Electric Arc Welding

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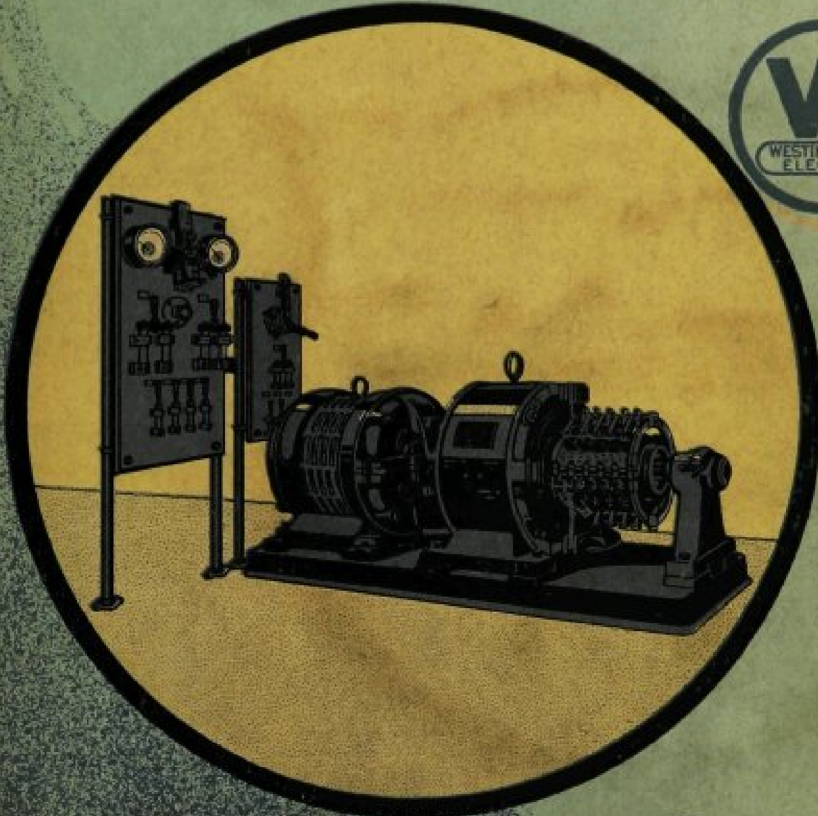
WESTINGHOUSE ELECTRIC

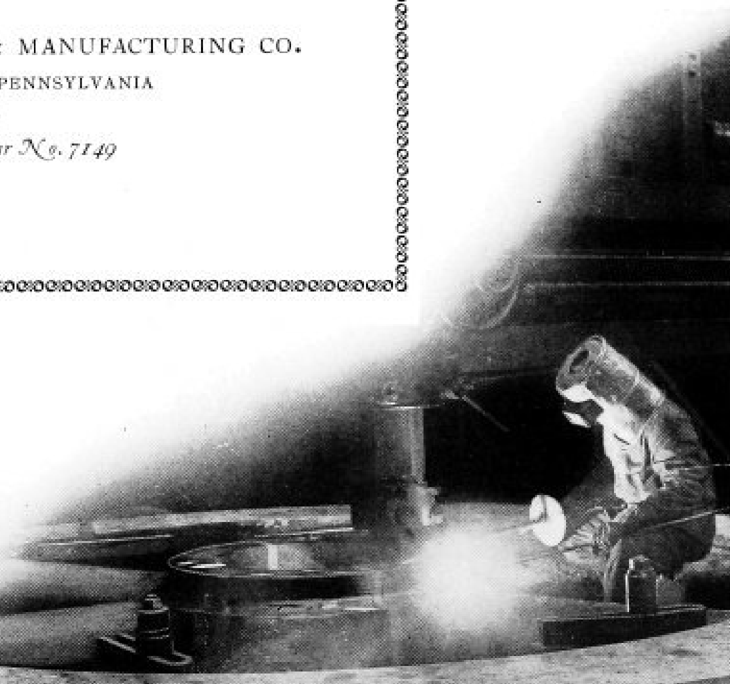


ELECTRIC ARC WELDING

The Field of its Application and An Explanation of Modern Welding Practice

WESTINGHOUSE ELECTRIC & MANUFACTURING CO.
EAST PITTSBURGH · PENNSYLVANIA

Application Circular No. 7149



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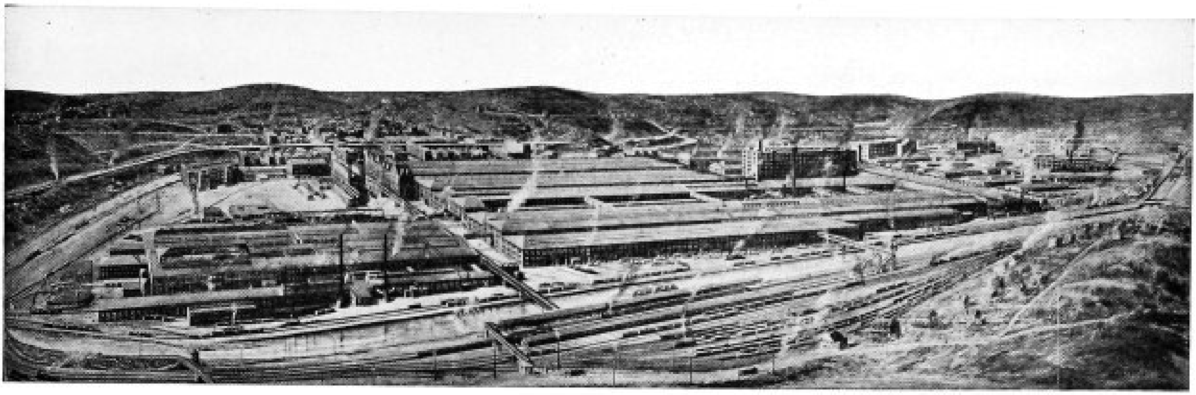


Works of the Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

ELECTRIC ARC WELDING

THE PROCESS of arc welding may be defined as the utilization of the intense concentrated heat produced by the electric arc for melting and fusing the metals to be welded. The electric arc produces the hottest flame known to science and is, therefore, particularly well adapted to welding.

During the last few years an unusually rapid advance has been made in electric arc welding and it has now become recognized as an art very essential to a number of industries. The process, however, is not a new one, as is evidenced by the fact that in 1887, Bernados secured a patent covering the use of the electric arc for this purpose. A few years later, Salvianoff introduced a process for casting metal into blow holes of defective castings by producing an arc between an electrode consisting of a metallic rod and the metal to be welded.

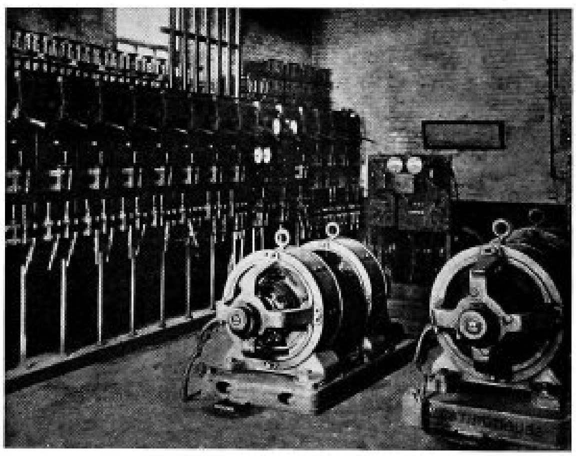
The following definitions briefly explain the different forms of welding to which reference is sometimes made.

Autogenous Welding is that process by which the metals to be welded are raised to such a temperature that they will flow together and form a weld without the use of force or pressure. The arc weld belongs to this class.

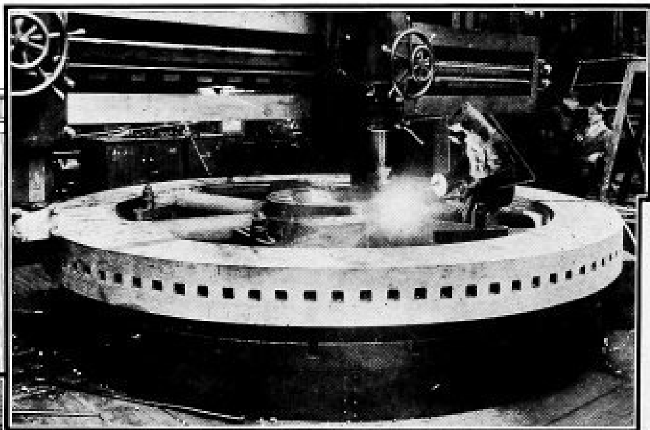
Forge Welding is that process by which metals to be welded are raised to such a temperature that they can be forged into a perfect union by hammering or pressure. The spot and butt (incandescent) welds are of this class.

Oxy-Acetylene Welding is a process for the welding of two metals in which use is made of the heat produced by the combustion of acetylene gas supported by oxygen, in a common pipe or torch. The oxy-acetylene process is largely used for cutting metals, and for welding in places where electric current is not available.

Thermit Welding is a process by which two pieces of metal are welded through the heat produced by a chemical combination of certain substances. This is a casting process and requires a mold built around the material to be welded.

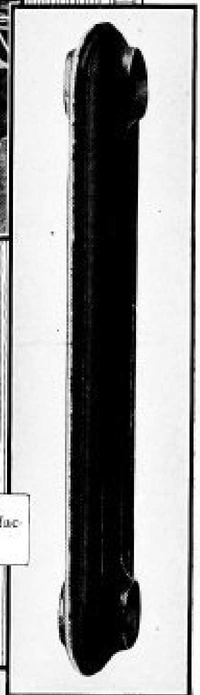


Arc Welding Motor Generator Sets, used in Baltimore & Ohio Railroad Shops.

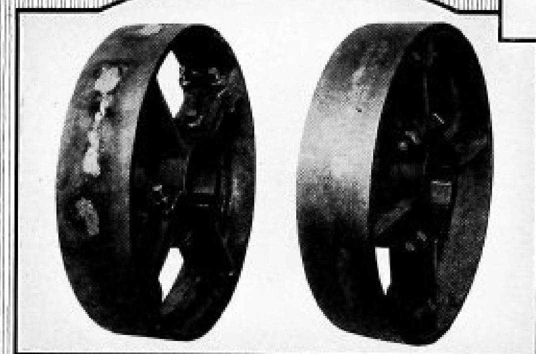


Repairing defects in casting developed during machining.

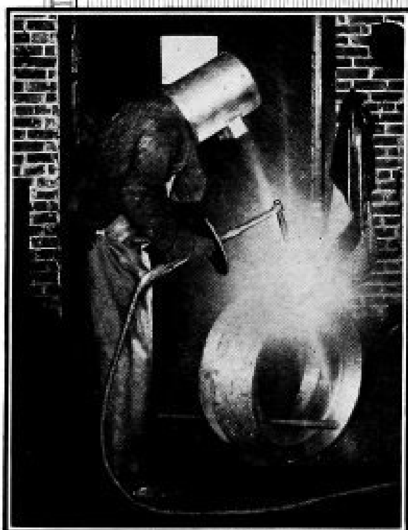
Application of Metal Electrode welding in the manufacture of Tanks.



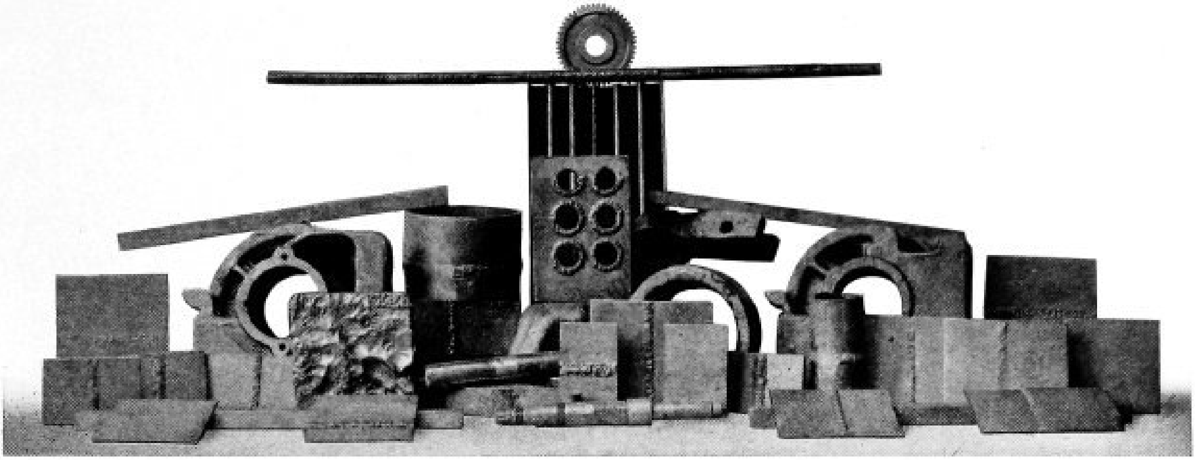
Electric Arc Welding used in the manufacture of Steam Radiators.



Defective Fly-wheel casting filled in and afterwards machined.



Welding the ends of a hot-rolled steel ring.



Samples showing the wide application of Electric Arc Welding.

ELECTRIC ARC WELDING APPLICATIONS

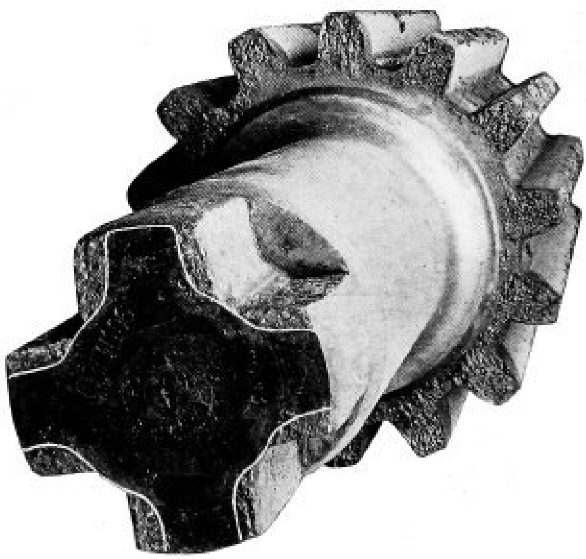
The field for electric arc welding is unlimited. Practically every industry employing iron and steel, or other alloys, can utilize it to advantage. The process is used not only for joining two pieces of metal, but also for cutting metal, building on, or adding to other metal parts.

As previously stated, the process has made enormous strides during the last few years until now it is widely used throughout those branches of the metal industry in which work is done on iron or steel in rolled, cast, or fabricated forms. New fields for its successful application are being discovered every day.

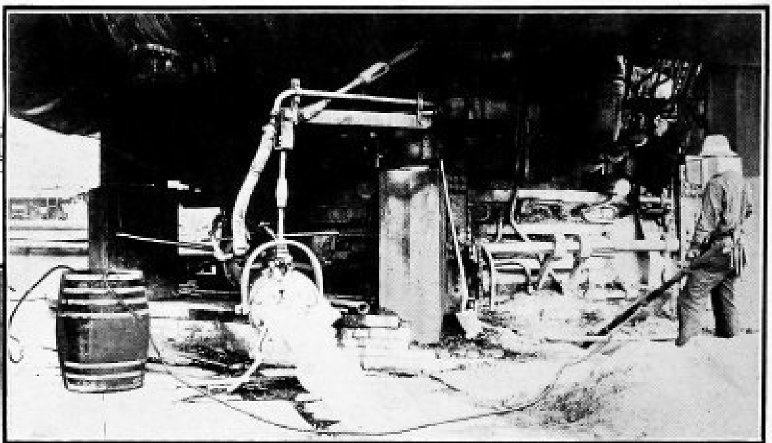
Manufacturing Plants. Not only has arc welding become a well recognized process in manufacturing plants for repair and reclamation work, but it is now very generally being used as a manufacturing process, superseding riveting and other means of joining metal parts. Familiar examples of this class of work are:—ship construction, the manufacture of pressure vessels, steel barrels, caskets, structural steel buildings, tanks, boilers, automobile frames, machine tools, and hundreds of other applications. Excellent economies have been effected by the use of the arc process, especially when employed in quantity production.

Many applications for arc welding have been developed by manufacturers to meet their own individual requirements, and have, therefore, never become known outside of the companies by which they are employed, owing to the fact that they form parts of competitive manufacturing processes which, for commercial reasons, it is not desired to divulge.

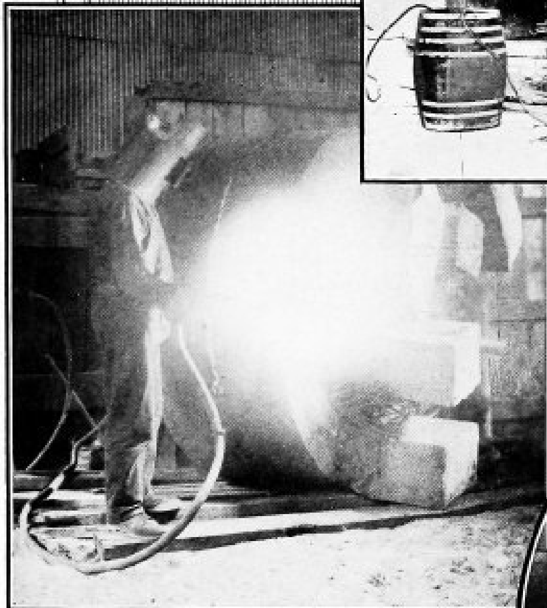
An unusually successful application of the process to new work is in the laying of pipe lines where the two ends of the pipe are welded together instead of being joined by pipe couplings. This results in a stronger



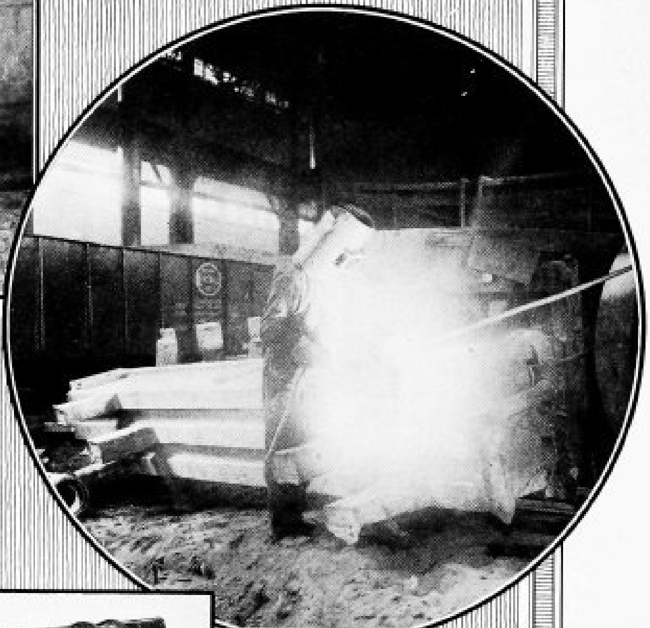
A worn blooming mill pinion repaired by the Arc Welding Process. The White Lines show the original outlines, the metal outside having been added. The cost of repairing four ends (two pinions) was $170.00. The pinions cost $1,000.00 each and could be saved by no other process.



Clogged tap hole in blast furnace being burned out by means of Electric Arc.



Using the Electric Arc to remove Sink Heads from Castings.



Using the Electric Arc to remove Sink Heads from Castings.

Wobblers saved from the scrap heap by building up worn ends with the electric arc.

Welding on the end-piece of a tank using a Metallic Electrode.

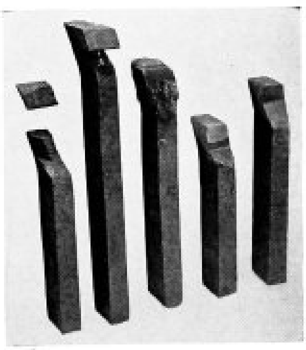
and more permanent joint and what is practically a continuous pipe line that has a tendency to reduce leakage at the joints.

The Westinghouse Electric & Manufacturing Company employs the arc welding process very extensively throughout its shops for both manufacturing and repairs.

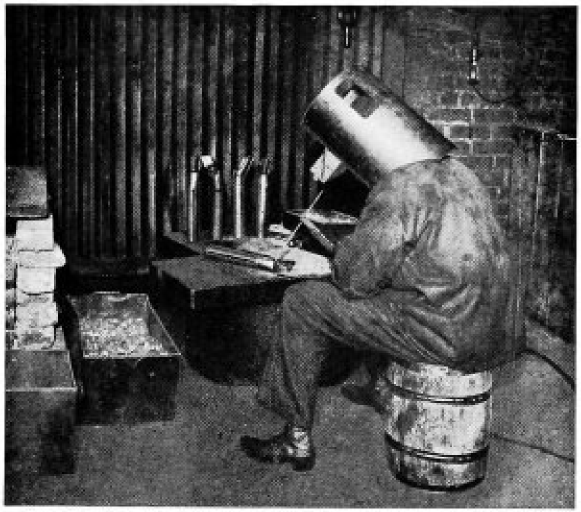
One instance of the former is the making of industrial motor frames. This frame consists of a slab of open hearth steel, rolled to the form of a ring by a special forging machine. This ring, after being tested for size and diameter, is allowed to cool and then the two ends of the slab are welded together by the carbon electrode process, thus forming a continuous ring.

Machine Shops. Arc welding makes it possible to rectify errors in machining or to build up worn parts of equipment by welding on additional metal and then re-machining. Frequently, defects develop in castings after considerable machining has been done; in such cases, the castings may be saved by use of the electric arc.

One of the important economies effected by the arc welding process is in connection with welding small sections of high-speed tool steel to shanks of ordinary machinery steel. The saving in this case is naturally dependent on the relative cost of the high-speed tip and the tool steel shank. A piece of the latter metal is forged to shape, and a piece of high-speed steel is cut to shape and then welded on the shank. The finished tool is then ground and tempered, and a high-speed steel tool is obtained at practically the cost of the shank, plus the nominal cost of welding.



Lathe tool made by welding high speed steel tip to shank of low carbqn steel.



Reducing the cost of tools by welding high-speed steel tips to carbon steel shanks.

Steel Mills. There are many places in steel mills where the arc welding process can be employed with a saving in time and expense over methods previously in use. The ends of the driving spindles, pinions, or wobblers which have become badly worn, and that otherwise would probably have to be scrapped, can readily be built up to their original size, machined, and put back into service. Chipped and worn rolls can be welded and reground, thus materially prolonging their usefulness.

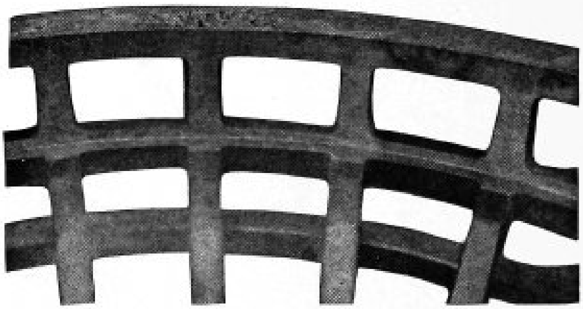
A particularly important application of the electric arc in this industry is its use to burn out clogged tap-holes in blast furnaces, which can be done in a very expeditious manner by this process.

Foundries. Broken and defective steel castings can be reclaimed by arc welding. Steel castings which are found defective from sand spots, blow holes or shrinkage cracks can be quickly repaired with perfectly satisfactory results. When these defects develop during machining, they can be filled up without removing the casting from the machine and the work continued with little loss of time. The welds in the casting, if properly made, are as readily machined as any other part of the work. Risers and sink-heads can be cut off quickly and more cheaply than by other methods.

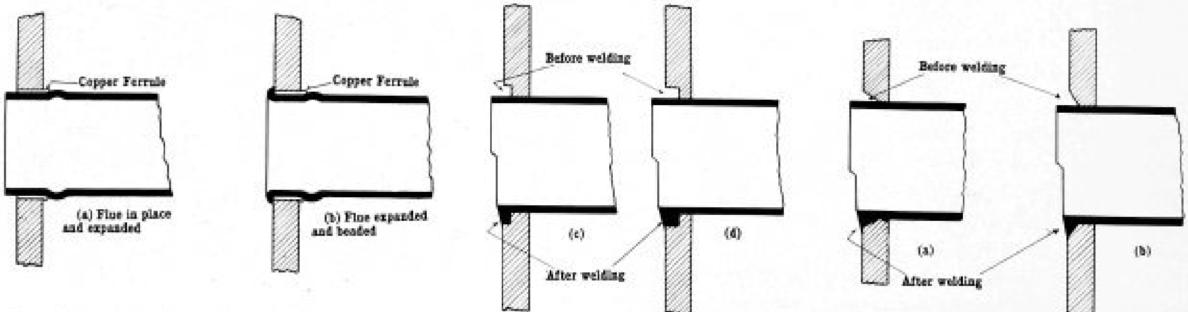
Boiler Shops. The arc welding process has been extensively used in the manufacture of tanks, cars, flues and similar equipment. The work is done not only simpler and cheaper, but with more satisfactory results, and the welded portions are found to be stronger and less apt to leak than riveted work.

Railroad Shops. Arc welding finds an extensive field of application in railroad shops. Not only is it largely used in making repairs but also in the manufacture of equipment. Some locomotive builders use the process in the manufacture of fire boxes and smoke boxes, and it is very generally employed in making repairs to fire and smoke boxes, locomotive frames, flue welding, building up mud rings, and other work of this character. In addition, a wide field is found in welding roofs and side sheets and in cutting rivets.

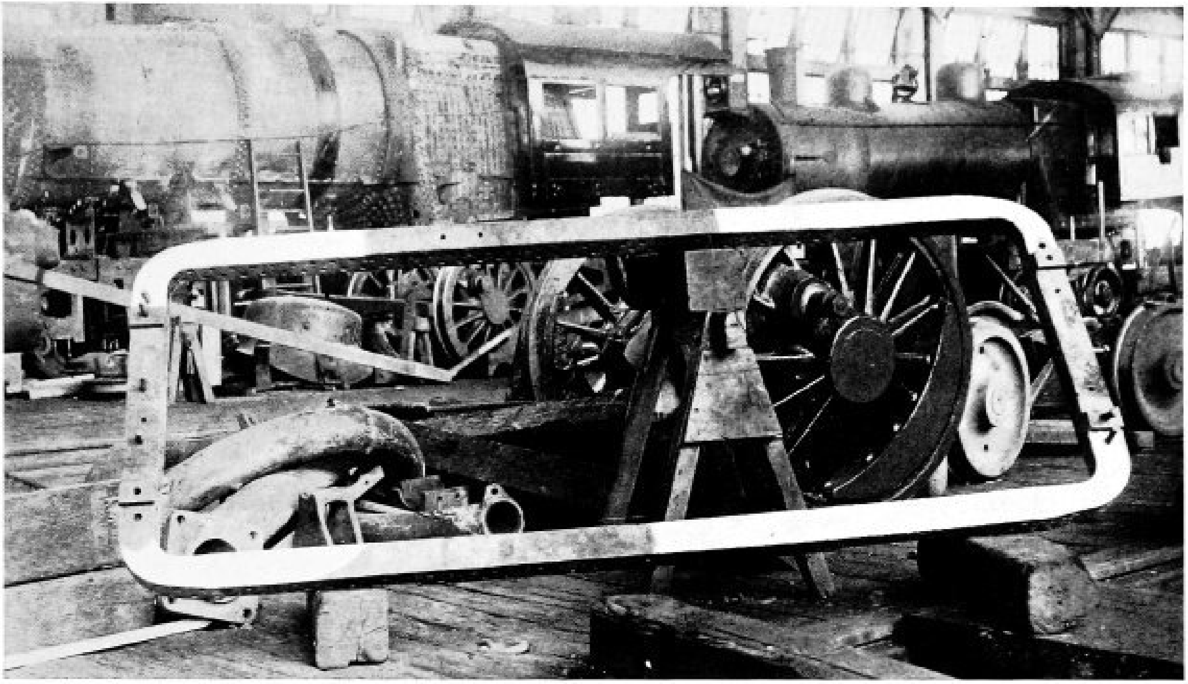
Another operation in which the electric arc has been employed to great advantage in railroad shops, is the



Blow holes developed in this large casting during machining. The holes on the left have been chipped and cleaned for Electric Welding. Completed welds are shown at the right before being remachined.



Two left sketches show old method of expanding and beading over boiler flues in end sheets without welding. Four right sketches show methods used in welding boiler flues in place.

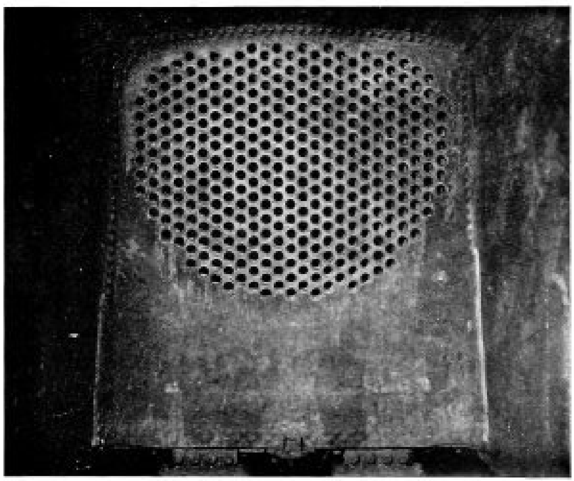


Corroded surface of locomotive boiler mud ring repaired by Electric Arc Welding.

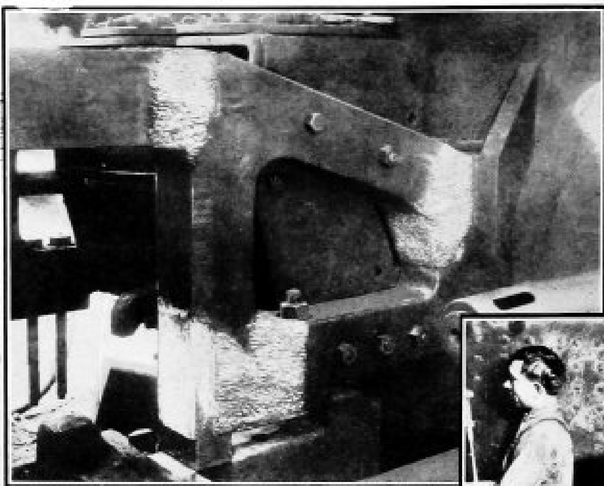
maintenance of steel driving wheel centers, which can be easily repaired and restored to service with a very considerable saving not only in time but also in expense, over former methods. This process is of very great value in reclamation work, as it is not only the most economical, but at the same time, the most effective method of repairing and reclaiming worn equipment, which otherwise would have to be scrapped. The esteem in which the arc welding process is held by the railway master mechanics may be determined from a report made after a year's investigation by the Committee on Design, Construction and Inspection of Locomotive Boilers of the American Railway Master Mechanics Association, a quotation from which follows:

"From the reports received from different roads, they indicate that considerable difficulty is experienced from welding flues with the oxy-acetylene process, while the roads using the electric process report very satisfactory results, especially one of the roads that tried out both methods and found that the electric process gave such good results that it has adopted this for standard practice and has at least 200 engines now running with flues welded in. The flues have seen considerable service and when engines were brought into the shop for intermediate repairs it was not necessary to remove the flues, which had been their practice heretofore. Therefore, your committee recommends the electric process for welding flues.

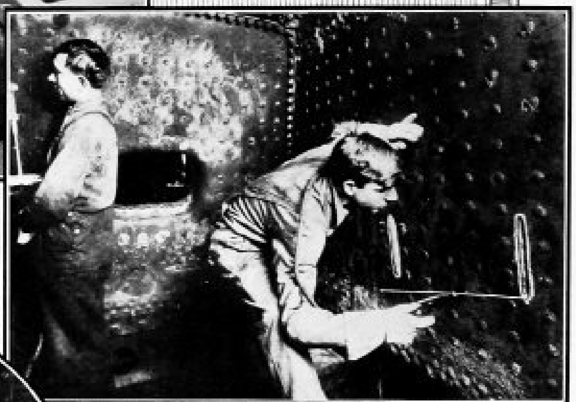
"It appears that the cost of welding flues in accordance with the electric process is cheaper than with the oxy-acetylene process. It also gives better service. It must be remembered that maintenance cost is al-



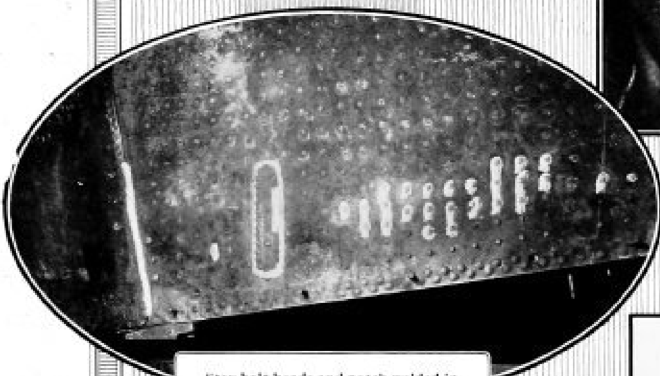
Welding seams in back tube sheet of locomotive fire box.



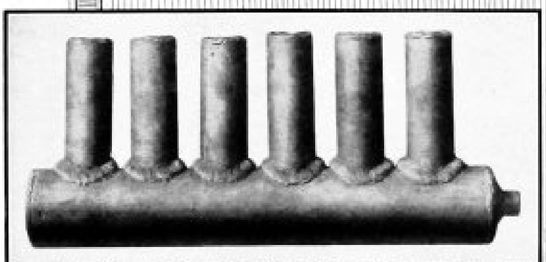
Welded triple fracture in locomotive frame.



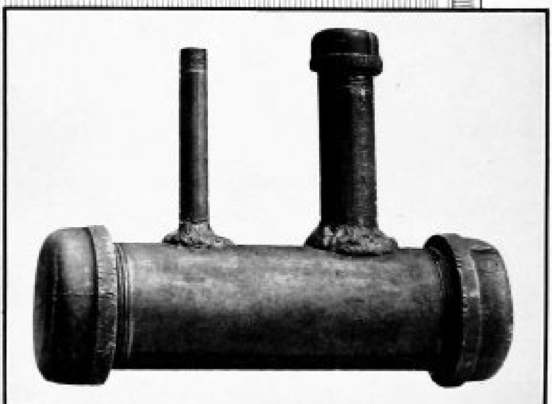
Welding patches in side walls of locomotive fire box.



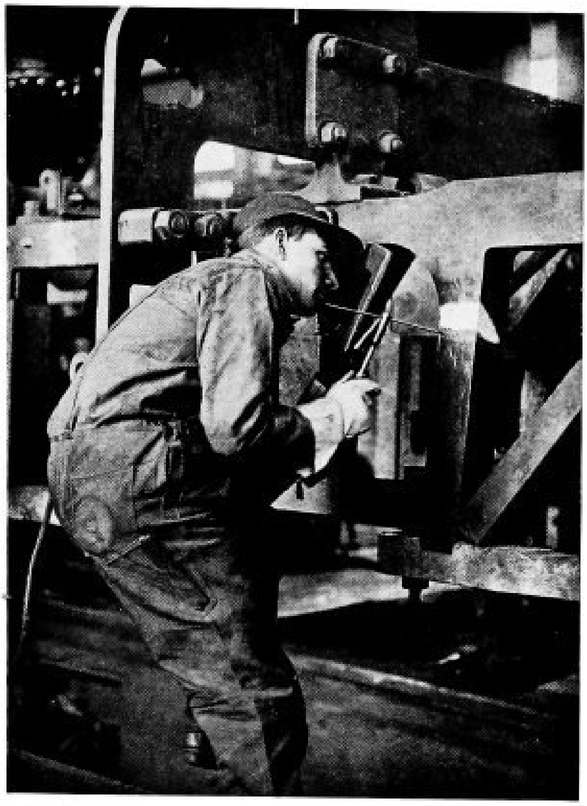
Stay bolt heads and patch welded in locomotive fire box.



Welded pipe sections.



3450 Pounds pressure per sq. inch failed to rupture welded pipe joints.



Repairing a broken locomotive frame. The weld, which is shown in white is 3 inches high, $4\frac{1}{2}$ inches wide, and 4 inches deep. One man finished the entire job in about 5 hours.

most entirely eliminated; also that engine failures are avoided and engines can be kept in service a greater length of time. The present indications are that flues can be run the three-year limit without removal."

Electric Railway Shops. Arc welding is in extensive use in this field. Broken axle brackets and motor frames are quickly repaired. Worn or broken parts of cars such as truck frames, brake hangers, journal boxes, gear cases, resistors, drawheads and underframing, can nearly always be repaired without taking the truck from under the car, owing to the ease of application of the electric arc.

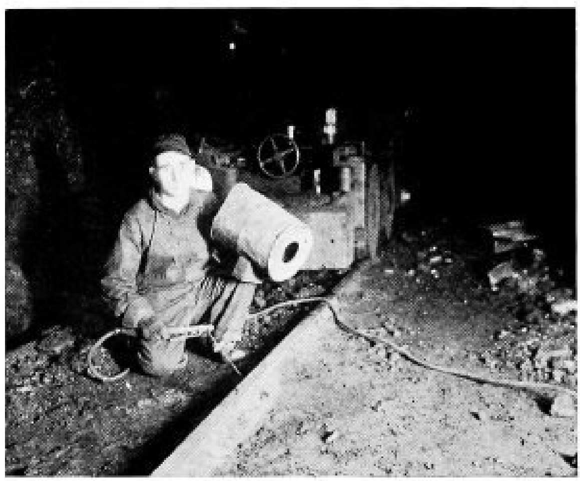
The arc welding process is capable of effecting many economies in this field on account of the numerous repairs which can be made to the rolling stock without the necessity of dismantling it, which, coupled with the saving resulting from keeping the car in service rather than having it idle in the shops, is typical of the savings being effected by street railway master mechanics all over the country.

Railway Track Systems. Another interesting application on electric and steam railroads is that of building material on cupped rails, worn track frogs, and cross-overs which are subject to severe and rapid local wearing at points which are hammered by the wheels of passing cars. It is frequently difficult as well as expensive to replace such pieces of work in busy streets of large cities, and therefore the arc welding process is particularly adaptable as the worn parts can be built up by depositing metal thereon, and subsequently ground into shape without being removed. In fact, the only way in which they can be repaired is by the use of the arc process, the other alternative being to put in new rails, frogs or cross-overs.

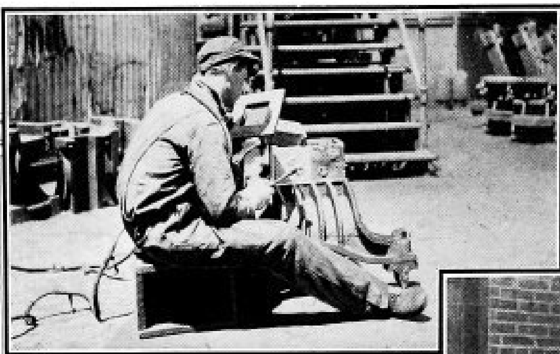
Some railway companies also make a practice of welding fish plates or rail joints to the rails instead of the bolted or riveted construction previously used.

Shipyards. Probably in no one industry has the arc welding process made more advance recently than in the building of ships. Formerly used only for incidental work on repair of boilers, hatchways, engine room equipment and detail parts about the ship, it is now being applied to other portions of ship construction such as bulkheads, coffer dams, and work of a similar character. The indications are that the fabrication of ships in this manner, thereby replacing to a great extent the riveted construction, will very considerably shorten the time and reduce the expense of ship construction.

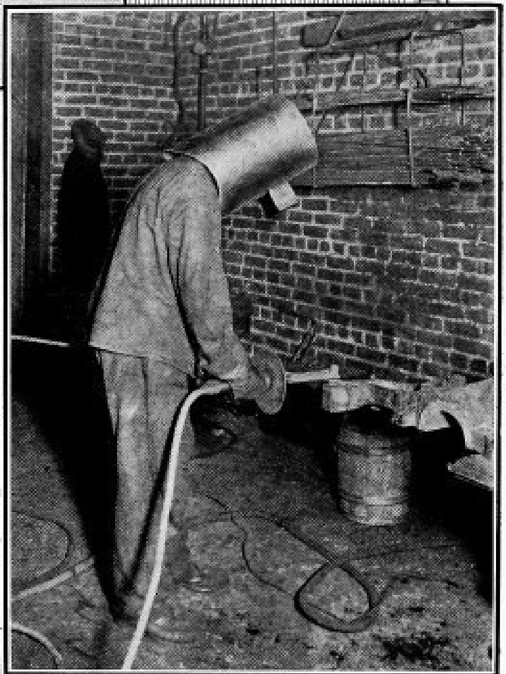
There are so many fittings and parts employed in ship building which can be welded at a reduced cost by the arc process that it has already become a vitally important and indispensable adjunct to this industry.



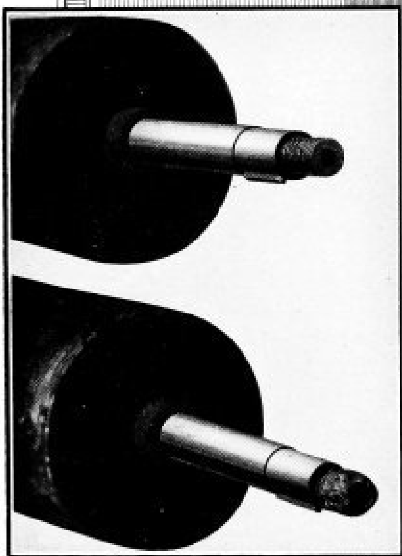
Cupped rails, worn track frogs and cross-overs can be easily built up and subsequently ground into shape without being removed.



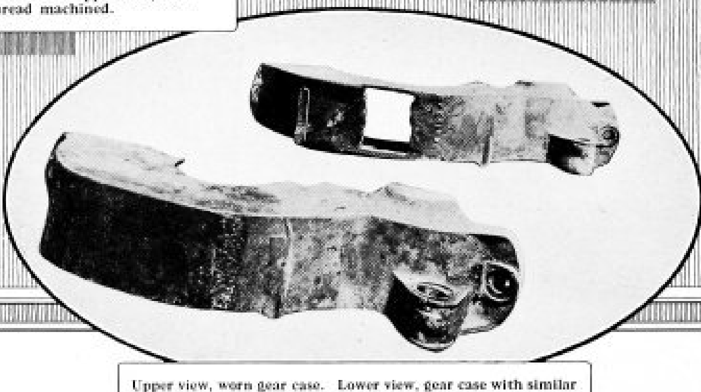
Welding a worn electric railway truck spider.



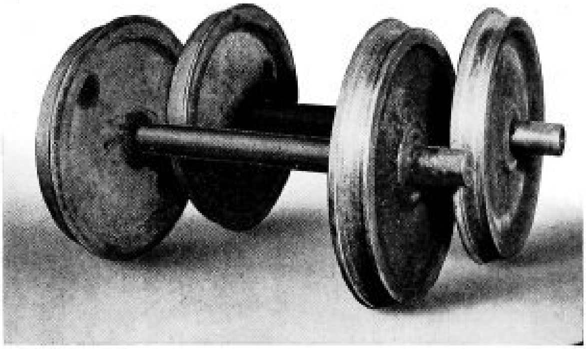
Repairing a railway motor bracket.



Lower view, worn thread of armature shaft covered over with new metal—Upper view, new thread machined.



Upper view, worn gear case. Lower view, gear case with similar hole patched by Arc Welding.



Worn car wheels that can be built up and re-machined for further service.

Advantages of Arc Welding

The principal advantages of arc welding are:

1—Low cost.

2—Ease and convenience of application.

3—Speed of operation.

4—Reliability of results.

5—Reclaiming defective material.

6—Safety.

7—Conservation of material.

8—Less skilled labor required.

The cost of welding by the electric arc process in its field of application is lower than by any other process with which it can be compared. The reason for this is the high temperature produced by the electric arc within a given area. Comparative costs made on the performance of the same work by means of the oxy-acetylene method show the arc process to be invariably from one-half to one-third cheaper than the oxy-acetylene process.

The ease and convenience of its application is another big advantage which has brought arc welding into popular favor to such a great extent during recent years. The fact that it is possible to do overhead welding with the metal electrode process widens its application considerably.

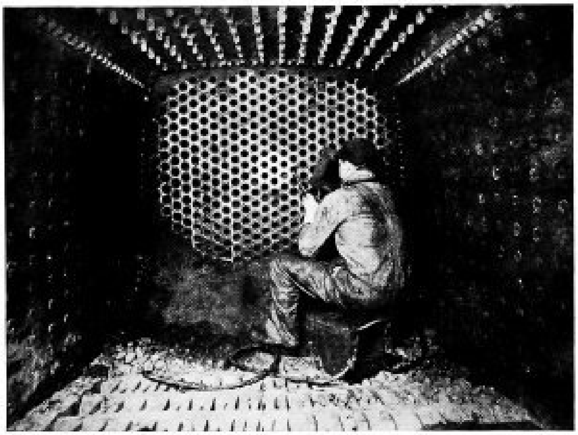
The following examples of savings effected by arc welding in a railroad shop are taken from actual jobs carried through the shop at different times and show the actual costs of welding and of putting the apparatus back into service by either replacement or repair of the old parts.

Savings Effected in a Railway Shop

Operation	Cost of Welding	Cost of Replacement or Repair by Other Methods
1—Welding tender draft casting	$ 1.11	$ 18.31*
2—Plugging 51 holes in expansion plate holes 1" dia. x ½" deep	2.75	10.15
3—Repairing mud ring	6.50	34.57°
4—Building up flat spots on locomotive drivers	.40	225.00**
5—Building up 4 piston valve flanges	9.52	24.20*
6—Repairing mud rings	5.57	32.70°
7—Cutting four 6-inch holes in tender deck sheets ½-inch thick	1.08	8.35
8—Building up jaws of 2 pedestal caps	3.49	10.00
9—Welding main rod, broken through end	6.35	70.49*
10—Repairing fire box	134.89	869.58†
11—Welding three spokes in driving wheel center	11.20	126.60*
12—Welding cracks in bulkhead in tender tank	2.33	8.00
13—Welding cracks in side and door sheets of fire box	4.23	24.35°
14—Repairing air drum	2.83	12.64*
15—Welding crosshead	.90	35.40‡
16—Welding casting for tank	3.69	19.83‡
17—Welding guide yoke	.55	47.00‡
18—Repairing mud ring	2.32	29.40
19—Welding four eccentric rods	.75	13.08
20—Welding expansion plate	.45	4.09‡
21—Welding cracked crown sheet	1.03	95.00‡
22—Welding flue bridges	.78	67.00‡
23—Welding cylinders	.76	13.80
24—Welding door holes	4.53	10.51

* New parts required
° Repair
** Estimated cost to turn down all drivers as would otherwise be required. This would mean also the loss of at least one year's wear on the tires.
† New fire box required
‡ New part

Worn car wheel (tread and flange) built up by Electric Arc Welding before re-machining.



Welding flues in back flue sheet in locomotive fire box.

Ease of Application. One of the prime features of electric arc welding that makes it so essential to industry is its ease of application. It can be applied wherever electric current is available, and can be carried to the work. This is of particular value in many instances, especially in the case of a railroad desiring to repair a locomotive frame. The equipment can be taken to the yard and the work done without the necessity of taking the locomotive to the round house or of dismantling it.

It is simple, easily operated and can be applied to overhead work, where it would not be possible to use other welding processes.

Speed of Operation. It is possible to weld a great deal faster with the arc process because of the ease of application and the intense heat produced by the arc within a limited area. While machining a cast steel fly wheel recently, a large blowhole was discovered which seriously affected not only its strength but also the appearance. Without removing the casting from the machine, the defect was repaired in fifteen minutes and the machining work proceeded. Had it not been for the use of the arc welding process, the work would have been delayed until a new casting could have been obtained.

Reliability of Results. Not only has the arc welding process demonstrated its value as to cost and time saving but reliable results are assured. For example one railroad reports the use of approximately 100 locomotives with welded frames without any subsequent failures and another road has had 80 per cent of its locomotives operating with electrically welded frames without a single failure. Examples of successful welds might be multiplied by the hundreds of thousands.

Reclaiming Defective or Worn Material. It frequently happens in many manufacturing operations that a defect in a casting is not discovered until a considerable amount of machine work has been done and its value correspondingly increased. By the use of the arc welding process the defect can be repaired, frequently without removing the work from the machine, and thereby obviating the probability of having to scrap the casting.

Worn parts of castings, such as shafts, pinions, gears, etc., can be built up by the addition of new metal, machined and put back into service, thus effecting very material savings, over the replacement by new castings.

Safety. Electric arc welding is essentially a low voltage operation as the potential across the arc will not exceed from 20 to 40 volts and the maximum open circuit potential for the best results, should not be over 60 volts. Therefore, danger from this source is eliminated.

Protective devices are provided which insure the operator against any injurious effects from the glare of the arc.

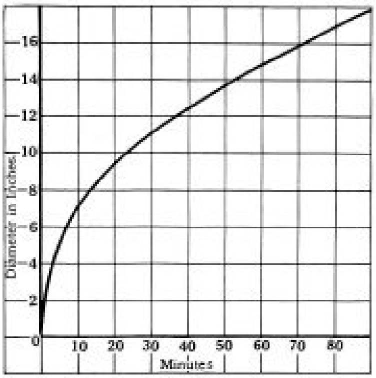
Conservation of Metal. Less metal is used when a job is done by the arc welding process than when riveting construction is employed, as in the latter case, it is necessary to lap the ends over one another and pass the rivets through the lap, whereas with the arc it is only necessary to supply the metal to fill in a small gap between the two ends and no rivets or other fasteners are required. This may seem like a small matter, but when used in connection with a process like the manufacture of wash boilers and similar receptacles, where the quantities run into the thousands, the saving is a very marked one.

Less Skilled Labor Required. Due to the numerous manufacturing and repair operations in which arc welding has superseded other processes, it has been possible to dispense, in many cases, with the skilled mechanics and operators formerly required. This applies particularly to the riveting process in which the operator always requires a helper.

Frequently, it is difficult to obtain skilled labor required in the different processes, whereas operators can be easily and readily instructed in arc welding. The mistakes made by beginners can generally be easily corrected, and the time required for instruction is brief for a man possessed of ordinary intelligence.

Cutting Metals

In this application the carbon electrode process is used (See page 22), and a current value of 150 to 800 amperes, depending on the thickness of the metal and the speed of cutting desired. A moderate cutting speed is obtained at a small operating expense, adapting it particularly for use in foundries for cutting off risers, sink heads, for cutting up scrap, and general work of this nature where a smooth finish cut is not essential.

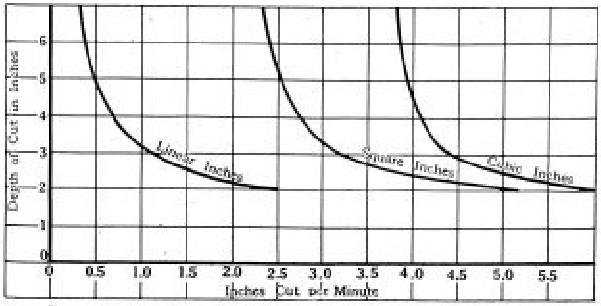


Rate of cutting cast iron of circular cross section.

The cross section of these risers, etc., is frequently of considerable area, but by the use of the proper current value, they may be readily removed.

The following table shows the results obtained from tests in cutting steel plate with the electric arc and the accompanying curves show the rate of cutting cast iron sections of various shapes, cast iron plates, circular cross sections, and square blocks. The curves are based on data secured through an extensive series of observations using about 600 amperes.

THICKNESS IN INCHES	CURRENT IN AMPS.	SPEED MINUTES PER FT.	KW-HRS. PER FT.	POWER COST PER FT.	TOTAL COST PER FT.
3/8	400	.50	.312	\$.00312	\$.0056
1/2	400	1.20	.75	.0075	.0135
5/8	400	2.14	1.34	.0134	.0240
3/4	400	3.00	1.88	.0188	.0340
1	600	3.75	3.50	.0350	.0540
1 3/8	600	4.32	4.10	.0410	.0630
2	600	6.75	6.30	.0630	.0970
4	600	16.90	15.50	.1550	.2390
6	800	29.00	36.20	.3620	.5100
8	800	40.50	50.00	.5000	.7000
10	800	59.00	74.00	.7400	1.0300
12	800	65.00	82.00	.8200	1.1500



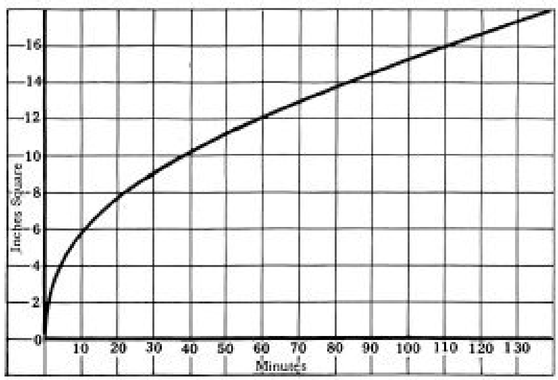
Rate of cutting cast iron plates.

Metals that can be Welded

The question naturally arises as to what metals can be welded with uniform results. Although theoretically it is possible to weld any two metals, practically, there are limitations. Causing metal to melt and run into a joint does not constitute a good weld. The weld is made when the pieces of metal to be welded are in a liquid state with the slag and oxide floating on the top.

The metals best adapted to the arc welding process are wrought iron, boiler plate, and those grades of steel used for fabricated shapes in general commercial work, which under proper conditions can be welded with unvarying success.

In order to afford a clear conception of the workable metals and some of their characteristics, the following explanatory paragraphs are given in which



Rate of cutting cast iron square blocks.

use has been made of the definitions contained in the report of the Arc Welding Committee of the American Railway Electrical Engineers' Association.

"Iron ore as it is mined from the earth is a mixture of red oxide of iron, silicon, sulphur, phosphorus, carbon, either in the free or combined state or both, copper, quartz, slate, in fact the ore may contain almost any of the minerals of the earth. The mining of this ore and its conversion into iron and steel products forms the world's greatest industry.

"Iron ore is smelted in blast furnaces to produce metallic iron. The smelting process consists essentially of the removal of the oxygen which is combined with the iron. The product, however, is not chemically pure iron. Pure iron is a laboratory product and is of no commercial value. The metal which comes from the blast furnaces of this country contains the following elements: iron, carbon, silicon, manganese, sulphur, phosphorus, and oxygen. Solutions and chemical compounds of these elements exist in the metal, but for our purposes here it is sufficient to state only that the elements are present in the metal in some form. The molten metal from the blast furnace is cast into the form known as pig iron.

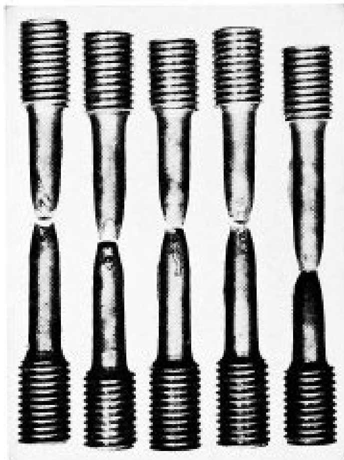
"**Cast Iron.** The term 'cast iron' is applied to pig iron after it has been re-melted in a cupola and cast into some commercial shape. There may or may not be a difference in chemical composition between pig iron and cast iron. The two terms are used to designate the form of the iron rather than any difference in chemical composition.

"The gray iron casting is obtained by melting pig iron in a cupola and casting the molten metal in sand. If there is a slight change in the chemical composition of the metal, it is unsought and incidental to the remelting. The sand mold allows the metal to cool slowly. The amount of free carbon in the form of graphite in gray iron is comparatively large. This gives the gray appearance to the fracture from which the name is derived.

"The white iron casting is made of metal of the same chemical composition as is used to make gray iron castings. The molten metal is cast in cold metal molds and is thereby 'chilled.' It is evident that no very great change in the chemical composition could take place in this 'chilling' process. However, the sudden cooling arrests the formation of the crystalline structure to such an extent that the physical properties of 'chilled' iron are different from those of gray iron in which the normal crystalline structure exists. Chilled iron is hard and brittle. The white appearance of the fracture of the metal gives the cause for its name and is due to the comparatively small amount of free carbon present in the metal."

A large amount of cast iron usually reaches the welder's table and he is frequently asked to weld broken iron castings. Cast iron is difficult to weld by any process under the most favorable conditions due to its brittleness and low tensile strength, but it can be done by the exercise of care in the selection of welding equipment, proper electrodes, and pre-heating the casting. There is no way, however, by which the strength of the welded joint may be accurately predetermined and the work should never be undertaken unless the person responsible is thoroughly familiar with these facts and of the uncertainty of the results.

"Malleable castings are annealed white iron castings. The castings before they are annealed are hard and brittle as compared with gray iron castings. White iron contains carbon in the combined state. White iron is annealed to free the carbon. Malleable iron, therefore, is essentially free iron or ferrite in which is intermingled free carbon in the form of graphite. Since ferrite is soft and malleable, the annealed casting partakes of these properties and is called a malleable casting. Annealed castings seldom show the effect of the annealing throughout their entire mass; as a rule the annealing does not produce a noticeable effect beyond a fraction of an inch below the surface of the casting."



1 2 3 4 5

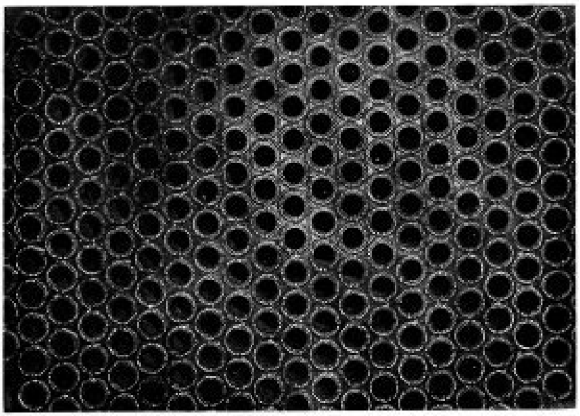
Negligible effect of striking an arc on the physical characteristics of mild steel.

TEST PIECE	1	2	3	4	5
Ultimate Tensile Strength —Lbs. per Sq. In.	49100	49200	48400	48600	49350
Percent Elongation	43	41.7	41.8	44	40

The correction of flaws in malleable castings by the electric arc process effects very large savings. The welding is always done after the casting has been annealed and made into a malleable casting. The annealing usually affects the casting only to a small depth, and the welding is done in this annealed or softened section which then becomes similar in character to carbon cast steel. The work may be done with either the carbon or metal electrode process, depending on the size and shape of the casting. Due to the thinness of the annealed section a comparatively low current density is used on the carbon electrode. The electrode in the hand of the operator is sometimes made the positive terminal in order to reduce the effective heat on the casting. If the casting is to be machined in the welded section, it must be re-annealed.

Wrought Iron. Wrought iron is different from all cast iron in that it has not only been melted, but also been given mechanical treatment. The mechanical treatment consists of squeezing the slag out of the metal and rolling it into bars of convenient shape. These bars are called "merchant bars." The quality of wrought iron is a function of its purity, i.e., its freedom from every substance except iron or ferrite. Norway and Swedish irons have heretofore been the purest which could be obtained, due principally to the fact that the ore of these countries does not contain phosphorus or sulphur.

Wrought iron is used as a base in the manufacture of the highest quality of crucible steels, owing to its purity.



Flues are welded to rear flue sheet in locomotive fire box.

Converter Steel. The manufacture of steel by the Bessemer or Open Hearth process, amounts essentially to the melting of pig iron in a cupola from which it is transferred to the converter and the impurities removed by oxidation, after which the elements desired are added. The process is said to be acid or basic, according to the kind of lining which is used in the converter. The basic lining produces a chemical reaction in the iron which removes the phosphorus. After the metal is freed, so far as that is possible, from the impurities, a number of different elements may be added to get certain properties in the steel. Among the elements which are added are: carbon, manganese, nickel, chromium, vanadium, tungsten. In ordinary boiler plate and structural shapes, the controlling elements are carbon and manganese, and these two elements are the only ones added. The carbon content determines the tensile strength. The manganese is added simply to toughen the metal and prepare it for the mechanical treatment in the rolls. Boiler plate and shapes usually contain from two to three-tenths of one per cent carbon and from four to six-tenths of one per cent manganese.

After the steel has been given the desired composition it may be drawn from the converter into ladles and later poured into the molds to make steel castings, or it may be drawn from the converter into ingot molds and prepared for the rolls. It should be noted that plates and shapes are simply cast steel which has been subjected to mechanical treatment in the rolls.

If the steel is to be finally used for forgings, the ingot is simply rolled into bars called billets. These billets are then subjected to a final mechanical treatment in the drop-forging machine.

The heat treatment of steel is a broad subject, but it consists essentially of changing the crystaline structure of the steel without changing its chemical composition in order to get certain desirable properties.

Cast Steel. Neglecting the effect of heat treatment, the physical properties of cast steel are determined by the kind and amount of the several "impurities" which are contained in the metal. There are many combinations of these "impurities," which are used to get certain characteristics in the steel which seem to meet the requirements of the service demanded of the casting.

While there are almost an unlimited number of combinations of these elements which may be obtained, the ordinary steel foundry uses a relatively small number of the possible combinations. Each element produces its characteristic effect on the metal, but the effect on the tensile strength, ductility, toughness and malleability, is not necessarily proportional to the quantity of the added element over a very wide range.

General Effect of Impurities

Silicon—The presence of silicon in iron or steel causes brittleness. Silicon in the metal increases its ability to resist abrasion. One-half of one per cent is about the largest amount of silicon present in any commercial cast steel.

Arc Welding Accessories used in preparing and making the welds shown in steel casting.

Phosphorus—This element is undesirable in any quantity and is eliminated to as great an extent as possible. Phosphorus causes "cold short" or brittleness.

Sulphur—Like phosphorus, sulphur in steel is undesirable. Sulphur causes "hot short" or brittleness when the metal is red hot or hotter.

Manganese—Up to .2 per cent, the presence of manganese in steel improves the ductility and toughness. It also helps to remove the phosphorus and sulphur from combination with the iron. Between 1.5 and 5.5 per cent manganese causes brittleness in steel. Around 10 per cent the steel is ductile again, but very hard and cannot be softened.

Nickel—Nickel increases the tensile strength of steel without impairing the elasticity. Nickel steel does not rust as badly as steel without the nickel. From 3 to 3.5 per cent is the usual amount added.

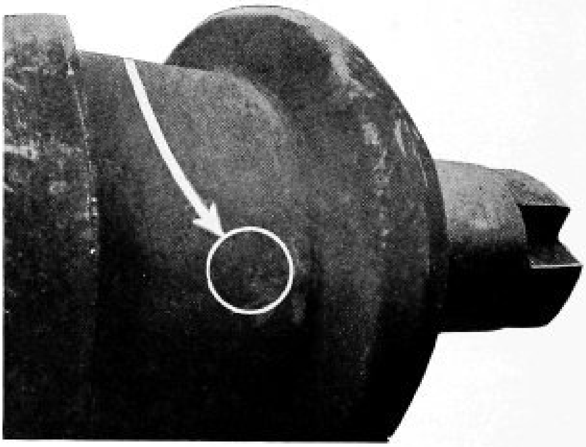
Vanadium—Vanadium is similar in its effect on steel to nickel.

Chromium—Chromium is similar in its effect on steel to manganese.

Tungsten—Tungsten is used in the manufacture of high speed steels. High speed steel has the property of retaining its hardness at high temperatures.

Little is known at present regarding the effect on the weldability produced by the presence of most of the impurities given above, where the electric arc welding process is used. No data has been published on the subject. It is known, however, that steel containing 5 per cent or more carbon is subject to "burning" at much lower temperatures than low carbon steels. This fact can readily be observed in arc welding practice, i.e., the tendency being toward "burnt" metal in the weld. The observations which have been made up to the present time seem to indicate that the tendency toward "burning" shown in steels of comparatively high carbon content, is the only considerable effect which is produced on the weldability by the presence of any of the impurities in their usual amount.

Metals with comparatively low fusing points, such as brass or bronze that have less than 3 per cent zinc content and copper, can be welded by the arc process if care is taken. Brass having a high percentage of zinc is quite apt to be porous as the zinc volatilizes at a comparatively low temperature. Aluminum is difficult to weld because of its oxidation at a lower temperature than its melting point. All of these metals fuse at points so much below the heat of the electric arc that unless great care is used they are injured by the heat.



Chipped roll repaired by means of Electric Arc.

The Electric Arc

Electric Arc Welding is the transformation of electrical energy into heat through the medium of an arc for the purpose of melting and fusing together two metals without pressure, allowing them to melt, unite, and then cool. The process is sometimes referred to as autogenous welding, since fusion is accomplished entirely without pressure. The heat is produced by the passage of an electric current from one conductor to another through air which is a poor conductor of electricity, and offers a high resistance to its passage. The heat of the arc is the hottest flame that is obtainable, varying in temperature estimated to be between 3500 and 4000 degrees Centigrade.

The metal to be welded is made one terminal of the circuit, the other terminal being the electrode. By bringing the electrode into contact with the metal and instantly withdrawing it a short distance, an arc is established between the two. Through the medium of the heat thus produced, metal may be entirely melted away or cut, added to or built up, or fused to another piece of metal as desired.

A particularly advantageous feature of the electric arc weld is afforded through the concentration of this intense heat in a small area, enabling it to be applied just where it is needed.

Direct current is now generally used for arc welding because at the present stage of development of the art, results are more satisfactory than can be obtained by the use of alternating current.

When using direct current, the metal to be welded is made the positive terminal of the circuit, and the electrode is made the negative terminal. More heat is generated at the positive than at the negative terminal, therefore, if the work to be welded is made positive, more of the heat is concentrated at the point where it is most needed.

Two systems of electric arc welding, based on the type of electrode employed, are in general use:—

1—Metal electrode.

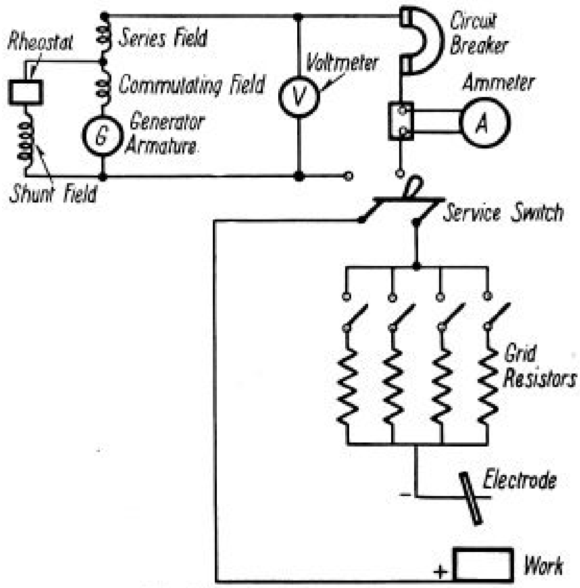
2—Carbon electrode.

Metal Electrode Process

In this process, a metal rod or pencil is made the negative terminal, and the metal to be welded becomes the positive terminal.

When the arc is drawn, the metal rod melts at the end and is automatically deposited in a molten state in the hottest portion of the weld surface. Since the filler is carried directly to the weld, this process is particularly well adapted to work on vertical surfaces and to overhead work.

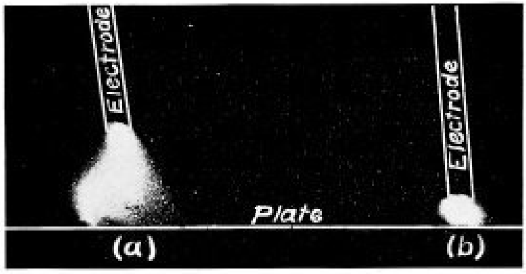
If the proper length of arc is uniformly maintained on clean work, the voltage across the arc will never greatly exceed 22 volts for bare electrodes and 35 volts for coated electrodes. The arc length will vary to a certain degree, however, owing to the physical impossibility of an operator being able to hold the electrode at an absolutely uniform distance from the metal throughout the time required to make the weld.



Simple schematic welding circuit.

It is very essential that the surfaces be absolutely clean and free from oxides and dirt, as any foreign matter present will materially affect the success of the weld.

Characteristics of the Arc. When using a metallic electrode, the arc which is formed by withdrawing it from the work, consists of a highly luminous central core of iron vapor surrounded by a flame composed largely of oxide vapors. At the temperature prevailing in the arc stream and at the electrode terminals, chemical combinations occur instantaneously between the vaporized metals and the atmospheric gases. These reactions continue until a flame of incandescent gaseous compounds is formed which completely envelops the arc core. However, drafts created by the high temperature of the vapors and by local air currents tend to remove this protecting screen as fast as it is formed, making it necessary for the welder to manipulate the electrode so that the maximum protective



Welding Arcs. (a) Long arc of 175 amperes showing deflection of arc stream to left and oxide flame being blown to right, thereby exposing the new metal. (b) Short arc of 175 amperes showing concentration of gases completely enveloping the newly deposited metal. By reason of intensely actinic light from the arcs, the electrodes and the plate did not show in the photograph, and their position was sketched on in the print.

flame for both arc stream and electrode deposit is continuously secured. This can be obtained automatically by the maintenance of a short arc and the proper inclination of the electrode towards the work in order to compensate for draft currents.

Selection of Electrodes. The use of a metallic electrode for arc welding has proved more satisfactory than the use of a carbon or graphite electrode which necessitates feeding the new metal or filler into the arc by means of a rod or wire. The chief reason for this is that, when the metallic electrode process is used, the end of the electrode is melted and the molten metal is carried through the arc to be deposited on the material being welded at the point where the material is in a molten state produced by the heat of the arc. Thus a perfect union or fusion is produced with the newly deposited metal.

Wire for metallic arc welding must be of uniform homogeneous structure, free from segregation, oxides, pipes, seams, etc. The commercial weldability of electrodes should be determined by means of tests performed by an experienced operator, who can ascertain whether the wire flows smoothly and evenly through the arc without any detrimental phenomena.

The following table indicates the maximum range of the chemical composition of bare electrodes for welding mild steel:

Chemical Composition

Carbon trace up to	*.25%*
Manganese trace up to	*.99%*
Phosphorus not to exceed	*.05%*
Sulphur not to exceed	*.05%*
Silicon not to exceed	*.08%*

The composition of the mild steel electrodes, commonly used, is around .18 per cent carbon, and manganese not exceeding .5 per cent, with only a trace of phosphorus, sulphur and silicon.

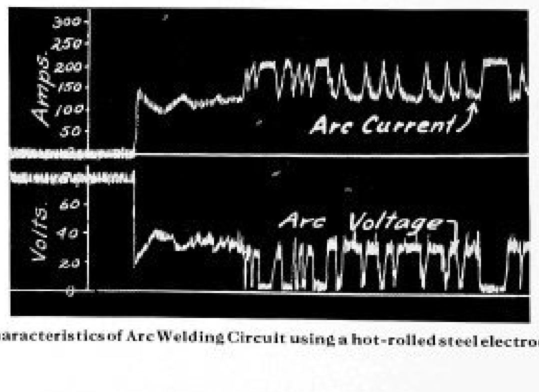
The size, in diameter, ordinarily required will be 1/8 in., 5/32 in., and 3/16 in. and only occasionally the 3/32 in.

These electrodes are furnished by a number of firms, among whom are John A. Roeblings Sons Co., Trenton, N. J.; American Rolling Mills Co., Middletown, Ohio; American Steel & Wire Co., Pittsburgh; and Ferride Electric Welding Wire Co., New York City; Page Woven Wire Co., Monessen, Pa.; John Potts Company, Philadelphia.

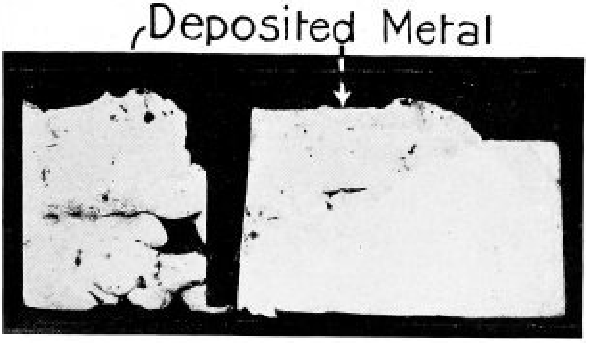
Coated Electrodes. A coated electrode is one which has had a coating of some kind applied to its surface for the purpose of improving the metal in the weld by totally or partially excluding the atmosphere from the metal while in a molten state when passing through the arc and after it has been deposited. By employing such coating, the use of special alloy steel electrodes has been made possible—for example: manganese steel, carbon steel, nickel steel, vanadium steel, and tungsten tool steel have all been deposited successfully as well as Ampco bronze and copper, using the metallic arc.

A cheap simple coating not only for the special steels but also for the commoner mild steel electrodes as well, is needed not only to improve the metal in welds made with the present grade of welding wire now in general use, but also to make possible the use of a better grade of welding wire for some of the more important operations.

The proper size of electrode may be determined from the accompanying curve, from which it will be seen that the class of work, and current used are both factors determining the size of the electrode for welding steel plates of various thicknesses. To find the diameter of the metallic electrode required, select, for example, a three-eighths plate, and follow horizontally to the "Thickness of the Plate Curve." The vertical line through this intersection represents about 110 amperes as the most suitable current to be used with



Characteristics of Arc Welding Circuit using a hot-rolled steel electrode.



Cross section of weld made with coated electrode showing slag inclusions liable to be characteristic of deep welds when using asbestos-covered electrodes.

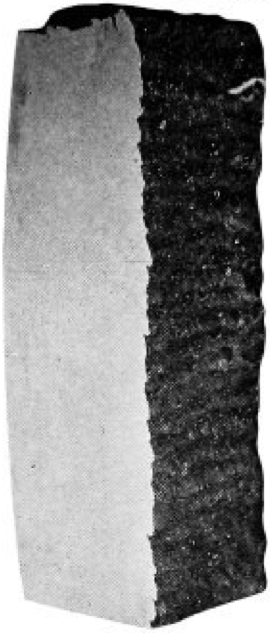
this size of plate. Then follow this vertical line to its intersection with the "Diameter of Electrode" curve which locates a horizontal line representing approximately five thirty-seconds inch diameter electrode. In a similar manner, a one-half inch plate requires about 125 amperes and a five thirty-second inch electrode.

Cross sections of weld made with Norway iron electrodes, showing slag content caused by excessive oxidation characteristic of very low carbon electrodes.

The Current Value. The amount of current to be used is dependent on the thickness of the plate to be welded when this value is ¾-inch or less. Average values for welding mild steel plates with direct current are indicated by the curve referred to above in connection with the selection of the electrode of proper size. This data is also shown by the following table:

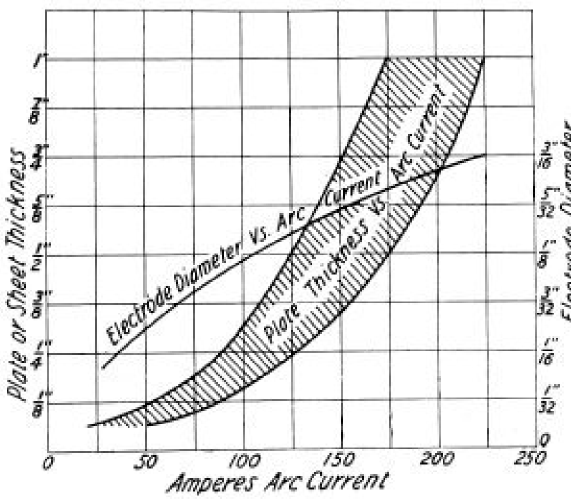
PLATE THICKNESS IN INCHES	CURRENT IN AMPERES	ELECTRODE DIAMETER IN INCHES
1/16	20 to 50	1/16
1/8	50 to 85	3/32
3/16	75 to 110	1/8
1/4	90 to 125	1/8
3/8	110 to 150	5/32
1/2	125 to 170	5/32
5/8	140 to 185	5/32
3/4	150 to 200	3/16
7/8	165 to 215	3/16
1	175 to 225	3/16

It should be borne in mind, however, that these values are only approximate as the amount of current to be used is dependent on the temperature of the plate and also upon the type of joint (see page 29). For example, when making a lap weld between two one-half inch steel plates at ordinary air temperature of about 65° F. it has been found that the best results were obtained by using a current of about 225 amperes, and a 3/16 inch diameter electrode. The explanation for the high current permissible is the tremendous heat storage and dissipation capacity of the lapped plates which makes the combination practically equivalent to that of a butt weld of two one-inch plates. For that reason the above values will be very greatly increased in the case of lap welds which require practically twice the amount of current taken by the butt welds.



Section through fourteen pound metallic electrode deposit on ⅜" plate.

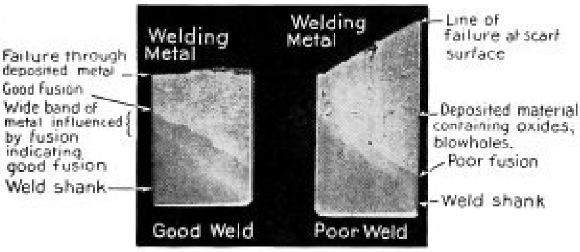
When the proper current value is used there will be a crater, or depression, formed when the arc is in-



Relation of approximate Arc currents and Electrode diameters.

terrupted. This shows that the newly deposited metal is penetrating or "biting into" the work.

The importance of the proper current value in determining the strength of a weld is shown in the accompanying illustration of two welds. The weld at the left shows good fusion and recession of original surface or material as well as no slag inclusion, all of which results from careful manipulation of the arc, and the use of the proper arc current. The weld at the right is poor, having been made with too low a value of current with consequent incomplete fusion, porosity caused by unfused overlapping metal, and failure during the test at the scarfed face instead of through the weld.



Character of welds.

Carbon Electrode Process

In this process, the negative terminal or electrode is a carbon pencil from 6 to 12 inches in length and from ¼ to 1½ inches in diameter. This was the original process devised by Bernados and has been in more or less general use for more than thirty years. The metal is made the positive terminal as in the metal electrode process in order that the greater heat developed in this terminal may be applied just where it is needed. Also, if the carbon were positive, the tendency would be for the carbon particles to flow into the weld and thereby make it hard and more difficult to machine.

The current used in this process is usually between 300 and 450 amperes. For some special applications as high as from 600 to 800 may be required, especially if considerable speed is desired. The arc supplies the heat and the filler metal must be fed into the weld by hand from a metallic bar.

The class of work to which the carbon process may be applied includes cutting or melting of metals, repairing broken parts and building up materials, but it is not especially adapted to work where strength is of prime importance unless the operator is trained in the use of the carbon electrode. It is not possible to weld with it overhead or on a vertical surface but there are many classes of work which can be profitably done by this process. It can be used very advantageously for improving the finished surface of welds made by metal electrodes. The carbon electrode process is particularly adapted to welding cast iron and nonferreous metals.

Preparation of the Work

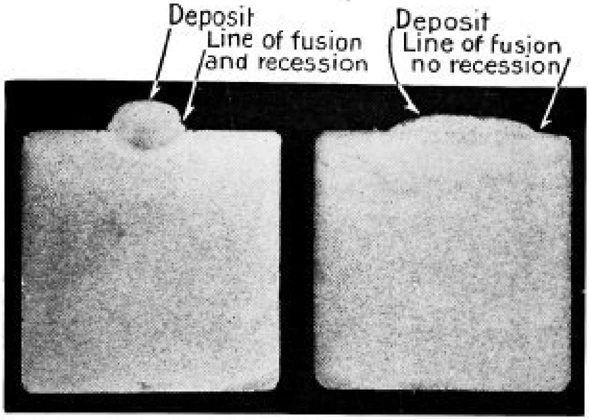
In order to prepare the metal for a satisfactory weld, the entire surfaces to be welded must be made readily accessible to the deposit of the new metal which is to be added. In addition, it is very essential that the surfaces are free from dirt, grease, sand, rust or other foreign matter. For this service, a sand blast, metal wire brush, or cold chisel are recommended.

If the edges of two plates are to be welded together with the plates in a common plane, the edges of both should be bevelled to an angle of 45 degrees, making a total of 90 degrees, into which metal can be deposited.

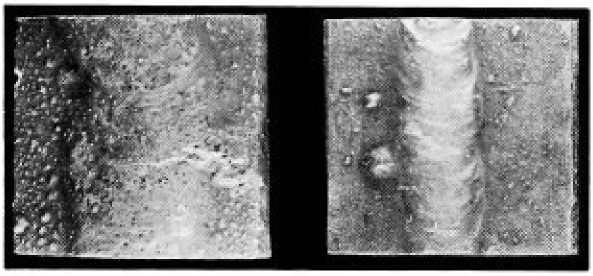
If the pieces can be turned for welding from both sides, then both edges of each plate may be bevelled only one-half as much, as new filler will be required to fill the angles. When cracks in castings are to be repaired, the material should be bevelled along the cracks in a similar manner. It is not advisable to remove more metal than is necessary to obtain the proper bevel.

Pre-heating. During the past few years rapid strides have been made in the improvement of steels by the proper correlation of heat treatment and chemical composition. The characteristics of high carbon and alloy steels, particularly, have been radically improved. However, no amount of heat treatment will appreciably improve or change the characteristics of medium and low carbon steels which comprise the greatest field of application for arc welding. Furthermore, the metal usually deposited by the arc is a low carbon steel often approaching commercially pure iron. It must be evident therefore that the changes of steel structure due to the arc welding process will not be appreciable and furthermore that any subsequent heat treatment of the medium or mild steel material will not result in improvements commensurate with the cost.

Pre-heating of medium and mild steel before applying the arc is not necessary and will only enable the operator to make a weld with a lesser value of current. This, however, will reduce the speed of welding because the rate of depositing the electrode metal is dependent upon the current flowing.



Left—Concentrated deposit on mild steel obtained by using a short arc length. Right—Diffused deposit on mild steel obtained by using a long arc length.



Top or plane view of cross sections shown above.

It is conceded that cast iron welds, especially if made with the metallic electrode, must be annealed before machining is done in the welded sections. This is necessary because at the boundary between the original cast iron and the deposited metal there will be formed a zone of hard, high carbon steel produced by the union of carbon (from the cast iron) with the iron filler. This material is chilled quite suddenly after the weld is made by the dissipation of the heat into the surrounding cast iron which is usually at a comparatively low temperature.

Although it is not absolutely necessary to pre-heat cast iron previous to arc welding, this is done in some instances to produce a partial annealing of the finished weld. The pre-heating operation will raise the temperature of a large portion of the casting. When the weld is completed, the heat in the casting will flow into the welded section, thereby reducing the rate of cooling. This will not yield as good results as actual annealing. To get the best results the annealing should be done before the casting has a chance to cool to the room temperature.

Arc Length

The maintenance of the proper arc length for the metallic electrode process is very important. Sections through deposits formed with a short arc and a long arc are shown in the accompanying illustrations, as well as the top views of the same deposits. It will be noted that with a long arc, it has been caused to move around an extended surface of the work probably by the natural air drafts with the results that there is only a thin deposit of the new metal with poor fusion. If, however, the arc is maintained short, much better fusion is obtained, the new metal will be confined to a smaller area, and the burning and porosity of the fused metal will be reduced by the greater protection from atmospheric oxygen afforded by the enveloping inert gases. With increase in arc length, the flame becomes harder to control, so that it is impossible to adequately protect the deposited metal from oxidation.

The arc length should be uniform and just as short as it is possible for a good welder to maintain it. Under good normal conditions the arc length is such that the arc voltage never exceeds 25 volts and the best results are obtained between 18 and 22 volts. For an arc of 175 amperes the actual gap will be about ⅛ inch.

Manipulation of the Arc

The arc is established by touching the electrode to the work, and drawing it away to approximately ⅛ inch, in the case of the metallic electrode. This is best done by a dragging touch with the electrode slightly out of vertical. The electrode is then held approximately at right angles to the surface of the work, as the tendency is for the heat to go straight from the end of the electrode. This assures the fusing of the work, provided the proper current and arc length have been uniformly maintained.

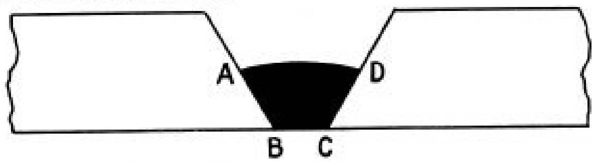


Diagram illustrating filling sequence.

A slight semi-circular motion of the electrode, which at the same time is moved along the groove, will tend to float the slag to the top better than if the electrode is moved along a straight line in one continuous direction and the best results are obtained when the welding progresses in an upward direction. It is necessary in making a good weld to "bite" into the work to create a perfect fusion along the edges of the weld, while the movement of the electrode is necessary for the removal of any mechanical impurities that may be deposited. It is the practice to collect the slag about a nucleus by this rotary movement and then float it to the edge of the weld. If this cannot be done, the slag is removed by clipping or brushing with a wire brush.

Filling Sequence

When making a long seam between plates, the operator is always confronted with the problem of expansion and contraction which causes the plates to warp and produce internal strains in both plates and deposited material. To minimize these difficulties welders have found numerous shop kinks from practical experience, some of which are given below.

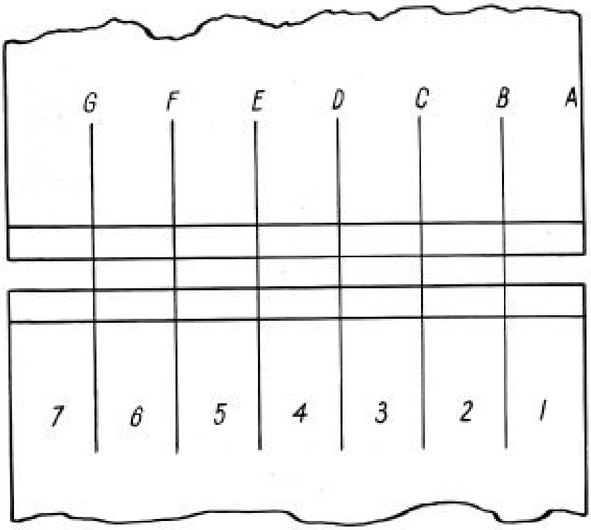


Diagram illustrating back-step method.

The accompanying sketch shows the method of welding two plates together. The plates are prepared for welding as previously described, and the arc is started at the point A. The welding then progresses to the point B, joining the edges together, to point D and back to A. This procedure is carried on with the first layer filling in a space of 6 or 8 inches in length, afterwards returning for the additional layers necessary to fill the groove. This method allows the entire electrode to be deposited without breaking the arc, and the thin edges of the work are not fused away as might be the case if the operator should endeavor to join these edges by moving the electrode in one continuous direction. This method also prevents too rapid chilling with consequent local strains adjacent to the weld.

*When making a long seam weld, for example, a butt weld between two plates, the two pieces of metal will warp and have their relative positions distorted during the welding process, unless the proper method is used. One which has been quite satisfactory is that in which the plates are fastened together by light tack welds about eight inches apart along the whole seam. The operator then makes a complete weld between the first two tacks as described in the preceding paragraph, and, skipping three spaces, welds between the fifth and sixth tacks and so on until the end of the seam is reached. This skipping process is repeated by starting between the second and third tacks and so on until the complete seam is welded. The adoption of this method permits the heat, in a restricted area, to be dissipated and radiated before additional welding is performed near that area. Thus the weld is made on comparatively cool sections of the plates which keeps the expansion at a minimum.

Another method very similar to the preceding one, is known as the back-step method, in which the weld is performed in sections as in the skipping process. After the pieces are tacked at intervals of six inches or less for short seams, the arc is applied at the second tack and the groove welded back complete to the first tack. Work is then begun at the third tack and the weld carried back to the second tack, practically completing that section. Each section is finished before starting the next.

The accompanying sketch shows the procedure of welding in a square sheet or patch. Work is started at A and carried to B completely welding the seam. In order that work may next be started at the coolest point, the bottom seam is completed starting at D, finishing at C. The next seam is A to D, starting at A. The last seam is finished, starting at B, and completing the weld at C.

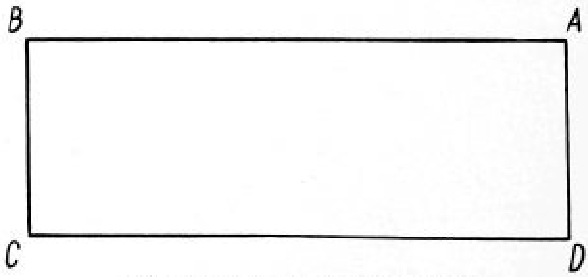


Diagram illustrating square patch method.

*This method was devised and has been successfully put into operation by Messrs. E. Wanamaker and H. R. Pennington, of the Chicago, Rock Island and Pacific R. R.

Alternating Current Arc Welding

Direct current has been used for arc welding because of the fact that it possesses certain inherent advantages that make it especially adaptable for this class of work. Very recently, however, the use of alternating current for arc welding has found a number of advocates.

When employing this form of energy, use is made of a transformer to reduce the distribution voltage to that suitable for application to the weld. Some manufacturers find it necessary to supply a fan for cooling the transformer in order to keep its size down to a minimum.

Inasmuch as the arc voltage is obtained directly from the distribution mains through a transformer, the theoretical efficiency is high compared with the direct current process which requires the introduction of a motor-generator or resistor or both. The efficiency of the A.C. equipments now on the market ranges from 60 to 80 per cent. The transformer, however, is designed to have a large leakage reactance so as to furnish stability to the arc, which very materially reduces its efficiency when compared with that of the standard distribution transformer used by lighting companies.

It is very difficult to maintain the alternating arc especially when using a bare electrode though this difficulty is somewhat relieved when use is made of a coated electrode.

If power is purchased from a central station, the cost for actual energy used will probably be less on account of the higher efficiency of the transformer. However, the welding process produces a very low power factor in the circuit, and if this is taken into consideration, as is being done generally by central stations at the present time, the resultant cost will be higher than that of the direct current process. The power factor is generally in the neighborhood of from 20 to 30 per cent, depending on the current value used.

If power generating equipment is purchased, the cost will be higher than for the equivalent capacity in the kilowatts of direct current machinery, owing to the very low power factor. For example, if it requires 10 KW at the arc, and the power factor is 25%, this would require a capacity of 40 KVA in the power house.

The speed of welding is slower with the A.C. process as it is practically impossible for an operator to hold the alternating arc throughout a working day of eight or ten hours, owing to the frequency with which the arc breaks and allows the crater to become oxidized.

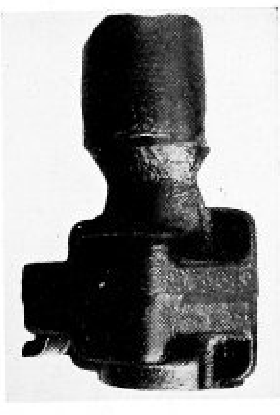
A fractured locomotive frame repaired by means of the Electric Arc.

Also, the alternating current process does not permit the use of the carbon arc with its attendant advantages for cutting and certain other classes of work.

The open circuit voltage of most transformers for this service is 135 to 150 volts which is sufficiently high to be a real life hazard to the operators.

Other objections offered are the introduction of oxide into the weld when the arc is broken, need of skill to hold the arc when using a bare electrode, sputtering of the electrode resulting in a more rapid use of the electrode, and excessive noise of the arc.

It is reasonably safe to predict, therefore, that until some commercially satisfactory static apparatus for power-factor correction is developed, or until a comparatively new and entirely satisfactory electrode of the coated, cored or alloy type is developed, the application of alternating-current arc welding will probably be confined to a very limited field.



In foundries sinkers are removed by using the carbon electrode process.

Inspection

The determination of the character of the welded joint is of the utmost importance, as all manufactured apparatus is now accepted practically on the basis of complying with a process specification rigidly enforced in connection with the application of certain tests on the finished product.

A large steel tank with seams welded by the Electric Arc process.

The four factors which determine the physical characteristics of the metallic electrode arc weld are: fusion, slag content, porosity, and crystal structure. Some important methods that have been used for indicating these characteristics are:

(1) Examination of the weld by visual means to determine:

(*a*) *Finish of the surface as an index to workmanship.*

(*b*) *Length of deposits, which indicates the frequency of breaking the arc, and therefore, the ability to control it.*

(*c*) *Uniformity of the deposits, as an indication of the faithfulness with which the filler metal is placed in position.*

(*d*) *Fusion of deposited metal to bottom of weld scarf as shown by appearance of under side of welded joint.*

(*e*) *Predominance of surface porosity and slag.*

(2) The edges of the deposited layers chipped with a cold chisel or calking tool to determine the relative adhesion of deposit.

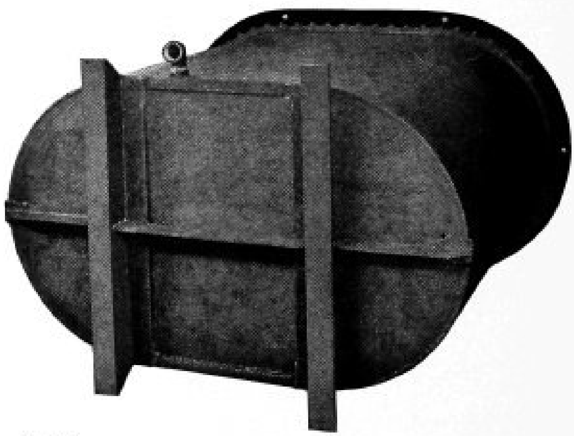
(3) Penetration tests by kerosene to indicate the linked unfused zones, slag pockets and porosity.

It is not necessary, however, except under unusual circumstances, to apply such an elaborate series of tests.

Of the above methods, the visual examination is of more importance than is generally realized. Together with it, the chipping and calking tests are of particular usefulness, the latter serving to indicate the neglect by the operator of the main principles of welding, as only a very poor weld will respond to the test.

Since the characteristics of the weld are almost entirely under the control of the operator, it is very desirable to develop his judgment by encouraging frequent examination of test welds. The inspector may consider that through the proper use of the visual, chipping and penetrating tests a more definite appraisal of the finished joint may be secured, than is possible in other manufacturing processes. The operation may be still further safeguarded by requiring the rigid adherence to certain prescribed specifications. Even by visual means a very good estimate can be made by one familiar with characteristics of good welds. The finish of the weld indicates the kind of workmanship done. The lengths of the deposits show the frequency with which the arc was broken, and therefore, the operator's ability to control the arc. The faithfulness with which the filler metal is placed in position is indicated by the uniformity of the deposits while the fusion of the deposited metal to the bottom of the weld is shown by the appearance of the under side of the welded joint. By this visual test, the predominance of surface porosity and slag is also observed if present.

The essential information relating to fusion, slag content, porosity and crystal structure may be secured



Angle iron supports securely welded to bottom of tank by metal electrode process.

by observing the surface exposed by cutting through the zone of fusion. The exposed section should be ground to a smooth surface and then dipped in a ten per cent nitric acid solution for a few seconds at a time, until the line of fusion appears. If the scarf surfaces have been completely fused and but little slag and porosity is in evidence, a large mild steel weld should have a tensile strength of 45,000 to 55,000 pounds per square inch, and a reduction in area of about seven per cent. However, an experienced operator can determine the kind of welding done by merely chipping the deposited layers with a cold chisel to test the adhesion.

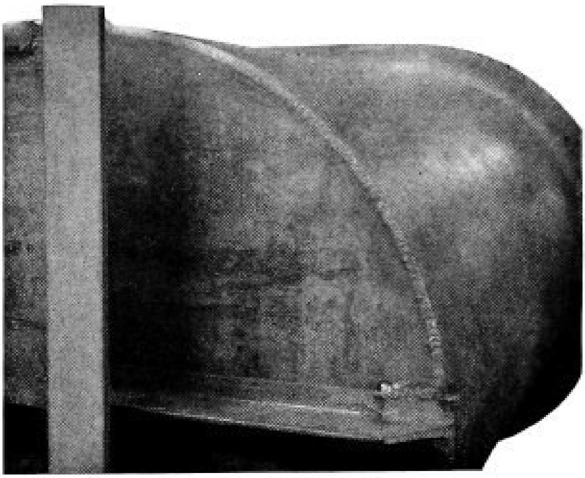
Training

The most successful applications of arc welding undoubtedly have been in places where thorough supervision and training of welders have been carried on and systematic studies have been made to determine the best sequence of operation and the most suitable materials to be used for the welding work. No matter what kind of material is to be welded nor what the type of electrode is, the reliability of the weld rests in a large degree upon the operator. If he has been properly trained and is skilled in the art, he knows whether he is making a good weld or not, and after much practice should be able to judge if a finished weld is a good one by looking at it.

In choosing men to be trained as operators it is found that the best ones come from the skilled crafts, such as boiler-makers, blacksmiths, and machinists or men of equal experience in the mechanical field. This type of men, if skilled and enthusiastic, will discover new and profitable applications for arc welding.

Mr. H. A. Hornor, head of the Electric Welding Branch, Education and Training Section, the United States Shipping Board, the Emergency Fleet Corporation, has made a thorough study of this subject and in a paper presented before the American Institute of Electrical Engineers, October, 1918, he discussed the matter at some length. He said in part:—"No matter what the type of electrode is nor its composition, no matter what kind of shank material is to be welded, no matter what kind of apparatus is employed, the reliability of the weld rests mainly upon the man who makes it. This man, if he has been properly trained and is skilled in the art, knows instantly whether he is making a weld or not."

Training courses have been established for operators all over the country, and men are taken from the various industries, given a course of training and then returned to their own employer to carry on the instruction among their fellow workmen. The methods employed are simple, at the same time thorough and include instruction of the proper method of handling the electrode in order to be able to give it the required



A "close-up" showing an excellent welded tank seam.

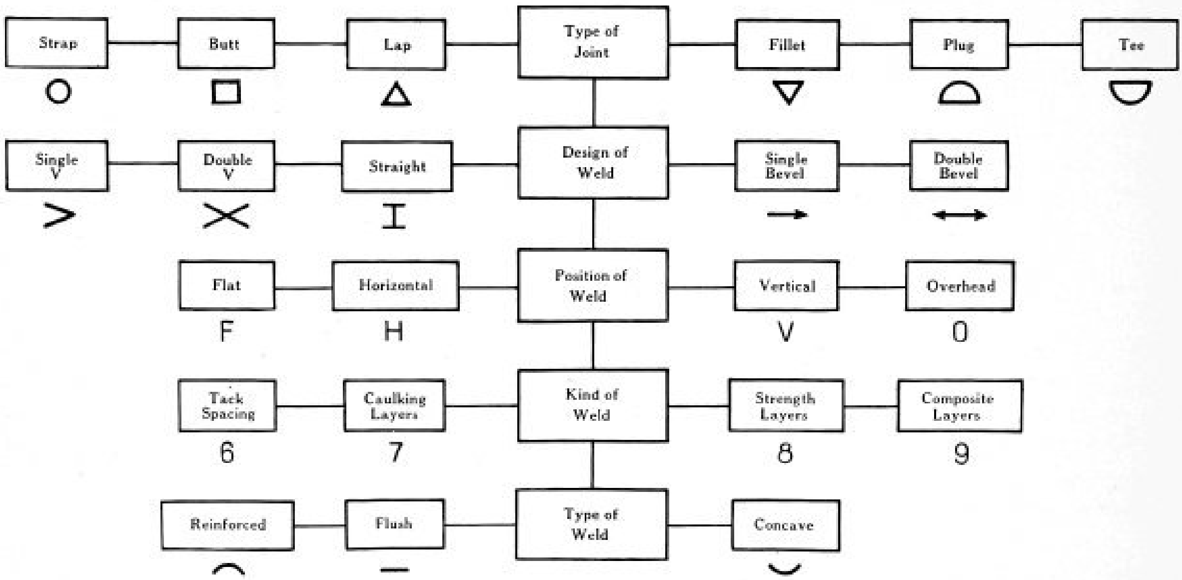
movement. It is also the object of the training course to give him intensive practice work so that he readily becomes a good craftsman.

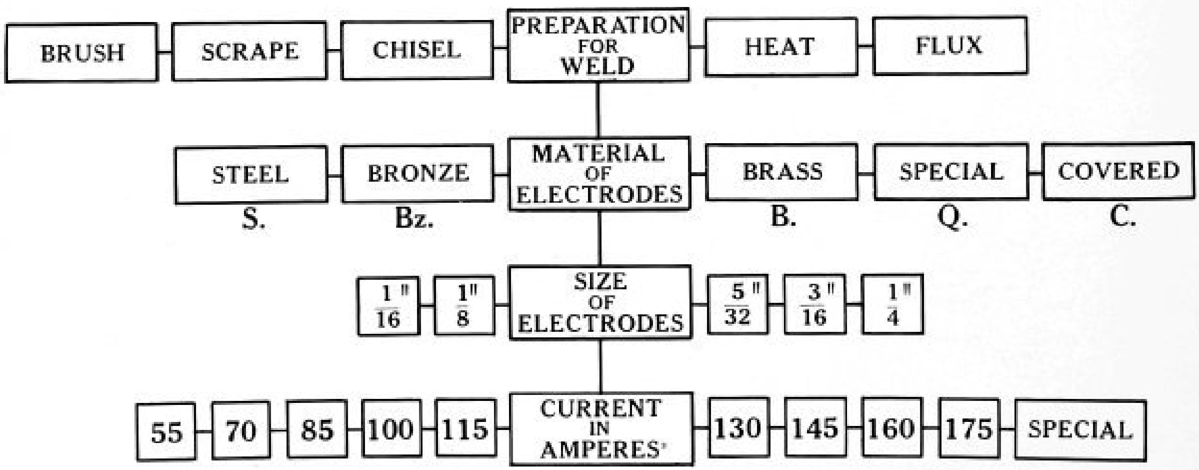
After a period, depending on his ability, the operator is allowed to do actual work on commercial jobs which will result in giving him confidence in his ability to perform such work. In this way he is fitted to become a skilled workman capable of making successful welds upon which reliance can be placed, providing he has conscientiously followed the instructions. The method is simple and operators soon acquire the knack of manipulating the electrode so as to maintain the arc satisfactorily.

Mr. Hornor also says:—"It is the consensus of opinion that all industries doing serious work with the electric arc should use men who are certified as to their ability in the art of electric welding. The main reason for this opinion is that the operator must be a conscientious workman, or the weld will not be of perfect quality."

NOMENCLATURE

In order to aid in the standardization of the various types of joints and welding operations the nomenclature prepared by the Welding Committee of the Emergency Fleet Corporation, United States Shipping Board is given. It is suggested that general use be made of it in the industrial world so that all may speak the same welding terms in the field or shop. The nomenclature is given as follows:



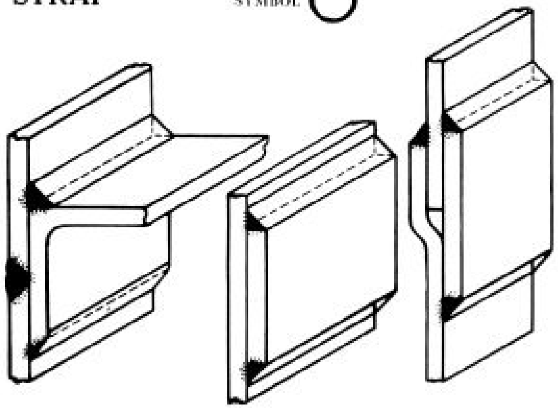


* For data on size of electrode and current value in amperes see table and curve on Page 21.

Type of Joint

STRAP

SYMBOL ○

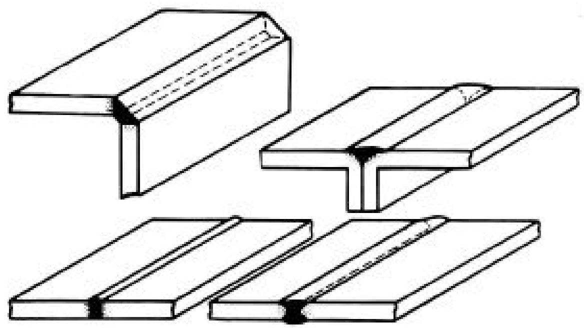


Strap weld is one in which the seam of two adjoining plates or surfaces is reinforced by any form or shape to add strength and stability to the joint or plate. In this form of weld the seam can only be welded from the side of the work opposite the reinforcement, and the reinforcement, of whatever shape, must be welded from the side of the work to which the reinforcement is applied.

BUTT

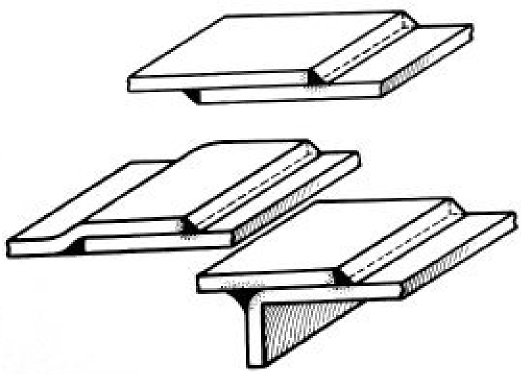
SYMBOL □

Butt weld is one in which two plates or surfaces are brought together edge to edge and welded along the seam thus formed. The two plates when so welded form a perfectly flat plane in themselves, excluding the possible projective caused by other individual objects as frames, straps, stiffeners, etc., or the building up of the weld proper.



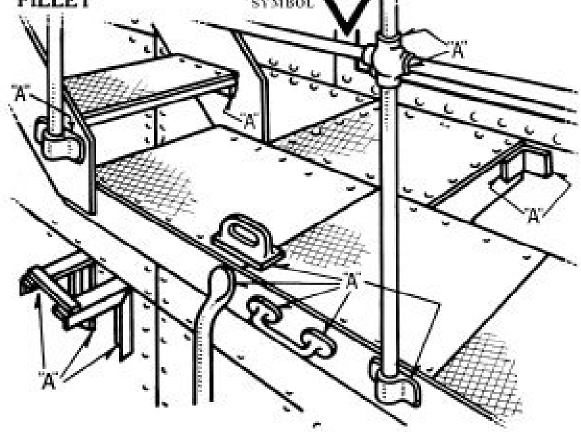
LAP

SYMBOL △



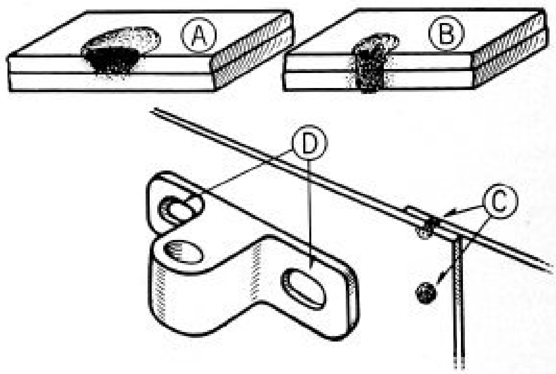
Lap weld is one in which the edges of two planes are set one above the other and the welding material so applied as to bind the edge of one plate to the face of the other plate. In this form of weld the seam or lap forms a raised surface along its entire extent.

FILLET SYMBOL ▽



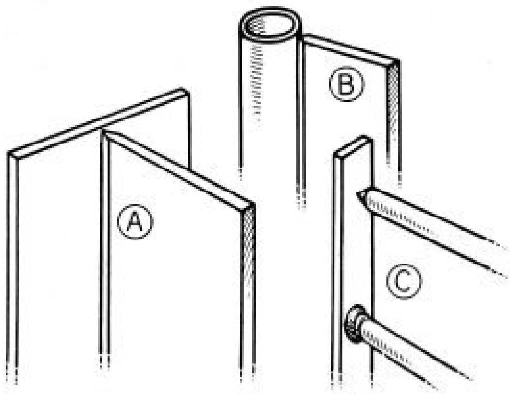
Fillet weld is one in which some fixture or member is welded to the face of the plate, by welding along the vertical edge of the fixture or member (see "welds" shown and marked "A" on illustration at left). The welding material is applied in the corner thus formed and finished at an angle of forty-five degrees to the plate.

PLUG SYMBOL



Plug weld is one used to connect the metals by welding through a hole in either one plate (Figure "A") or both plates (Figure "B"). Also used for filling through a bolt hole as at (Figure "C"), or for added strength when fastening fixtures to the face of a plate by drilling a countersunk hole through the fixtures (Figure "D") and applying the welding material through this hole, as at (Figure "D") thereby fastening the fixture to the plate at this point.

TEE SYMBOL

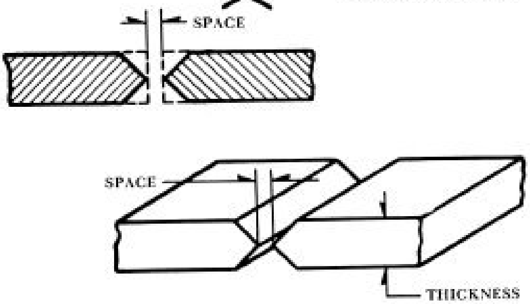


Tee weld is one where one plate is welded vertically to another as in the case of the edge of a transverse bulkhead (Figure "A"), being welded against the shellplating or deck. This is a weld which in all cases requires *exceptional* care and can only be used where it is possible to work from both sides of the vertical plate. Also used for welding a rod in a vertical position to a flat surface, as the rung of a ladder (Figure "C"), or a plate welded vertically to a pipe stanchion (Figure "B"), as in the case of water closet stalls.

Design of Weld

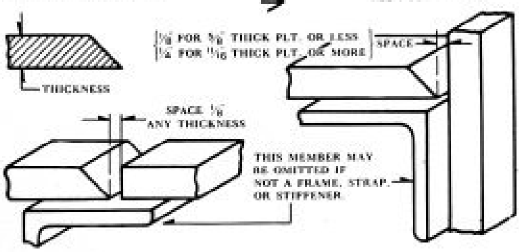
Single "V" is a term applied to the "edge finish" of a plate when this edge is beveled from *both* sides to an angle, the degrees of which are left to the designer. To be used when the "V" side of the plate is to be a maximum "strength" weld, with the plate setting vertically to the face of adjoining member, and only when the electrode can be applied from both sides of the work.

DOUBLE "V" SYMBOL ✕ SPACE ANY THICKNESS 1/8



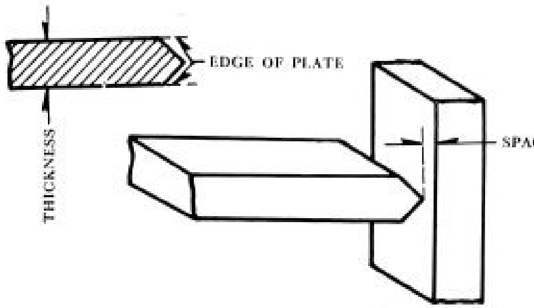
Straight is a term applied to the "edge finish" of a plate, when this edge is left in its crude or sheared state. To be used only where maximum strength is *not* essential, or unless used in connection with strap, stiffener or frame, or where it is impossible to otherwise finish the edge. Also to be used for a "strength" weld, when edges of two plates set vertically to each other—as the edge of a box.

SINGLE BEVEL SYMBOL → SPACE SEE NOTES BELOW



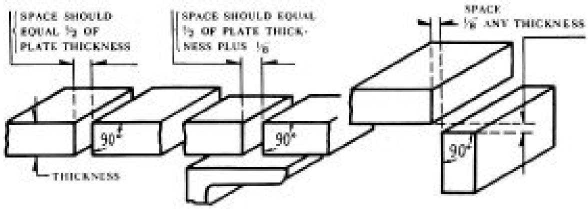
Double Bevel is a term applied to the edge finish of two adjoining plates, when the adjoining edges of both plates are beveled from *one* side only to an angle, the degrees of which are left to the designer. To be used where maximum strength is required, and where electrode can be applied from *one* side of the work only.

SINGLE "V" SYMBOL > SPACE ANY THICKNESS 1/8



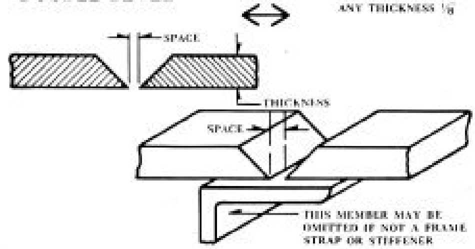
Double "V" is a term applied to the "edge finish" of two adjoining plates when the adjoining edges of both plates beveled from *both* sides to an angle, the degrees of which are left to the designer. To be used when the two plates are to be "butted" together along these two sides for a maximum "strength" weld. Only to be used when welding can be performed from both sides of the plate.

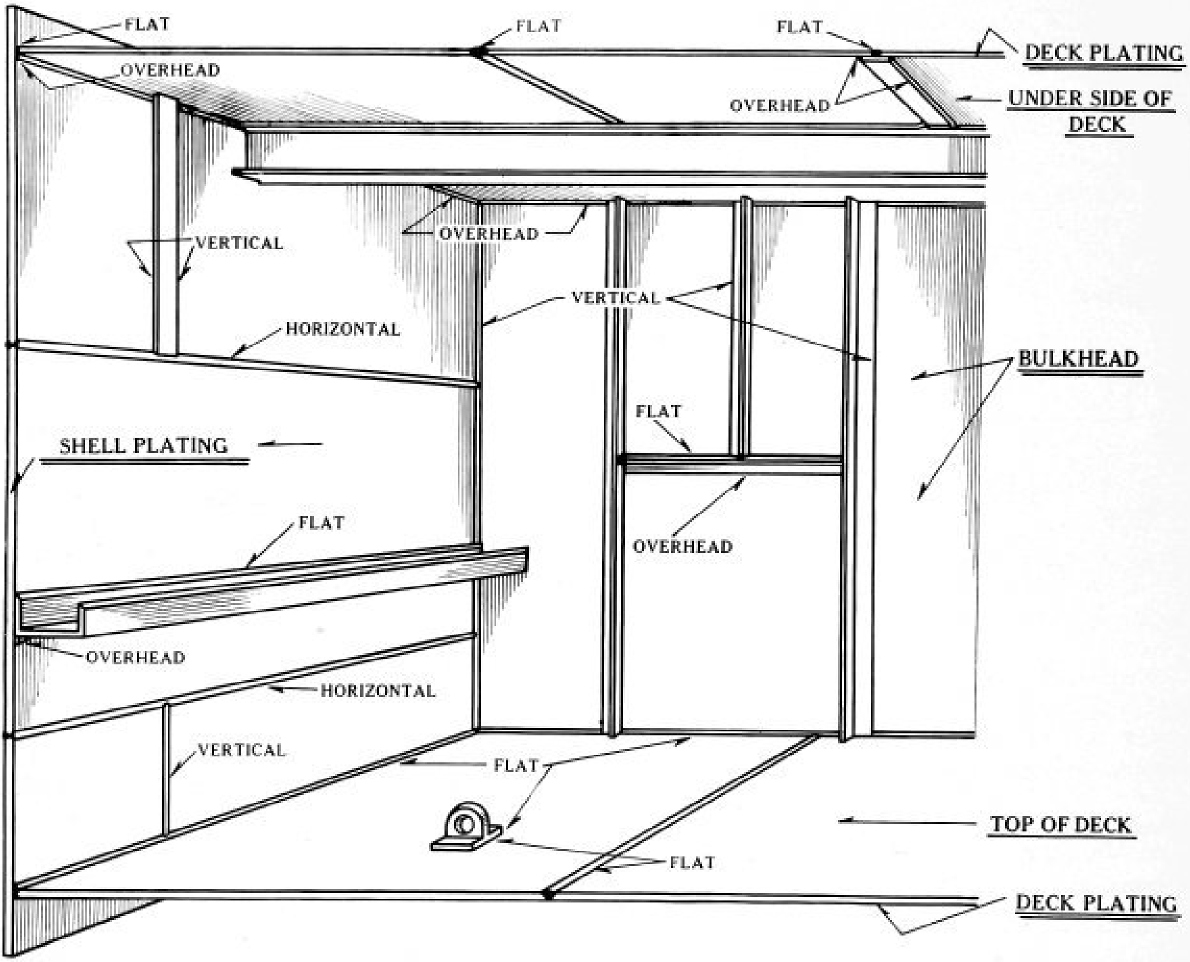
STRAIGHT SYMBOL I SPACE SEE NOTES BELOW



Single Bevel is a term applied to the edge finish of a plate, when this edge is beveled from *one* side only to an angle, the degrees of which are left to the designer. To be used for "strength" welding, when the electrode can be applied from *one* side of the plate only, or where it is impossible to finish the adjoining surface.

DOUBLE BEVEL SYMBOL ↔ SPACE ANY THICKNESS 1/8





Position of Weld

Flat position is determined when the welding material is applied to a surface on the same plane as the deck, allowing the electrode to be held in an upright or vertical position. The welding surface may be entirely on a plane with the deck, or one side may be vertical to the deck and welded to an adjoining member that is on a plane with the deck.

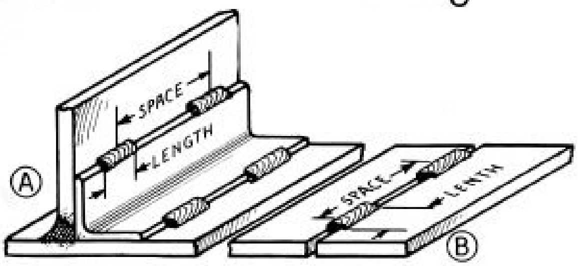
Horizontal position is determined when the welding material is applied to a seam or opening, the plane of which is vertical to the deck and the line of weld is parallel with the deck, allowing the electrode to be held in an inboard or outboard position.

Vertical position is determined when the welding material is applied to a surface or seam, whose line extends in a direction from one deck to the deck above, regardless of whether the adjoining members are on a single plane or at an angle to each other. In this position of weld, the electrode would also be held in a partially horizontal position to the work.

Overhead position is determined when the welding material is applied from the under side of any member whose plane is parallel to the deck and necessitates the electrode being held in a downright or inverted position.

Kind of Weld

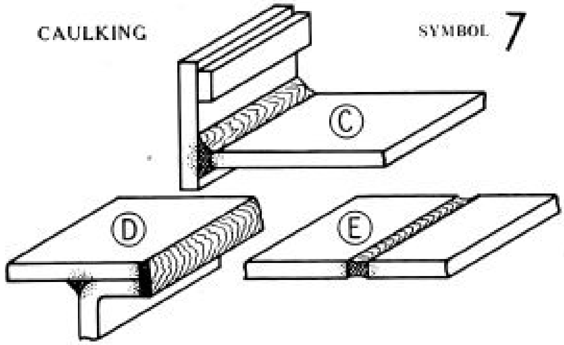
TACK — SYMBOL 6



A Tack weld is applying the welding in small sections to hold two edges together, and should always be specified by giving the *space* from center to center to weld and the *length* of the weld itself. No particular "design of weld" is necessary of consideration.

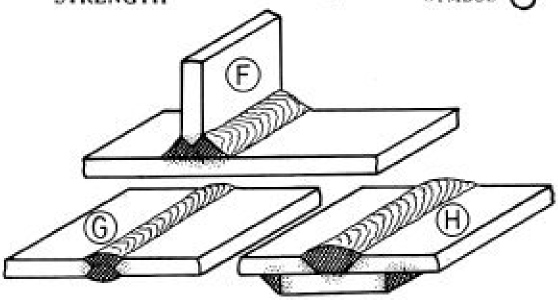
A Tack is also used for temporarily holding material in place that is to be solidly welded, until the proper alinement and position is obtained, and in this case neither the *length, space, or design of weld* are to be specified.

CAULKING — SYMBOL 7



A Caulking weld is one in which the density of the crystalline metal, used to close up the seam or opening, is such that no possible leakage is visible under a water, oil or air pressure of 25 lbs. per square inch. The ultimate strength of a caulking weld is not of material importance—neither is the "design of weld" of this kind necessary of consideration.

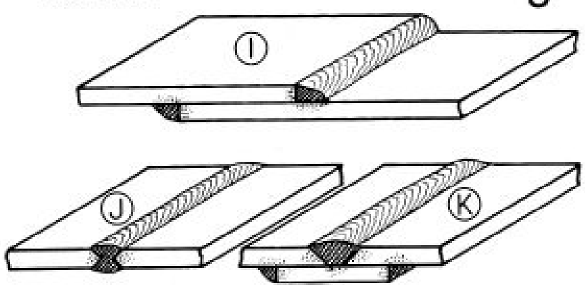
STRENGTH — SYMBOL 8



A Strength weld is one in which the sectional area of the welding material must be so considered that its tensile strength and elongation per square inch must equal at least 80 per cent of the ultimate strength per square inch of the surrounding material. (To be determined and specified by the designer.) The welding material can be applied in any number of layers beyond a minimum specified by the designer.

The density of the crystalline metals is *not* of vital importance. In this form of weld, the "design of weld" must be specified by the designer and followed by the operator.

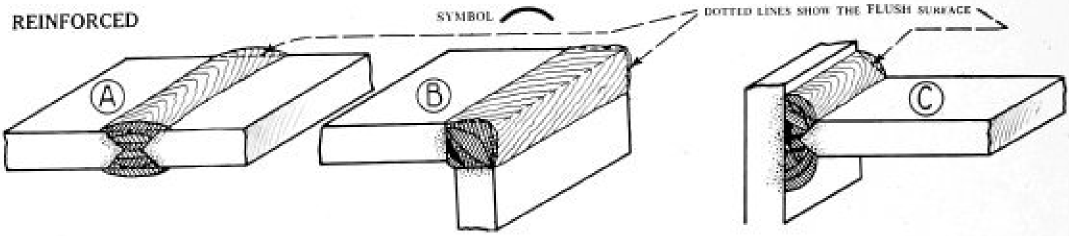
COMPOSITE — SYMBOL 9



A Composite weld is one in which both the strength and density are of the most vital importance. The *strength* must be at least as specified for a "strength weld," and the density must meet the requirements of a "caulking weld" both as above defined. The minimum number of layers of welding material must always be specified by the designer, but the welder must be in a position to know if this number must be increased according to the welder's working conditions.

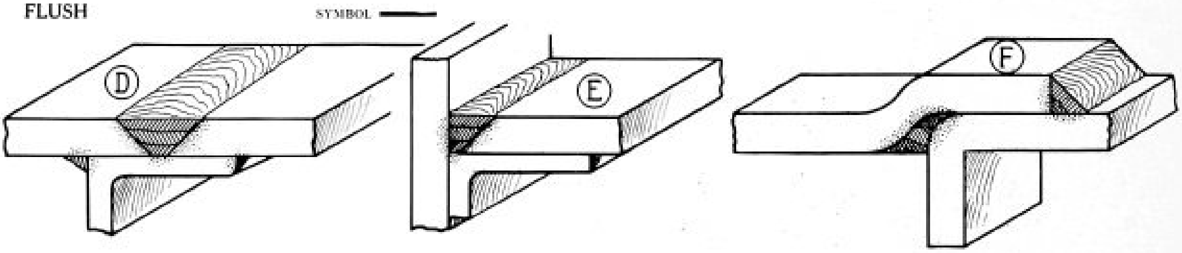
Type of Weld

REINFORCED



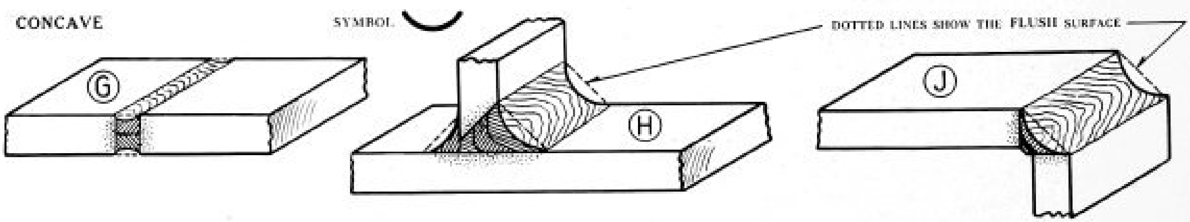
Reinforced is a term applied to a weld when the top layer of the welding material is built up above the plane of the surrounding material as at Fig. "A" or Fig. "B" above, or when used for a corner as in Fig. "C." The top of final layer should project above a plane of 45 degrees to the adjoining material. This 45 degree line is shown "dotted" in Fig. "C" above. This type is chiefly used in a "strength" or "composite" kind of weld for the purpose of obtaining the maximum strength efficiency, and should be specified by the designer, together with a minimum of layers of welding material.

FLUSH



Flush is a term applied to a weld when the top layer is finished perfectly flat or on the same plane as on the adjoining material as shown at Figs. "D" and "E" above or at an angle of 45 degrees when used to connect two surfaces at an angle to each other as at Fig. "F" above. This type of weld is to be used where a maximum tensile strength is not all important and must be specified by the designer, together with a minimum number of layers of welding material.

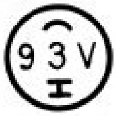
CONCAVE



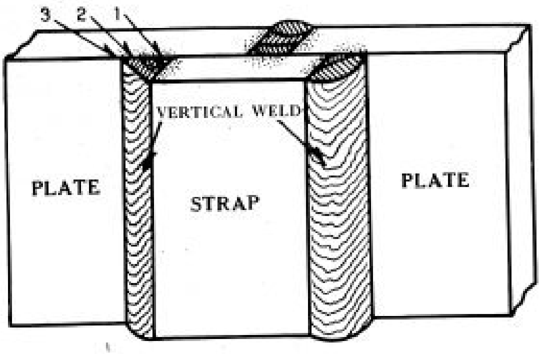
Concave is a term applied to a weld when the top layer finishes below the plane of the surrounding material as at Fig. "G" above, or beneath a plane of 45 degrees at an angular connection as at Figs. "H" and "J" above.

To be used as a weld of no further importance than filling in a seam or opening, or for strictly caulking purposes, when it is found that a minimum amount of welding material will suffice to sustain a specified pound square inch pressure without leakage. In this "type of weld" it will not be necessary for the designer ordinarily to specify the number of layers of material owing to the lack of structural importance.

Combination of Symbols



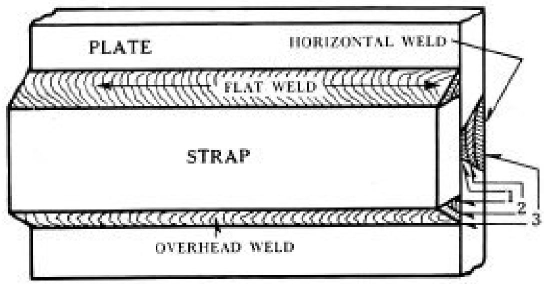
STRAP WELD, REINFORCED, COMPOSITE OF THREE LAYERS, VERTICAL, STRAIGHT,



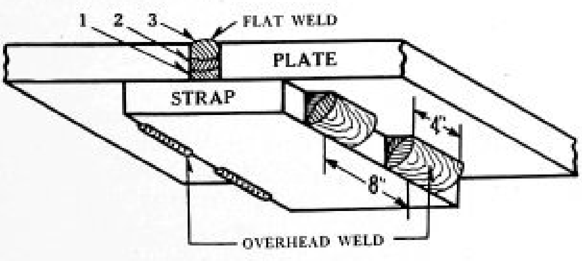
This sketch and symbol shows a strap holding two plates together, setting vertically, with the welding material applied in not less than three layers at each edge of the strap, as well as between the plates with a reinforced, composite finish, so as to make the welded seams absolutely water, air or oil tight, and to attain the maximum tensile strength. The edges of the strap and the plates are left in a natural or sheared finish. This type of welding is used for most particular kind of work where maximum strains are to be sustained.

STRAP WELD, FLUSH, STRENGTH OF 3 LAYERS, HORIZONTAL, FLAT AND OVERHEAD, DOUBLE BEVEL

This illustration shows a strap holding two plates together horizontally, welded as a strength member with a minimum of three layers and a flush finish. Inasmuch as the strap necessitates welding of the plates from one side only, both edges of the plates are bevelled to an angle, the degrees of which are left to the discretion of the designer. The edges of the strap are left in a natural or sheared state, and the maximum strength is attained by the mode of applying the welding material, and through the sectional area per square inch exceeding the sectional area of the surrounding material.



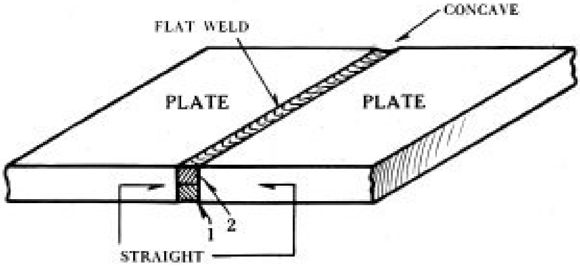
STRAP, TACK, OVERHEAD, 8" CENTER TO CENTER 4" LONG, BUTT, REINFORCED COMPOSITE OF 3 LAYERS, FLAT, STRAIGHT.



This symbol represents two plates butted together and welded flat, with a composite weld of not less than three layers, and a reinforced finish. A strap is attached by means of overhead tacking, the tacks being four inches long and spaced eight inches from center to center. In this case, the welding of the plates of maximum strength and water, air or oil tight, but the tacking is either for the purpose of holding the strap in place until it may be continuously welded, or because strength is not essential. All the edges are left in their natural or sheared state.

72F

BUTT WELD, CONCAVE, CAULKING OF 2 LAYERS, FLAT, STRAIGHT.

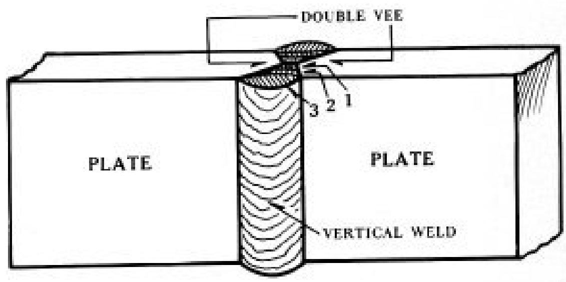


The symbol shown represents a butt weld between two plates with the welding material finished concaved and applied in a minimum of two layers to take the place of caulking. The edges of the plates are left in a natural shear cut finish. This symbol will be quite frequently used for deck plating or any other place where strength is not essential, but where the material must be water, air or oil tight.

83V

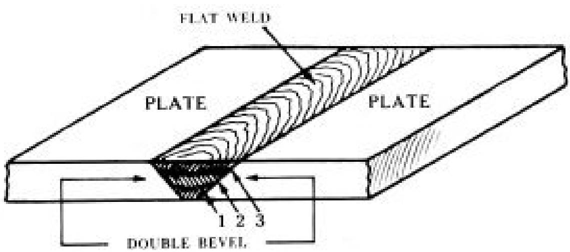
BUTT WELD, REINFORCED, STRENGTH OF 3 LAYERS, VERTICAL, DOUBLE VEE.

This symbol is used where the edges of two plates are vertically butted together and welded as a strength member. The edges of adjoining plates are finished with a "double vee" and the minimum of three layers of welding material applied from each side, finished with a convex surface, thereby making the sectional area per square inch of the weld, greater than that of the plates. This will be a conventional symbol for shell plating or any other members requiring a maximum tensile strength, where the welding can be done from both sides of the work.



93F

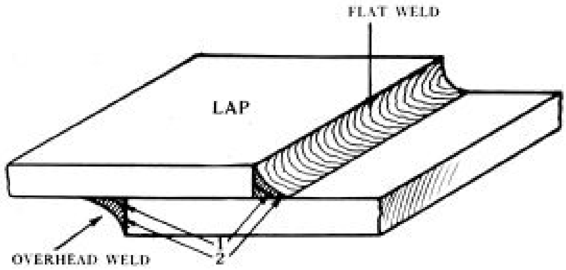
BUTT WELD, FLUSH, COMPOSITE OF 3 LAYERS, FLAT, DOUBLE BEVEL.



This symbol shows two plates butted together in a flat position where the welding can only be applied from the top surface. It shows a weld required for plating where both strength and watertightness are to be considered. The welding material is applied in a minimum of three layers and finished flush with the level of the plates. Both edges of the adjoining plates are beveled to an angle, the degrees of which are left to the discretion and judgment of the designer, and should only be used when it is impossible to weld from both sides of the work.

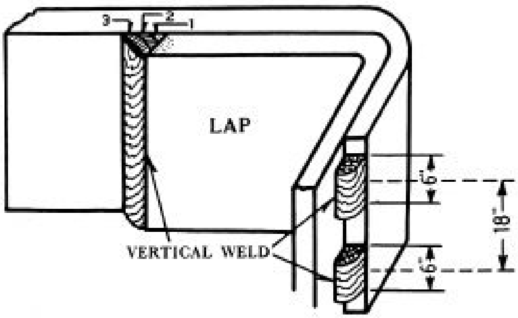
LAP WELD, CONCAVE, CAULKING OF 2 LAYERS, OVERHEAD AND FLAT, STRAIGHT.

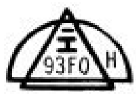
The sketch shows the edges of two plates lapping each other with the welding material applied in not less than two layers at each edge, with a concaved caulking finish, so applied, as to make the welded seams absolutely water, air or oil tight. The edges of the plates themselves are left in a natural or sheared finish. Conditions of this kind will often occur around bulk-head door frames where maximum strength is not absolutely essential.



LAP WELD, REINFORCED, STRENGTH OF 3 LAYERS AND TACKING, 18' CENTER TO CENTER, 6' LONG, VERTICAL, STRAIGHT.

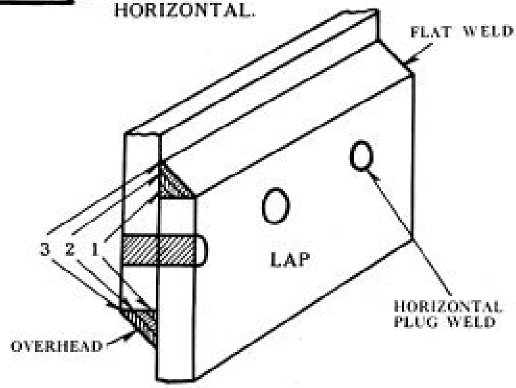
The illustration herein shown, is somewhat exaggerated as regards the bending of the plates, but it is only shown this way to fully illustrate the tack and continuous weld. It shows the edges of the plates lapped with one edge welded with a continuous weld of a minimum of three layers with a reinforced finish thereby giving a maximum tensile strength to the weld, and the other edge of the plate, tack welded. The tacks are six inches long with a space of 12 inches between the welds or 18 inches from center to center of welds. In both cases, the edges of the plates are left in a natural or sheared state.



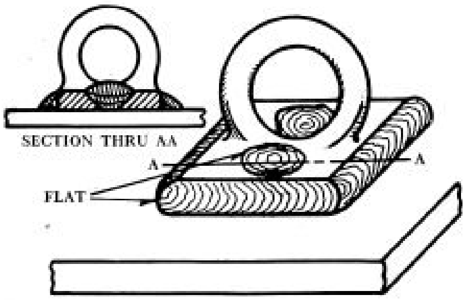


PLUG AND LAP WELD, STRENGTH OF 3 LAYERS FLUSH, FLAT, OVERHEAD, HORIZONTAL.

The sketch shows a condition exaggerated, which is apt to occur in side plating where the plates were held in position with bolts for the purpose of alinement before being welded. The edges are to be welded with a minimum of three layers of welding material for a strength weld and finished flush, and after the bolts are removed, the holes thus left are to be filled in with welding material in a manner prescribed for strength welding. The edges of the plates are to be left in a natural or sheared state, which is customary in most cases of lapped welding.



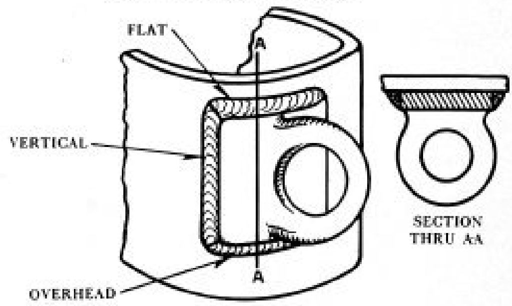
PLUG AND FILLET WELD, REINFORCED, STRENGTH OF 3 LAYERS, FLAT, SINGLE BEVEL AND STRAIGHT.



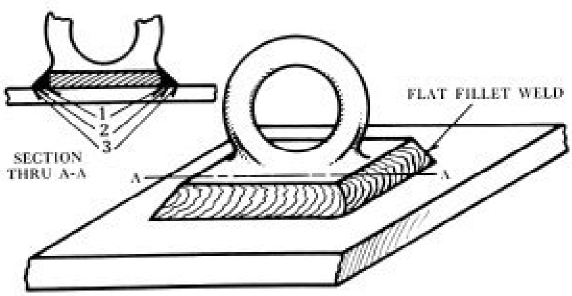
The adjoining sketch shows a pad eye attached to a plate by means of a fillet weld along the edge of the fixture, and further strengthened by plug welds in two countersunk holes drilled in the fixture. The welding material is applied in a flat position for a strength weld with a minimum of three layers and a reinforced finish. The edges of the holes are bevelled to an angle, which is left to the judgment of the designer, but the edges of the fixture are left in their natural state. This method is used in fastening fixtures, clips or accessories that would be subjected to an excessive strain or vibration.

FILLET WELD, REINFORCED, COMPOSITE OF 3 LAYERS, FLAT, VERTICAL AND OVERHEAD, STRAIGHT.

This illustration shows a fixture attached to a plate by means of a composite weld of not less than three layers with a reinforced finish. The fixture being placed vertically, necessitates a combination of flat, vertical and overhead welding in the course of its erection. Although a fixture of this kind would never be required to be watertight, the composite symbol is simply as a possibility of a combination.



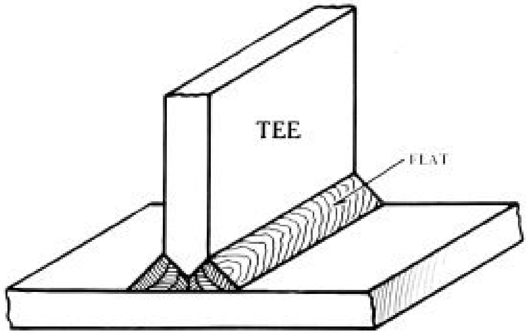
FILLET WELD, FLUSH, STRENGTH OF 3 LAYERS FLAT, STRAIGHT.



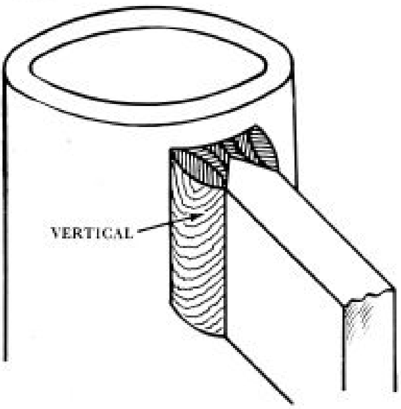
This *symbol* represents a fixture attached to a plate by a strength fillet weld of not less than three layers, finished flush. The edges of the fixture are left in their natural state, and the welding material applied in the corner formed by the vertical edge of the fixture in contact with the face of the plate.

TEE WELD, FLUSH,
STRENGTH OF 3 LAYERS,
FLAT, SINGLE VEE.

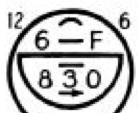
The adjoining sketch illustrates the edge of a plate welded to the face of another plate, as in the case of the bottom of a transverse bulkhead being welded against the deck plating. To obtain a maximum tensile strength at the joint, the edge of the plate is cut to "single vee" and welded on both sides with a strength weld of not less than three layers, and finished flush. This would be a convenient way of fastening the intercostals to the keelsons. In this particular case, the welding is done in a flat position.



TEE WELD, REINFORCED,
STRENGTH OF 3 LAYERS,
VERTICAL, SINGLE VEE.

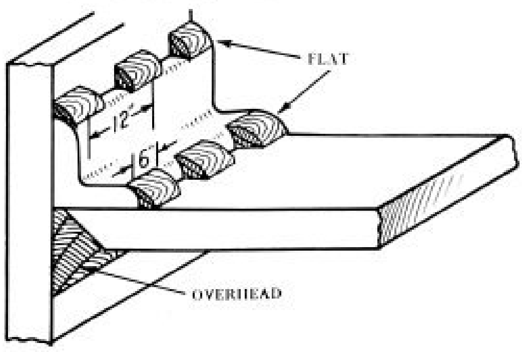


This *symbol* shows another case of tee weld with the seam setting in a vertical position, and the welding material applied from both sides of the work. The edge of the plate is finished with a "single vee" and a minimum of three layers of welding material applied from each side, finished with a convex surface, thereby making the sectional area, per square inch of the weld, greater than that of the plate, allowing for a maximum tensile strength in the weld.



STRAP AND TEE WELD,
FLAT, REINFORCED, TACK,
12" CENTER TO CENTER,
6" LONG, SINGLE BEVEL,
OVERHEAD, STRENGTH OF
3 LAYERS, FLUSH.

The illustration herein shown, represents an example of the possible combination of symbols. An angle iron is tack welded to the plate in the form of a strap or stiffener, though in actual practice, this might never occur. The tacks are spaced twelve inches from center to center, and are six inches long, and applied in a flat position, with a reinforced finish. As the strap prevents welding the plate from both sides, the edge of the plate is bevelled, and the welding material applied for strength in not less than three layers in an overhead position and finished flush. Note that in specifying tack welds, it is essential to give the space from center to center of weld, and length of weld by use of figures representing inches placed either side of the circumscribing symbol of the combination.



Arc Welding Equipments

The two systems now in general use in this country for electric arc welding are as follows:

1—Single operator system.

2—Multiple operator system.

A single operator equipment is one in which a separate machine is provided for each operator. As many of these machines are stationed at different points in a shop or terminal as the demands require, each machine receiving its current direct from the supply circuit.

A single operator *portable* equipment differs only from the single operator *stationary* equipment in that the machine is mounted on a truck in order that it may be moved from one point to another as the occasion requires, receiving its power from outlets on the supply circuit, conveniently located about the shop.

The multiple operator equipment is one in which more than one operator receives current for welding direct from the same machine which is centrally located in a shop, or terminal. There is provided for each operator, a control panel which will enable currents of different values to be obtained in any one circuit without interference with the other operators.

WESTINGHOUSE EQUIPMENT FOR ELECTRIC ARC WELDING

The successful application of the arc welding process is largely dependent on the selection of the proper equipment. Engineers of the Westinghouse Electric & Manufacturing Company have for many years been actively engaged in an investigation of this subject and the company has been making extensive use of the process in its own shops for over 15 years.

The Westinghouse equipment described in the following pages, therefore, has been built in accordance with the latest information and practice. It has been designed to give stability and penetrating power, frequently referred to as "Pep," which produces good fusion.

The prime requisites of Electric Arc Welding Equipment are:

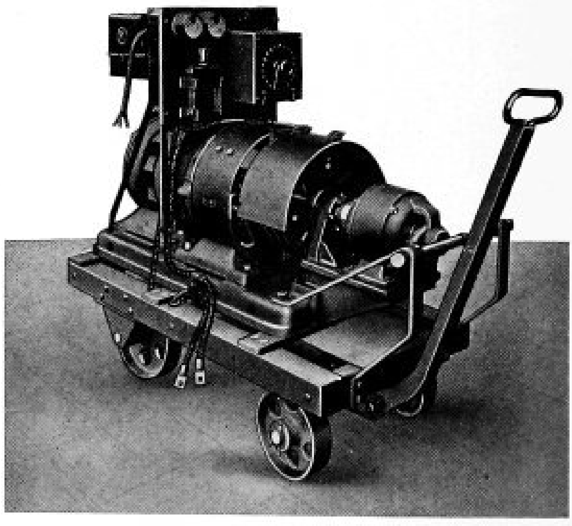
1. **Sufficient potential capacity to sustain the arc when lengthened.** This is necessary to overcome irregularities in the material being welded, which in turn cause variations in the resistance of the circuit.

2. **Minimum reactance in circuit** to permit the arc to penetrate deeply into the work thereby insuring thorough fusion.

3. **Constant heat at the arc in order to produce constant flow of metal.** This requires variable voltage at the arc in order to maintain constant current, as the rate of fusion of the metal depends on the current. The reason that variable voltage is required to maintain constant current is because of variation in the resistance of the arc path or circuit due to the following:

(a) Foreign matter such as scale, rust, etc., in the path of the arc. (b) Variation in the length of the arc caused by the molten metal traveling from the electrode to the weld. (c) Unsteadiness of the operator's hand, and (d) unevenness of the surface over which the welding is directed.

In developing apparatus to meet the above requirements, the Westinghouse Electric & Manufacturing Company has produced thoroughly reliable outfits which are economical in operation, and at the same time are so simple in construction as to require little attention from the operator. All current-limiting devices such as relays and other complications have been eliminated from the control system, an ordinary circuit-breaker, or National Electrical Code enclosed fuses being the only protective devices required.



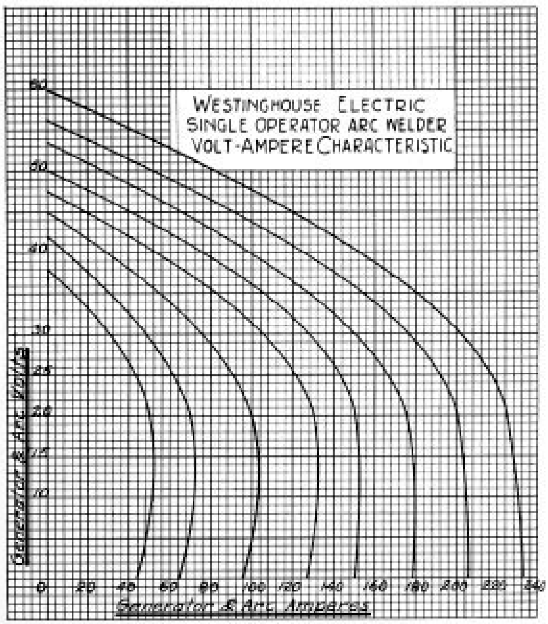
175 ampere Portable AC-DC Welding Motor Generator Set.

Westinghouse Electric generating equipment for arc welding is divided into two classes:

1—Single Operator

2—Multiple Operator

The Single Operator Equipment is designed to supply welding power for one operator only. It is a most efficient equipment because the generator operates at arc voltage and no resistance is used in circuit with the arc. The generator is designed to inherently stabilize the arc, thereby eliminating the necessity for providing automatic moving devices such as relays, solenoid control resistors, etc., which not only increase the cost of investment and maintenance but may not be quick enough in action to follow the instantaneous



Volt Ampere Characteristic.

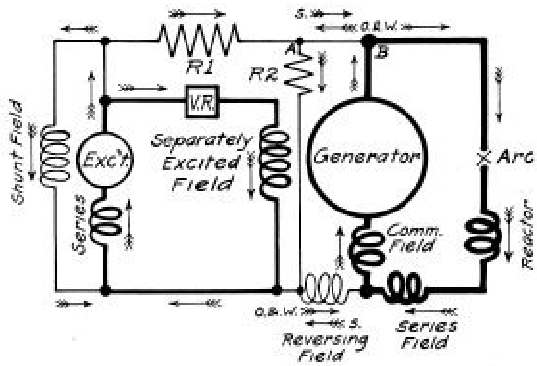
changes of the arc circuit.

The generator of the set has a rated capacity of 175 amperes, is of Westinghouse standard design and construction, provided with commutating poles.

The design of the control is such that very close adjustment of current may be easily and quickly made, and once made the amount of current at the weld will remain fixed within close limits until changed by the operator. There are 21 steps provided from 50 to 225 amperes. This gives a current regulation of less than 9 amperes per step which makes it much easier for a welder to do vertical or overhead work often encountered in railroad shops and ship construction.

Due to the special design and interconnections of the generator and its exciter it is unusually easy for the operator to strike and maintain the arc. Although the generator is strictly a short arc machine the arc produced is very tenacious and causes the deposited metal to penetrate deeply into the work. These features are extremely desirable as they make it easier for a new operator to learn to do welding work and enable experienced welders to accomplish more in a working day.

The generator is mounted on common shaft and bedplate with the motor. A pedestal bearing is sup-



Diagrams of Connections of Single Operator Generator and Exciter.

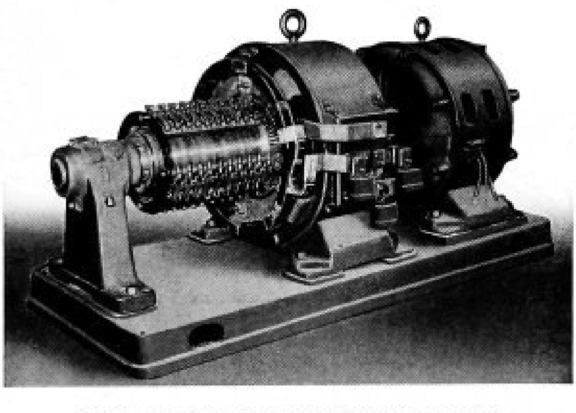
plied on the commutator end which carries a bracket for supporting the exciter which is coupled to the common shaft of the set by means of a flexible coupling. Motors can be supplied for either direct or alternating current circuits. When an alternating-current motor is used leads are brought outside the motor frame for connecting either 220 or 440-volt circuits. An electrician can change these connections in a few minutes time. This feature is particularly desirable on portable outfits which may be moved from one shop to another having a supply circuit of different voltages.

Ball bearings are used on the single operator motor generator set. This type of bearing is particularly adaptable to this class of service, especially on portable equipments.

Where the equipment is required for portable service, the motor generator set with the control panel is mounted on a fabricated steel truck, equipped with roller bearing wheels. The portable equipment can be easily hauled about the shop or yards by one man. The suitable plugs and receptacles for 3-phase, 3-wire or 2-phase, 4-wire, alternating-current and direct-current motors allow the set to be quickly and conveniently connected to the supply circuit at any desirable point. Only one plug is required for the motor but the number of receptacles required depends upon the number of points at which it is desired to do welding work.

Multiple Operator—The equipment for this service consists of a motor-generator, control panel and accessories.

Motor-generators are furnished in the following capacities: 300, 500, 750 and 1000 amperes. They are of the standard Westinghouse design and construction, but have special features fitting them for this service. Particular attention is paid to the commutation of the generators which are provided with commutating poles and exceptionally long commutators so that they will carry heavy momentary over-loads with no special protection even at the time of striking the arc. The circuit-breaker on the control panel is designed to take care of prolonged over-loads. The generator is compound wound, flat compounded. That is it delivers 60 volts at no-load and also at full load. It is driven by a motor of the proper size and with characteristics to suit the requirements of the power circuit and is mounted compactly on a bedplate where two or more

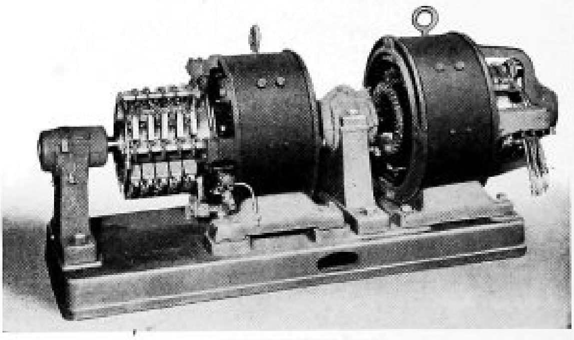


1000 ampere AC-DC Welding Motor Generator Set.

operators, each provided with a separate control or outlet panel, can do welding at the same time with current taken from the same generator without any interference between operators, provided the main circuit is of sufficient capacity.

Proper starting devices are supplied with the motor-generators for DC-DC sets, suitable wall-mounting starters being furnished with low-voltage release and overload protection. For AC-DC sets, auto-starters are provided.

Control—The control equipment for Multiple Operator Equipment is divided into several classes and types as follows:



300 ampere DC-DC Welding Motor Generator Set.

Class I—In this class the main generator panel provides for the control of the generator and for one welding circuit of the same capacity as the generator, except in the case of 1000-ampere outfit, on which the welding circuit has a capacity of only 800 amperes. To provide for more than one welding circuit, outlet panels, such as are described later, are necessary. The apparatus on the control panel is as follows:

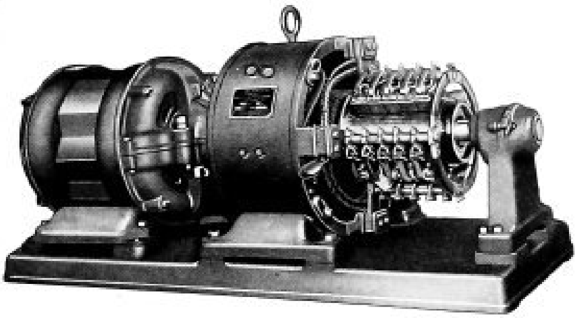
1—Voltmeter
1—Ammeter
1—Carbon Circuit Breaker
1—Rheostat Mounting
4 or 5—Switches to control the resistance and obtain adjustments of the welding current.

Class II—This panel is arranged for the control of the generator only, no provision being made for welding circuits, which are controlled by the use of outlet panels. The panel has the following apparatus mounted thereon:

1—Voltmeter
1—Ammeter
1—Carbon Circuit Breaker
1—Rheostat Mounting
1—D. P. S. T. knife switch to connect generator to circuit.

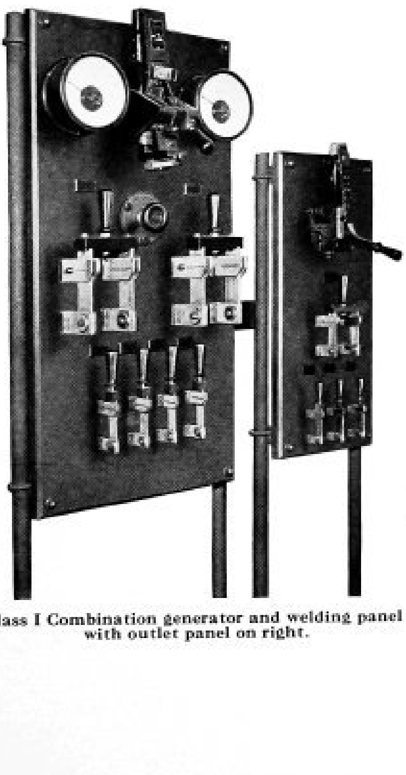
Multiple Operator Portable Equipment

For portable service, the 300 and 500 ampere motor-generators and control panels are mounted on a substantial four-wheel truck made of structural steel so designed as to permit of easy movement from one part of the shop to another. The set is placed over the rear wheels and the control equipment, being lighter, over the front wheels. This arrangement permits easy guiding and handling by one or two men on the ordinary shop floor.



300 ampere AC-DC Welding Motor Generator Set.

Direct current motors for this service are started by means of a multipoint knife switch; those sets with A. C. motors, by means of auto-starters. In each case, the starting device is provided as a part of the equipment.



Class I Combination generator and welding panel with outlet panel on right.

The control for the portable equipment consists of the following class and types:

Class III—The control apparatus supplied with the portable arc welding outfit is compactly mounted on the truck with the motor generator.

The panel for the 300-ampere portable equipment is equipped with:

1—Voltmeter
1—Ammeter
1—Rheostat
2—D. P. S. T. service switches
8—Switches to control resistors

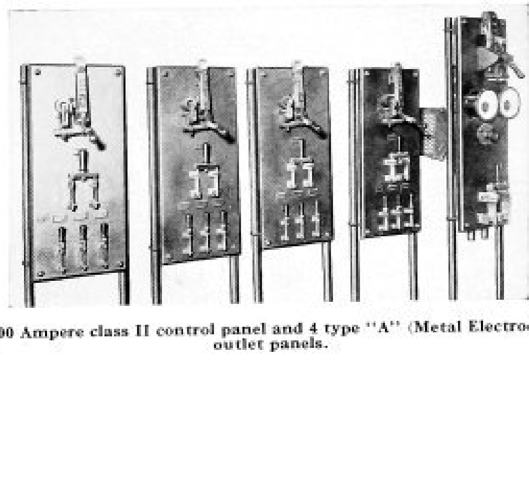
The generator is protected by a railway type circuit-breaker. The control circuits are arranged so that two operators can weld with the metal electrode at the same time, each using one service switch and three switches to control the resistors, obtaining current from 20 to 185 amperes in 15 steps.

In case it is desired to use the carbon-electrode, the two cables for the metal electrode holders may be paralleled, the current may then be adjusted from 160 to 320 amperes in eight steps.

The control panel for the 500-ampere portable equipment is designed for metal and carbon electrode welding and is provided with:

1—Voltmeter
3—Ammeters
1—Rheostat
3—D. P. S. T. service switches
12—Double throw switches to control resistors

The generator of this outfit is protected by fuses. The three main service switches control three welding circuits each of 15 to 225 amperes for carbon or metal electrode welding. By paralleling the three circuits



500 Ampere class II control panel and 4 type "A" (Metal Electrode) outlet panels.

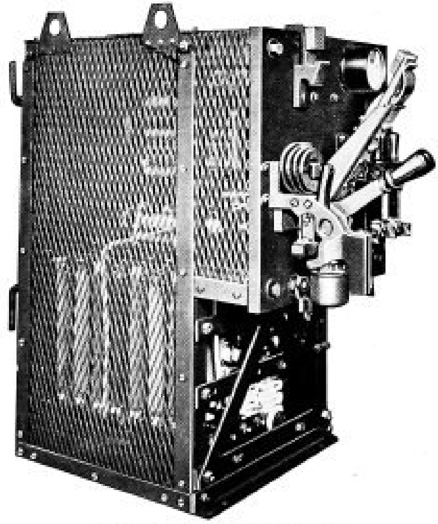
carbon welding at 450 to 675 amperes can be done.

For both the 300 and 500-ampere control panels, the resistors are mounted in angle iron frames behind the slate and the entire top, rear, and sides are covered with expanded metal.

Outlet Panels. These are located at various points about the shop where welding is to be done. Classes I and II panels, previously described, control the generator and connect it to the main welding circuit. The outlet panels are operated by the individual welders so that each can control his own circuit without any interference whatever with other welding circuits. The various types of outlet panels are as follows:

Type A Panel. This panel is used exclusively for light metal electrode work and has mounted upon it a carbon circuit-breaker, service switch, and four switches for controlling the welding resistors. The current is adjustable from 20 amperes to 170 amperes in 15 steps.

Type B Panel. This panel is designed for either metal electrode or light carbon electrode work. The apparatus consists of a carbon circuit-breaker service switch, and five switches for controlling the welding resistors by which the current can be adjusted from 25 to 190 amperes in 15 steps, for use with the metal electrode. For use with carbon electrode the current can be adjusted from 210 to 350 amperes in 14 steps.

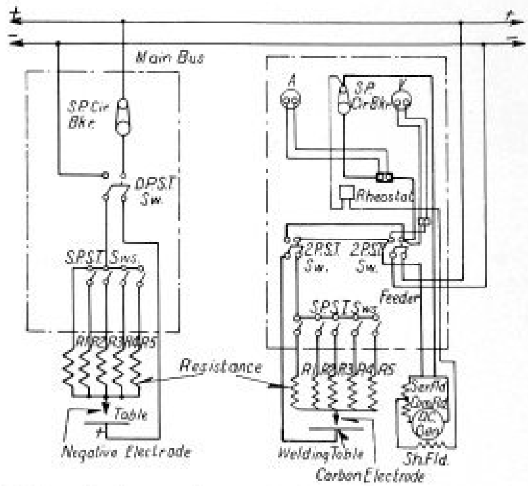


Type E Portable Outlet Panel.

Type C Panel. Carbon electrode welding only is done with this panel on which is mounted a carbon circuit-breaker, service switch, and four switches for controlling the welding resistors. The current can be adjusted from 150 to 550 amperes in 6 steps.

Type D Panel. The conductors and resistors furnished with this panel are suitable for the heaviest kind of carbon welding or for metal electrode work. The equipment consists of a carbon circuit-breaker, service switch, and four double-throw switches for controlling the resistors. The switches are made double-throw to provide for both carbon and metal electrode welding. Consequently, current adjustments from 15 to 225 amperes in 15 steps can be obtained for metal-electrode work and adjustments from 125 to 650 amperes in 11 steps for carbon-electrode work.

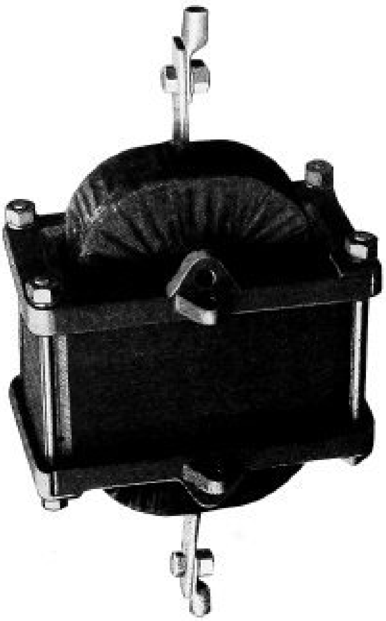
Type E Portable Outlet Panels. These panels are designed for metal electrode welding. The resistors are mounted in an angle iron frame and completely protected by an expanded metal cover. On the top of the unit are eye bolts so that the panels can be lifted



Left-Schematic diagram of outlet panel. Right-Schematic diagram class I combination control panel.

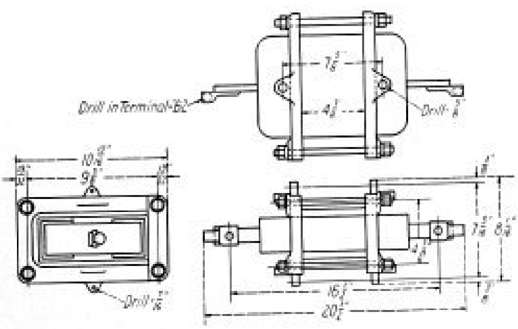
by a crane and moved about as desired. On the front of the framework is mounted an ebony asbestos panel provided with a carbon circuit-breaker, ammeter, and four switches for controlling resistors. The current adjustment obtainable is from 15 to 225 amperes in 15 steps. With its equipment of connections either one or two-wire operation can be obtained.

Type F Portable Outlet Panels. These panels are designed especially for portable service being provided with a handle and mounted on ball bearing castors, so that they can be easily moved about the shop. The resistors are mounted in a frame work and protected by expanded metal covers. The panel on the front supports a railway type circuit-breaker and the dial contracts for controlling the resistors. The entire panel is covered with a hinged metal cover through which the operating handles of the dial switch and circuit-breaker protrude. Nine current steps from



Reactor for metallic electrode welding circuits.

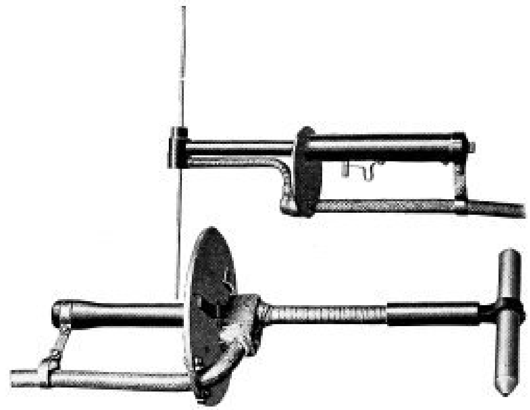
70 to 210 amperes can be obtained for metal electrode work, and four steps from 200 to 350 amperes for carbon electrode work.



Outline diagram of reactor.

Reactors. To improve the characteristics of the metal electrode welding circuit, a reactance is oftentimes desirable for each operator's circuit as with it in the circuit, the arc can be much more readily struck without the electrode "freezing" to the work. It assists in holding back the first heavy rush of current and increases the stability of the arc momentarily. Its action is frequently compared with that of a flywheel to an engine. The reactor is also especially desirable where the work cannot be thoroughly cleaned of grease, paint, anti-rust compounds, absorbed oil or gas, etc., as it will help the operator to keep the arc from being broken or blown out.

It may be secured for operation with the 300-ampere Class I control panels, also with types A, B, D and E outlet panels. For the 300-ampere portable equipment two reactances are desirable, one for each of the two metal electrode circuits, and 3 for the 500 ampere set.



Metal electrode holder above and carbon electrode holder below.

Accessories

Protective Equipment. A considerable amount of ultra-violet light radiates from the electric arc, and produces an effect similar to that of sunburn if any part of the operator's body is unprotected from the rays for many minutes at a time. For this reason, it is necessary for the operator to wear heavy closely woven clothing that completely covers the body, arms and limbs. For the protection of the hands and wrists, leather gauntlets or a double pair of cotton gauntlets are used.

Hood. The hood provides protection for the head, face and neck and is constructed, as shown in the illustration, of a non-conduction material, to avoid accidental shock or burn as might occur if the electrode or electrode holder should strike a metal hood while it was in contact with the work.

Shield. Still another form is that of the shield which is provided with a handle and is held in the free hand of the operator between the face and the arc.

Each of the above devices must be provided with some form of transparent lens, such as mica or glass so that the work may be observed without injury to the eyes. These lenses are usually two in number and consist of a special arc welder's glass and one clear glass, the latter to protect the other lens from being pitted by flying particles of hot metal.

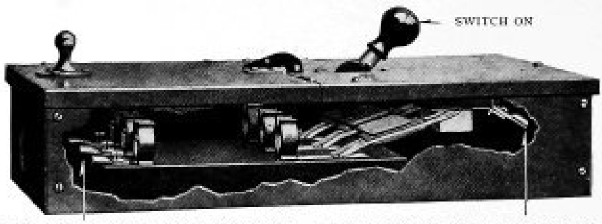
Enclosure. A suitable enclosure is highly desirable for each welding station to protect other workmen in the immediate vicinity from the glare and heat. These booths or stations should be located at convenient places in the shop where all miscellaneous work may be brought, and should be painted a dead mottled black on the inside.

Electrode Holders. Holders are necessary to use the electrode material and they are furnished in two types: one for carbon-electrode work, and one for metal-electrode work, both of which are shown in the accompanying illustration.

The carbon-electrode holder is provided with a simple effective clamp of rugged construction which grips the electrode securely, and yet readily permits rapid replacement of the electrode. As there is greater heat in the carbon arc, a disc is provided to protect the hand against the heat from the arc. The hand grip is so designed that the heat of the cable will not be injurious. The holder with the attached conducting cable is balanced so that in holding it, the strain on the operator's wrist is reduced to a minimum.

The metal-electrode holder is similar to, but somewhat smaller than the carbon electrode holder, as smaller currents are used. Furthermore, the protective disc is not necessary on account of less heat being developed at the arc.

Safety Enclosed Switches. Krantz safety auto-lock switches are desirable in steel mills, factories, mines and similar places employing men having practically no knowledge of electricity, and where switches must be placed in locations subject to damage from trucks or material.



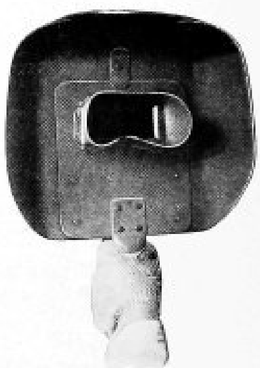
Krantz safety switch

The Krantz safety enclosed switches offer particular advantage in that they are 100 per cent safe under all conditions, and brush moving contacts are made use of in place of the knife-blade form of contact previously used for switch construction.

The switch parts are mounted inside of a sheet steel box so that the door over the fuses is automatically locked when the switch is in the closed position. When the contacts are open, the door can be opened, in which position it is held by means of a catch, and the switch cannot be closed.


Operator holding shield.


Protective Hood.


Interior of shield.

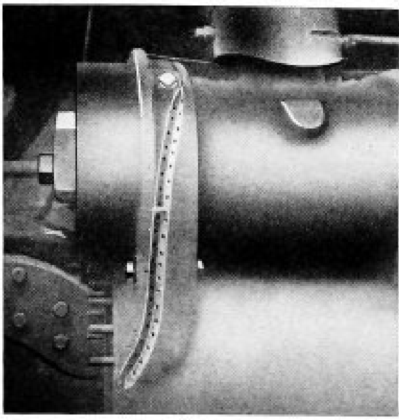


Fig. 1

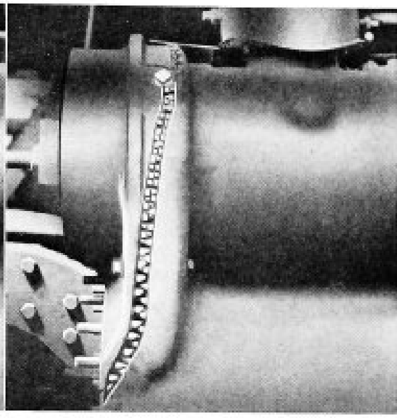


Fig. 2

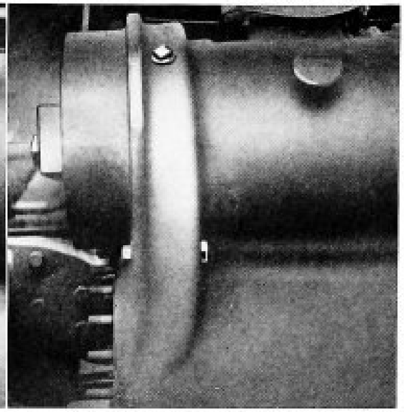


Fig 3

Fig. 1 shows a badly cracked locomotive cylinder. This illustration shows the cracked edges after they have been beveled and drilled and tapped for steel bolts. Fig 2 shows the steel bolts in position and the cylinder prepared for welding. Fig. 3 shows the weld completed and finished.

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