above, has opened passage *g* to passage *f* through cavity *i*, thus permitting the steam in the lower end of the high pressure steam cylinder to expand into the lower end of the low pressure steam cylinder. The latter being of materially larger volume than the former, it vill be seen that the steam is thereby made to do its work expansively in the low pressure steam cylinder. At the same time—

(*a*) the low pressure air piston, 9, is compressing air in the lower end of the low pressure air cylinder and forcing same through the intermediate valves 40, and passage *u* into the lower end of the high pressure air cylinder, and—

(*b*) air at atmospheric pressure is being drawn into the upper end of the low pressure cylinder, through the upper air strainer and inlet valve 37.

It will be observed that the steam exhausted into the lower end of the low pressure steam cylinder and the low pressure air forced into the lower end of the high pressure air cylinder act simultaneously on the lower sides of their respective pistons. The force thus exerted results in an upward movement of the low pressure steam and high pressure air pistons. The upward movement causes the high pressure air piston 10, to compress the air in the upper end of the high pressure air cylinder to its final pressure and to discharge it through passage *v*, discharge valve 41, and passage *w* into the main reservoir. Steam is exhausted from the upper end of the low pressure steam cylinder through passage *d*, chamber *h* and passage *e* to the atmosphere.

After the low pressure steam (high pressure air) piston has completed its upward stroke, as explained, the lower end of the high pressure air cylinder is, of course, filled with air compressed from the lower end of the low pressure air cylinder, and the lower end of the low pressure steam cylinder is filled with steam exhausted from the lower end of the high pressure steam cylinder. However, just as the low pressure steam (high pressure air) piston has completed its upward stroke, steam is by-passed through three by-pass grooves *x* from the lower to the upper side of the low pressure steam piston, thereby preventing an accumulation of back pressure in the lower end of the high pressure cylinder.

At this stage of the cycle, also, the upper end of the low pressure air cylinder is filled with air at atmospheric pressure and the upper end of the high pressure steam cylinder is filled with live steam; but just before the high pressure steam (low pressure air) piston completes its downward stroke, reversing valve plate 18 engages the button end of the reversing valve rod, moving it downward and carrying the reversing valve to its extreme lower position, thereby closing port leading to passage *n*, cutting off the supply of live steam to chamber *D*, and connecting passage *m*, cavity *q* and passage *l*, thereby exhausting steam from cavity *D* behind the outer end of the large piston of the piston valve. Since the pressure against the inner side of the large piston is now greater than the pressure exerted against the inner side of the small piston, the piston valve moves to the right or in the direction of chamber *D*, and all parts are in the position shown in Fig. 20.

Live steam is now supplied from passage *a*, through chamber *b*, and passage *g*, to the lower end of the high pressure steam cylinder, forcing upward the high pressure steam piston which, as already explained, carries with it the low pressure air piston. At this time also, steam is exhausted from the upper end of the high pressure steam cylinder, through passage *c*, chamber *h* and passage *d*, into the upper end of the low pressure steam cylinder. At the same time—

(*a*) the low pressure air piston is compressing the air in the upper end of the low pressure air cylinder and forcing same through the intermediate valves 76, and passage *u*, into the upper end of the high pressure air cylinder, and—

(*b*) air at atmospheric pressure is drawn into the lower end of the low pressure air cylinder, through the lower air strainer, passage *r′* and lower inlet valve 38.

Again it will be observed that the steam in the low pressure steam cylinder and air in the high pressure air cylinder act simultaneously against their respective pistons, steam being exhausted from the upper end of the high pressure steam cylinder through passage *c*, chamber *h* and passage *d*, to the upper end of the low pressure steam cylinder, in which it acts expansively on the low pressure steam piston. At the same time steam is exhausted from the lower end of the low pressure steam cylinder, through passage *f*, chamber *i* and passage *e*, to the atmosphere. The downward movement of the low pressure steam piston causes the high pressure air piston to compress the air in the lower end of the high pressure air cylinder to its final pressure, forcing same through passage *v′*, discharge valve 42, and passage *w′*, into the main reservoir. When the pistons have moved as explained, the low pressure steam (high pressure air) piston has completed its downward stroke; the upper end of the high pressure air cylinder is filled with air compressed from the upper end of the low pressure air cylinder; and the upper end of the low pressure steam cylinder is filled with steam exhausted from the upper end of the high pressure steam cylinder. However, just before the low pressure steam (high pressure air) piston has completed its downward stroke, steam is by-passed through the three by-pass grooves from the upper to the lower side of the low pressure steam piston, thereby preventing an accumulation of back pressure in the upper end of the high pressure steam cylinder. At this stage of the cycle also, the high pressure steam (low pressure air) piston has completed its upward stroke; the lower end of the high pressure air cylinder is filled with air at atmospheric pressure; and the lower end of the high pressure steam cylinder is filled with live steam. Here again the compressor is reversed, by means of the reversing valve plate attached to the high pressure steam piston coming in contact with the shoulder of the reversing valve rod, which in turn, actuates the reversing valve, and the cycle of operation already described is repeated.

10½-Inch Cross Compound Air Compressor

The use of compressed air in industrial fields has been so widely extended that for this particular purpose we have developed the 10½-inch cross compound air compressor which operates on a relatively low steam pressure (100 lbs.) and requires a lower differential between steam and air pressures than the 8½-inch cross compound. This compressor follows in all essential details the general design of the 8½-inch cross compound compressor. The air cylinders are not water jacketed and no intercooler is required.

The following table gives the principal dimensions, displacement, weight, etc., of the 10½-inch compressor.

GENERAL DIMENSIONS, DISPLACEMENT AND WEIGHT OF THE 10½-INCH CROSS COMPOUND COMPRESSOR.

Diameter of High Pressure Steam Cylinder		10½ in.
Diameter of Low Pressure Steam Cylinder		16¾ in.
Diameter of High Pressure Air Cylinder		9½ in.
Diameter of Low Pressure Air Cylinder		14½ in.
Length of Stroke		12 in.
Governor		1½ in.
Diameter of Steam Admission Pipe		1½ in.
Diameter of Steam Exhaust Pipe		2½ in.
Diameter of Air Admission Pipe		2½ in.
Diameter of Air Delivery Pipe		1½ in.
Designed for Steam Pressure of		100 lbs.
Working against an Air Pressure of		80 lbs.
Normal Speed, single strokes per minute, under above conditions		131
Displacement, cubic feet per minute, under above conditions		150
Over-all Dimensions: (Approximate)	Height	56⅞ in.
	Width	41⅞ in.
	Depth	21 in.
Average Net Weight		1800 lbs.
Weight, boxed for shipment		2150 lbs.
Lift of Air Valves:	Intermediate	⅛ in.
	Suction	$\frac{5}{32}$ in.
	Discharge	$\frac{5}{32}$ in.

SIZE OF GOVERNOR, STEAM VALVE AND PIPING FOR TWO COMPRESSOR INSTALLATION.

Governor	*
Steam Valve	2 in.
Steam Admission Pipe	
Main Pipe	2 in.
Branch Pipe	1½ in.

*NOTE—A 1½-inch duplex governor, less the excess pressure head, should be located in one branch pipe and a steam portion of a 1½-inch governor located in the other branch pipe, the two governors being connected by a pipe from the Siamese fitting of the former governor to the cylinder of the latter governor. (See separate publication, Forms 715 and 715-5 for piping diagram.)

Steam Exhaust Pipe	
Main Pipe	3 in.
Branch Pipe	2½ in.
Air Admission Pipe	
Main Pipe	3 in.
Branch Pipe	2½ in.
Air Delivery Pipe	
Main Pipe	2½ in.
Branch Pipe	1½ in.

INSTRUCTIONS

Piping. All pipes should be hammered to loosen the scale and dirt, have fins removed, and be thoroughly blown out with steam before erecting; bends should be used wherever possible instead of ells, and all sags avoided. Shellac or Japan varnish should be applied on the *male threaded portion only*, and *never* in the socket. Do not use red or white lead.

Figs. 21 and 22 show the recommended arrangement and sizes of piping for one 8½-inch compressor and also for a two 8½-inch compressor installation. The size of pipe, particularly of the steam supply pipe, should never be smaller than that indicated in order to obtain maximum efficiency from the compressor. (The 10½-inch compressor being essentially an industrial compressor, the installation diagrams are not given herein but are completely covered in Form 715.)

In a single compressor installation the governor should be located in the steam supply pipe *between the lubricator connection and the compressor* in order to insure its receiving the necessary lubrication. The lubricator connection consists of a tee, the side outlet of which connects to the lubricator. In a two-compressor installation the governor should be located in the main steam supply pipe between the lubricator fitting and the steam branch pipe leading to each compressor.

Starting and Running. The drain cocks are placed at the lowest points of the steam passages, as shown, for the purpose of draining condensed steam when the compressor is stopped and when starting it. They should always be left open when the compressor is to stand idle for any length of time. These drain cocks are provided with suitable union fittings, so that drain pipes may be connected if desired.

In starting the compressor, always run it slowly until it becomes warm, permitting the condensed steam to escape through the drain cocks and the exhaust, until there is sufficient pressure in the main reservoir (25 to 30 lbs.) to provide an air cushion. Then close drain cocks and open the steam (throttle) valve sufficiently to run the compressor at the proper speed, according to circumstances. Racing or running at excessive speeds should not be allowed. The compressor governor automatically controls the starting and stopping of the compressor.

To Stop the Compressor. (1) Close the feed and steam valves on the sight-feed lubricator, if the compressor has a separate one, or the feed, if supplied from the locomotive lubricator; (2) then close the steam (throttle) valve; (3) and open all the drain cocks on the compressor. Keep the steam valve closed and the drain cocks open when the compressor is not working. The main reservoir drain cocks should also be left open when the compressor is stopped for any length of time. The compressor should always be stopped while the engine is over the ash pit. If kept open, ashes and dust will be drawn into the air cylinder and injure it, besides clogging up the air strainer.

Lubrication—Air Compressors.—On account of the high temperatures developed by air compression, the variation between maximum and minimum delivered air pressures, and the necessity of preventing oil from passing into the system, one of the vital problems in efficient compressor operation is to provide a simple means for supplying lubrication to the air cylinders in proper quantity and at regular intervals.

To overcome the difficulties attending the lubrication of the air cylinders of the 8½-inch and 10½-inch cross compound compressors, two non-automatic oil cups are mounted on a bracket, which, in turn, is connected to the air cylinders by the necessary piping, thereby establishing an independent passage from each cup to the high and low pressure air cylinders respectively.

This cup, Fig. 9, is of extremely simple design. The lower end is threaded for a ⅜-inch tapped opening, while the upper end is provided with a tight-fitting screw cap. A screen prevents any dirt in the oil being carried into the cylinder. When the handle is turned, a cavity in the key, which normally forms the bottom of the oil cup, deposits a definite amount of oil in the air cylinders, at the same time preventing back pressure from reaching the oil chamber.

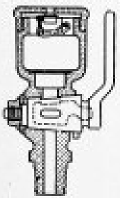


Fig. 9. Oil Cup

The bracket may be attached to the top head of the compressor, or placed in the locomotive cab, to suit the convenience or standard practice of any railroad.

To oil the *air cylinders*, fill oil cup with *valve oil*, screw on the covers, and turn the handles up, which allows a small quantity of oil to enter the cavity in the key. Now turn the handles down and leave them down so as to permit the oil in the cavity to find its way into the cylinders. To admit more oil to the cylinders, turn the handles up again to fill the cavity with oil and then turn them down to empty the cavity. Valve oil only should be used in the air cylinder. A lighter oil will not last and is dangerous. A heavier oil very soon clogs and restricts the air passages, causing the compressor to heat unduly and compress air slowly; valve oil gives the best performance. Judgment should determine the amount for both the air and steam cylinders, it being remembered that the lack of a little oil when needed may result in much damage to the compressor.

A *swab*, well oiled, is essential on each piston rod.

Many railroads now consider quite essential the use of a Double Sight Feed Lubricator Fitting *located in the cab* and connected in the piping leading from the oil well of the locomotive lubricator to the compressor air cylinders, and from the very satisfactory results obtained, we are prepared to recommend these fittings strongly as particularly advantageous and effective.

The Double Sight Feed Lubricator, Fig. 10, gives the engineer complete and convenient control of air cylinder lubrication, so that the minimum amount and proper

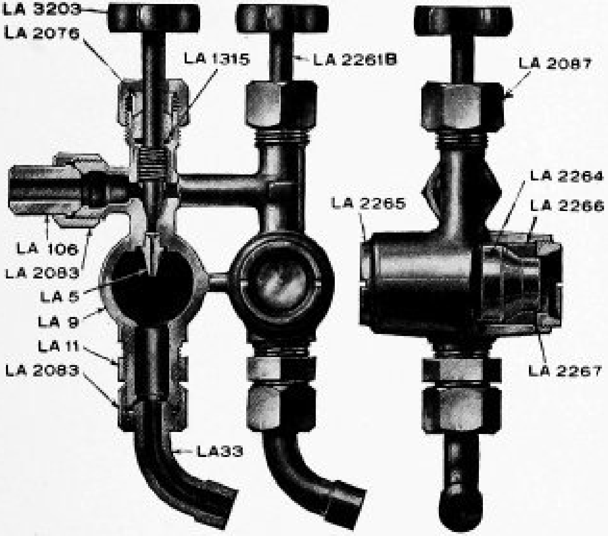


Fig. 10. Double Sight Feed Lubricator

quality of oil required may be supplied at regular intervals. The sight feed lubricator can be attached to any locomotive lubricator. In order to prevent compressed air from entering the oil delivery pipe between the sight feed fitting and the air cylinder, a ball check valve connection is screwed into the air cylinder.* No trap should

*NOTE—The cross compound compressor has recently been modified slightly by changing the location of the oil hole for the high pressure air cylinder. Whereas this hole was formerly located near the discharge passage from the high pressure cylinder, it is now located at a point where the oil will feed directly into the inlet passages to the high pressure air cylinder. The center piece is tapped for ⅜-inch pipe on both the front and back of the rear wall, thus permitting of attaching oil pipe, oil cock or cup at either the front or the back. Our standard practice, however, is to connect the oil pipe at the back for the sake of accessibility, with the front opening plugged. Interchangeability is not affected in any way since the old connection (marked "A" in Figs. 21 and 22) is still retained. When a compressor having the new location of oil hole is to be substituted for a compressor having the old location of oil hole, the plug A, Figs. 21 and 22, should be removed from the old oil hole and the new connection plugged. Thus the same length of oil pipe may be used.

exist in the oil delivery pipe between the sight feed fitting and the air cylinder. The recommended arrangement of the lubricating systems is shown in Fig. 23.

The lubricator illustrated in Fig. 10, is of the non-self-closing type. To avoid the possibility of lubricators being left open inadvertently, thereby resulting in the delivery of an excess quantity of oil to the air cylinder of the air compressor, a Self-Closing Lubricator is furnished when desired. This type of lubricator closes automatically as soon as the engineer removes his hand from the operating lever, thus insuring the exact amount of lubrication intended.

Lubrication—Steam Cylinders.—The *steam cylinder lubricator* should not be started until all condensation has escaped from the compressor and the drain cocks closed. After closing the drain cocks start the lubricator to feed in ten or fifteen drops of oil as rapidly as possible, then regulate the feed to about two or four drops per minute *for each compressor.* No definite amount can be specified, as the amount of lubrication required depends on the work the compressor has to do, the quality of the steam, condition of compressor, and so on. Keep the lubricator feeding while the compressor is running.

REPAIR SHOP AND ROAD TESTS

The Interstate Commerce Commission's "Rules and Instructions for Inspection and Testing of Steam Locomotives and Tenders" issued October 11, 1915, specifies as follows regarding steam compressor tests:

"The compressor or compressors shall be tested for capacity by orifice test as often as conditions may require, but not less frequently than once each three months."

The above Rules and Instructions also specify that with a 9-32-inch orifice and main reservoir pressure maintained at 60 lbs., the 8½-inch compressor must make only 100 single strokes per minute. For altitudes over 1,000 feet, the speed of the compressor may be increased five single strokes per minute for each 1,000 feet increase altitude.

We would recommend the following method for making the above test:

Before making any test, the main reservoir should be drained and it and its connections should be tested for leakage as follows: After obtaining the main reservoir pressure corresponding to the governor setting, close the throttle to the compressor. Then close the main reservoir cut-out cock when the standard SF governor is used; if, however, the SG type of governor or the SF type with a manifold providing for a single main reservoir connection to the governor is used, leave the main reservoir cock open and close the brake pipe cut-out cock under the brake valve and the cut-out cock in the supply pipe to the distributing valve and place the brake valve handle on lap. If no cut-out cock is used, as with the A-1 Equipment, place the brake valve handle on lap. Bleed down reservoir pressure to about 62 or 63 lbs. Allow the pressure to leak down to 60 pounds, (that is, to settle down to an equalization of temperatures) and note the amount of drop from this pressure during one minute. This drop must not exceed 2 lbs. If a greater leakage than this exists, it must be reduced to this limit before proceeding with the compressor test, otherwise the test would indicate a poorer condition of the compressor than is the case, due to extra labor required to maintain this leakage.

After the main reservoir and its connections have been tested for leakage as above, the compressor should be tested as follows:

Fig. 11. Disassembled View of Disc Holder with Disc

The orifice disc is placed in a special holder, Figs. 11 and 12, supplied for this purpose which should be screwed directly into the main reservoir drain cock, as shown in Fig. 13. Then close the main reservoir cut-out cock if the standard SF governor is used; if, however, the SG type of governor or the SF type with a manifold providing for a single main reservoir connection to the governor is used, leave the main reservoir cock open and close the brake pipe cut-out cock under the brake valve and the cut-out cock in the supply pipe to the distributing

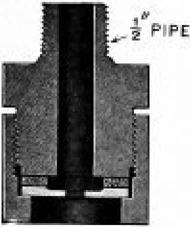


Fig. 12. Sectional View of Disc Holder and Disc

Fig. 13. Showing Orifice Disc Holder Screwed into Main Reservoir Drain Cock

valve and place the brake valve handle on lap. If no cut-out cock is used, as with the A-1 equipment, place the brake valve handle on lap. Then start the compressor and raise the pressure in the main reservoirs to slightly below 60 lbs. Open the drain cock to the orifice and throttle the steam supply to the compressor until the main reservoir pressure is maintained at approximately 60 lbs. Then count the strokes of the compressor required to maintain this pressure during one minute. This number must not be in excess of 100.

During the tests it should be assured that boiler pressure is at all times at least sufficient to obtain the required number of strokes against 60 lbs. air pressure when the throttle to the compressor is full open.

TEST OF STEAM END

While the Interstate Commerce Commission makes no mention of tests of the steam end, such tests should be made to determine whether or not the efficiency of the steam end of the compressor is lower than warrants continuing it in service or after having been repaired and overhauled, it is in proper condition to be returned to service.

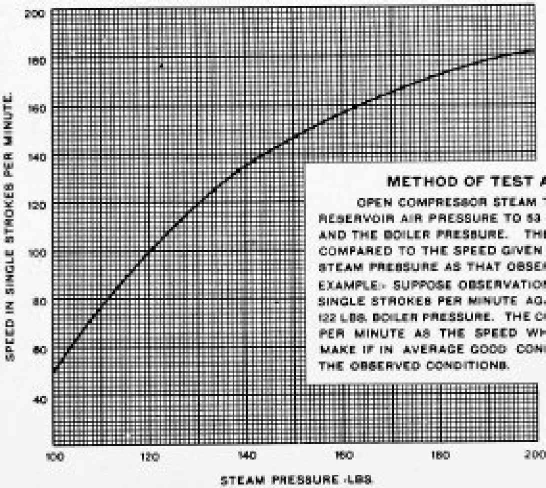
The test specifications given hereinafter are based upon the performance of a number of compressors in what may be termed good average condition. It should be understood that the limits specified are neither those which should condemn a compressor nor necessarily the best performance which should be expected from a compressor in the best possible condition. The condemning limit should be established by those familiar with existing service requirements. The tests specified merely indicate the method which we would recommend.

In establishing a minimum passable performance of the compressor, it should be borne in mind that this limit should not be set too low. This is to prevent the compressor getting into such poor condition as to require expensive repairs. For this reason we strongly recommend that the condemning limit should *never* be established below 75 per cent for the steam end of the tests specified hereinafter, no matter what the service may be or the apparent ability of the compressor to meet operating requirements, even with a considerably lower efficiency than this. Where operating conditions demand a more rigid requirement, the condemning limit should be raised to an amount determined by the judgment of those in charge.

The steam end of the compressor should be tested in the following manner:

The compressor steam throttle should be opened wide and the main reservoir pressure should be regulated by means of a cock or valve leading to the atmosphere until the pressure in the reservoir reaches 53 lbs. When this pressure has been obtained, the locomotive boiler pressure and the compressor speed in single strokes per minute should be observed and compared with that shown on the curve on page 36, which represents what the performance ought to be if its steam end is in good average condition.

SPEED CURVE
OF THE
8½" CROSS COMPOUND STEAM DRIVEN AIR COMPRESSOR
OPERATING AGAINST 53 LBS. AIR PRESSURE.
THIS CURVE TO BE USED AS BASIS FOR TESTING
THE STEAM END OF THE COMPRESSOR.



METHOD OF TEST AND USE OF CURVE.

OPEN COMPRESSOR STEAM THROTTLE, REGULATE THE MAIN RESERVOIR AIR PRESSURE TO 53 LBS., NOTE COMPRESSOR SPEED AND THE BOILER PRESSURE. THE OBSERVED SPEED SHOULD BE COMPARED TO THE SPEED GIVEN BY THE CURVE FOR THE SAME STEAM PRESSURE AS THAT OBSERVED.

EXAMPLE:- SUPPOSE OBSERVATIONS SHOW THAT THE SPEED IS 100 SINGLE STROKES PER MINUTE AGAINST 53 LBS. AIR PRESSURE AT 122 LBS. BOILER PRESSURE. THE CURVE GIVES 104 SINGLE STROKES PER MINUTE AS THE SPEED WHICH THE COMPRESSOR SHOULD MAKE IF IN AVERAGE GOOD CONDITION AND OPERATING UNDER THE OBSERVED CONDITIONS.

Speed Curve for the 8½-Inch Compressor

For example, suppose with the steam throttle opened wide and the main reservoir pressure maintained at 53 lbs. by bleeding it to the atmosphere at a given rate, observations show that a speed of 100 single strokes per minute is attained with a boiler pressure of 122 lbs. The curve shows that with a boiler pressure of 122 lbs. and operating against 53 lbs. main reservoir pressure, the compressor speed should be 104 single strokes per minute if the steam end of the compressor is in good average condition. If the observed speed is less than that indicated on the curve for the given conditions, the judgment of those in charge should determine whether the compressor should be overhauled.

If the condemning limit for the steam end has been set at 75 per cent of the performance of a compressor in good average condition, the speed of the compressor should not be less than 75 per cent of the speed called for by the curve at a point corresponding to the particular condition of steam pressure under which the compressor was tested. For instance, in the case under consideration, the compressor should have a speed of not less than 75 per cent of 104 strokes, or 78 single strokes per minute.

DISORDERS

Causes and Remedies

Compressor Refuses to Start. Cause:—Insufficient oil, from scant or no feed or working water; leaky piston rings in the small end of the main valve piston; or rust having accumulated during time compressor has lain idle.

Remedy:—shut off steam, take off reversing valve cap, pour in a small quantity of valve oil, replace cap, and then turn on steam quickly. In many cases when the compressor will not start when steam is first turned on, if steam is then turned off and allowed to remain off for one or two minutes, and then turned on quickly, it will start without the use of any oil, except that from the lubricator.

Compressor Groans. Cause:—(1) air cylinder needs oil. Remedy:—(1) put some valve oil in air cylinder. Cause:—(2) piston rod packing dry and binding. Remedy:—(2) saturate piston swab with valve oil. Cause:—(3) steam cylinder needs oil. Remedy:—(3) increase lubricator feed.

Excessive leakage past the air piston packing rings or past a discharge valve causes heating, destroys lubrication, and results in groaning.

Uneven Strokes of the Compressor. Cause:—probably (1) excessive leakage past air piston packing rings and sticky air valves; (2) improper lift of air valves; (3) clogged discharge valve passages; (4) leaky air valves; or (5) binding or cutting of the reversing rod. Remedy:—locate cause, if possible, and correct it by cleaning out clogged or dirty passages and air valves, replacing worn or leaky valves or rings, or straightening or replacing the reversing rod.

Slow in Compressing Air. Cause:—(1) leakage past the air piston packing rings, due to poor fit, or wear in cylinder or rings; (2) valves and passages dirty; or, (3) air suction strainer clogged. Remedy:—(1) and

(2). To determine which is causing the trouble, obtain about 90 lbs. air pressure, reduce the speed to from 40 to 60 single strokes per minute, then *listen* at the "Air Inlet" and note if air is drawn in during only a portion of each stroke, and if any blows back. If the latter, an inlet valve is leaking. If the suction does not continue until each stroke is nearly completed, then there is leakage past the air piston packing rings or back from the main reservoir past the air discharge valves. Remedy:—(3) clean strainer thoroughly.

Compressor Erratic in Action. Cause:—Worn condition of valve motion. Remedy:—Renew it.

Compressor Heats. Cause:—(1) air passages are clogged; (2) leakage past air piston packing rings; or, (3) the discharge valves have insufficient lift. Remedy:—(1) clean air passages; (2) renew air piston rings; (3) regulate lift of discharge valves to 3-32 of an inch on the 8½-inch and to 5-32 of an inch on the 10½-inch compressor. A compressor in perfect condition will become excessively hot and is liable to be damaged if run very fast and continuously, for a long time.

Compressor Pounds. Cause:—(1) air piston is loose; (2) compressor not well secured to boiler, or causes some adjacent pipe to vibrate; (3) the reversing valve plate, 18, is loose; or, (4) the reversing rod or plate may be so worn that the motion of compressor is not reversed at the proper time. Remedy:—repair and renew worn parts and tighten loose connections.

MAINTENANCE

In connection with the problem of good maintenance for steam driven air compressors of this type, the heating of the air cylinders incident to air compressor is perhaps the most important. The operation of the compressor continuously at high speed or against excessive pressures inevitably results in high temperatures which tend to destroy the lubrication, causing the air cylinders to cut, and the groaning of the air compressor, besides filling the discharge passages with deposits from burnt oil, producing undesirable condensation of moisture in the brake system and in general, reducing the overall efficiency of the compressor.

Under normal conditions, the speed should not exceed 140 exhausts per minute and such a speed should not be maintained continuously for any considerable time, as even this speed will cause excessive heating. Continuous running at high speed will cause excessive heating of the air end of the compressor. Overheating from this cause is an indication that a compressor of larger capacity is required.

It is therefore desirable, first, that the compressor be of ample capacity for the service desired (if one compressor does not have sufficient capacity, the obvious remedy is to install two compressors); second, that it be well lubricated and otherwise maintained in good condition; and third, that leakage from any source whether within the air compressor itself or in the brake system be minimized in every practical way.

One of the most serious leaks is through the air cylinder stuffing box if the stuffing box packing is not properly maintained, as it not only greatly decreases the air delivered, and, by the faster speed required, increases the heating, but it also causes pounding through loss of cushion. When tightening the packing, do not bind the rod, as to do so will damage both the packing and the rod. Be careful not to cross the gland nut threads.

With two compressors per engine, the separate throttles should be kept wide open and the speed regulated by the main compressor throttle. The purpose is to equally divide the work.

If necessary to replace a broken air valve on the road or elsewhere not permitting of proper fitting, at the earliest opportunity have the repairman replace the temporary valve with another so as to insure the correct angle and width of valve and seat contact, the needed ground joint and the requisite lift of 3-32 of an inch for all valves. For the purpose of readily determining the lift of air valves, we furnish an Air Valve Lift Gage (catalog price $6.00), as illustrated in Figs. 14, 15 and 16.

To determine the lift of the upper air valve, the gage is first applied to the top flange of the air cylinder, as illustrated in Fig. 14, and the sliding arm adjusted until its end rests against the top of the stop on the air valve, in which position it is locked by means of the thumb nut. With the arm thus locked, the gage is applied to the valve cap, as illustrated in Fig. 15, and if the valve has proper lift, the under side of the collar of the valve cap

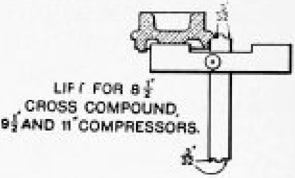


Fig. 15

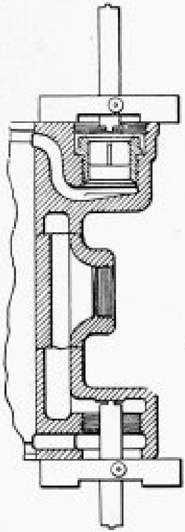


Fig. 14

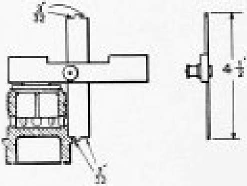


Fig. 16

Air Valve Lift Gage

will just rest upon the shoulder of the sliding arm, as illustrated. If the cap fails to thus fit properly between the two surfaces of the gage, it indicates that the valve has improper lift by an amount equal to the distance between the under side of the collar on the cap and the shoulder on the sliding arm.

To determine the lift of the lower air valve, the gage is first applied to the bottom flange of the air cylinder, as illustrated in Fig. 14, and the sliding arm adjusted until its end rests against the stop in the cylinder, in which position it is locked by means of the thumb nut. With the arm thus locked, the gage is applied to the air valve cage and air valve, as illustrated in Fig. 16, and if the valve has proper lift, the shoulder on the sliding arm will just rest upon the upper side of the collar of the air valve cage, as illustrated. If the air valve and cage fail to thus fit properly between the two surfaces of the gage, it indicates that the valve has improper lift by an amount equal to the distance between the upper side of the collar on the cage and the shoulder on the sliding arm.

Never remove or replace the upper steam cylinder head with the reversing valve rod in place, as to do so will almost invariably result in bending the rod. A bent rod is very liable to cause a "pump failure."

When assembling the sections of the piston valve, special care should be taken to insure proper alignment and thereby avoid possible trouble from binding of the piston in the bushing.

It is evident that a compressor cannot compress more air than it draws in and not that much if there is any leakage to the atmosphere about the air cylinder. Bearing this in mind, practice frequently listening at the "Air Inlet" when the compressor is working slowly while being controlled by the governor, and wherever a poor suction is noted on either or both strokes locate and report the fault.

Any unusual click or pound should be reported as it may indicate either a loose piston or a reversing-valve plate cap screw or other serious fault.

Any steam leakage that can reach the Air Inlet of the compressor should be promptly repaired as such increases the danger of water entering the brake pipe.

Keeping the suction strainer clean is of the utmost importance, as even a slightly clogged strainer will greatly reduce the capacity where the speed is at all fast. A seriously or completely obstructed strainer, as by accumulated frost, aggravated by rising steam, will increase the compressor speed and will also be indicated by inability to raise or maintain the desired pressure.

It is an aid to good operation to thoroughly clean the air cylinder and its passages at least three or four times a year, by circulating through them a hot solution of lye or potash, in the proportions of 2 lbs. of potash to one gallon of water. This should always be followed by sufficient clean, hot water to thoroughly rinse out the cylinder and passages, after which a liberal supply of valve oil should be given the cylinder. Suitable tanks and connections for performing this operation can easily be arranged in portable form. Never put kerosene oil in the air cylinder to clean it.

Westinghouse Air Brake Company

Pittsburgh, Pa., U. S. A.

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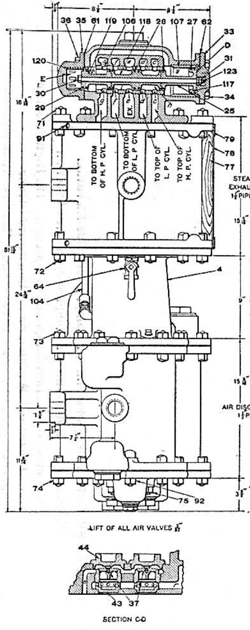


Fig. 17. 8½-Inch Cross Compound Air Compressor, Side Elevation

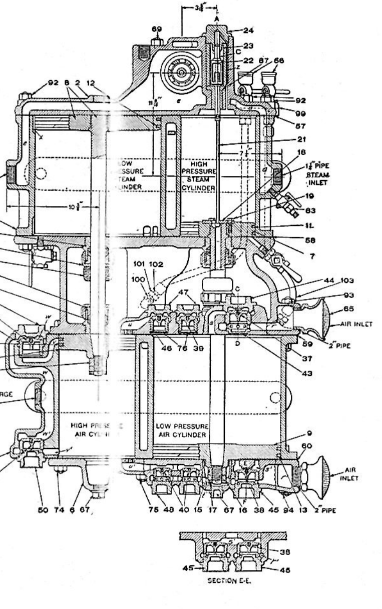


Fig. 18. 8½-Inch Cross Compound Air Compressor, Vertical Section

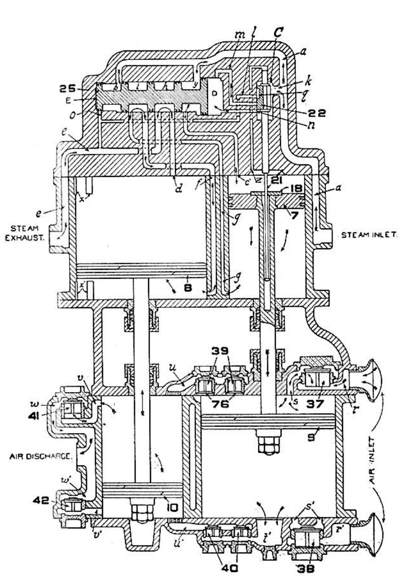


Fig. 19. Diagram of 8½-Inch Cross Compound Compressor. The High Pressure Steam (Low Pressure Air) Piston on its Downward Stroke

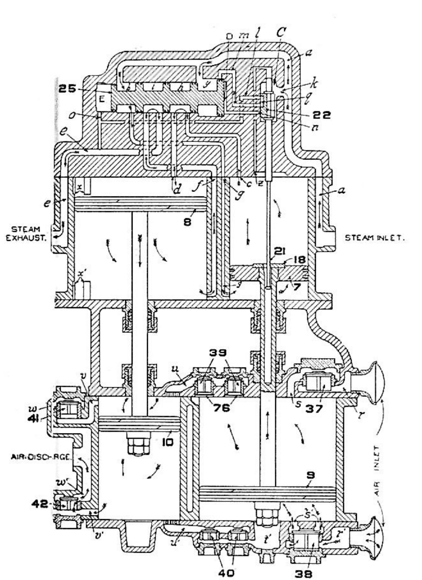


Fig. 20. Diagram of 8½-Inch Cross Compound Compressor. The High Pressure Steam (Low Pressure Air) Piston on its Upward Stroke

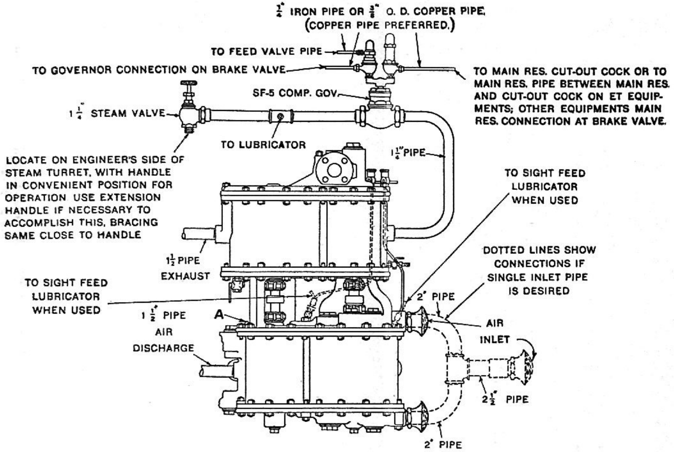
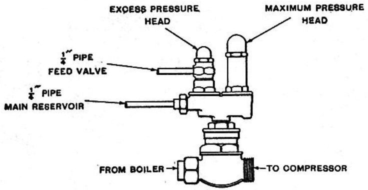
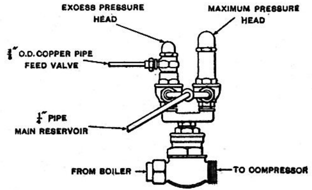


Fig. 21. Installation Diagram of 8½-Inch Cross Compound Air Compressor



NOTE—The piping arrangement of the governor may be simplified by the use of the SG type of governor, as illustrated above, with the No. 6 ET Equipment instead of the SF Type. The use of the SG governor eliminates the long copper pipe between the diaphragm portion of the excess pressure governor top and the H-6 brake valve.



☞ NOTE—The simplification of piping secured by the use of the SG type of governor, as above described, may also be secured with the SF governor by connecting the two diaphragm portions together by a duplex pipe fitting or manifold, as illustrated.

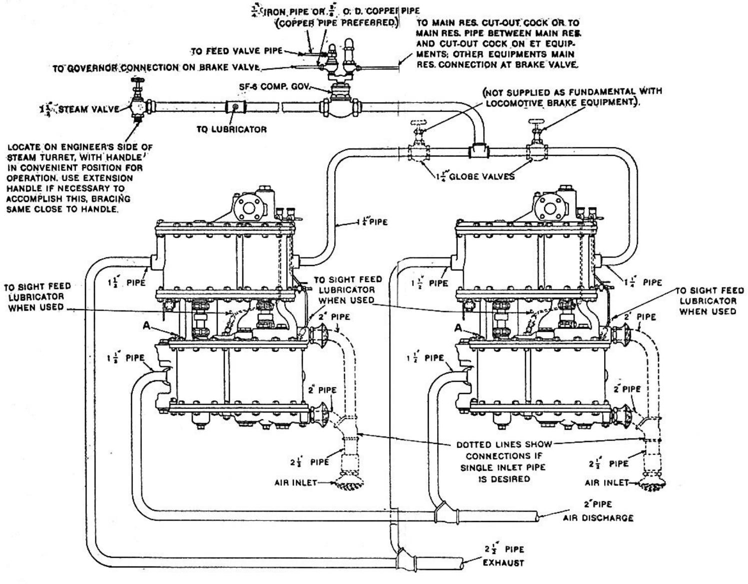


Fig. 22. Installation Diagram of Two 8½-Inch Cross Compound Air Compressors

Fig. 23. Diagram Showing Sequence of Parts in the Recommended Air Cylinder Sight Feed Lubricating System

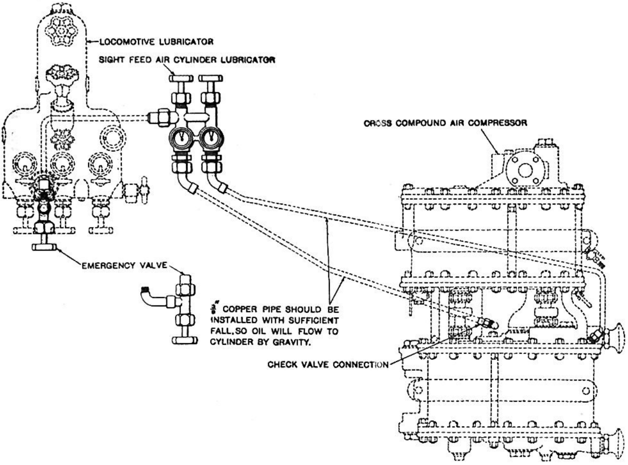


Fig. 23. Diagram Showing Sequence of Parts in the Recommended Air Cylinder Sight Feed Lubricating System