RIVETED AND WELDED STEEL PLATE CONSTRUCTION
ADVANTAGES OF EACH AS BROUGHT OUT ON ACTUALLY CONSTRUCTED PRODUCTS

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By

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PREFACE

To find in talking to Engineers that few are familiar with relative present day advantages of welded construction and of riveted construction in steel plate work.

In the last few years the arc welding process for joining metals in steel plate fabrication has experienced a most rapid growth in the more progressive plants throughout the country. The potential advantages of the use of this process have only been touched and with constant improvements its use will become practically universal in the next few years.

In view of this development and consequent interest, it was the thought of the writers that their experience in the fabrication of a wide range of products of steel plate might prove of general interest. The products included are representative of the industry and the conclusions and recommendations drawn from our test work will indicate to some extent the present range of use of the welding process as well as the trend.

Leland W. Browne.

Ralph W. Nichols.

Lawrence, Kansas, May, 1929.
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CHAPTER I

RIVETED AND WELDED CONSTRUCTION HISTORY
PART I

GENERAL HISTORY

Iron is older than history. The exact date of its discovery is unknown but its name has justly been used to designate that period in the history of civilization in which we are now living, the Iron Age.

Legend has it that the metal was discovered by the natives of Crete in much the same way as the Chinese are supposed to have discovered roast pork, it was found to have been melted from the ore by a forest fire. This was in the sixteenth century B.C. but iron was known before this as is evidenced by the discovery of a small piece of it in the pyramid of Ciosh and an iron tool in the pyramids of Kepron, the latter dating from 3500 B.C.

There is evidence that iron was familiar to the Assyrians, Chaldeans, and Babylonians, who occupied the plains of Mesopotamia for thousands of years before the time of Christ. The remains of large iron works were discovered in the Peninsula of Sinai. The Hebrews were familiar with the metal as it is mentioned several times in the Bible.

The Homeric poems reveal that the Greeks knew of iron and considered it a rare and precious metal. Several centuries later Alexander took plunder of iron from the conquered princes of India.
The Roman craftsmen used tools of iron in the third century B.C. and the Roman historian, Pliny, informs us that "iron ores are to be found almost everywhere." The Romans, however, had evidently been preceded by the Spaniards as iron makers since history tells us that the Spanish swords in the hands of Hannibal's men mercilessly cut down the more poorly equipped Romans at Cannae, 216 B.C.

Caesar found the Britons in possession of iron which they had made, indicating that iron was known to Northern Europe this early. The remains of the Viking boats show that the Scandinavians were iron and bronze craftsmen in the days of the Roman Empire.

From this we know that iron was known and used in wide-spread areas in the ancient world but everywhere it was a very dear and rare metal. As late as the fourteenth century A.D., it was too costly to replace brass in the kitchenware of the ordinary dwelling in England. Indeed, it was used only where its great strength and cutting ability was required, as in hoes, scythes, forks, and swords.

The great cost of iron was due to the lack of knowledge of how best to manufacture it. There had been surprisingly little progress made in the art from the time when it was first used until the epochal voyage of Columbus and it might be considered to be still in its primitive stages for several centuries thereafter.

An idea of the primitive method of iron manufacture may be had from the system that was still used in Central
Africa as late as seventy-five years ago. Two men would squat over a charcoal fire, which was between them. Both used hand bellows and charged the improvised furnace alternately with charcoal and iron ore. One day's labor of two men provided about one dozen pounds of iron.

In Roman times the Britons and Belgians dug conical holes on some hill-top having free access to the prevailing winds which would rush through a converging tunnel to the bottom of the fire hole. This primitive method of iron manufacture could be used only on days when the wind blew and at other times the furnace was necessarily idle.

Another primitive method of supplying the necessary forced draft was used in Southeastern Asia where bamboo was plentiful. The natives had learned that by forcing a loosely fitted piston through a hollow bamboo pole, in much the same way as we work a piston pump today, they could force air through into their fire. In this way they made iron before the dawn of the Christian Era.

Still another ingenious primitive device was used in Egypt thirty-five centuries ago. This was the goatskin bellows, the operator of which had two goatskins, one under each foot and both connected to the same main pipe which carried air to the fire. When one skin was filled with air the operator's weight forced it out into the fire. At the same time he pulled a string which inflated the other skin through a hole in its upper part. When it was inflated he would deftly place his bare heel over the hole and start a
current of air through the pipe. By deflecting the two alternately, he would maintain an almost constant blast.

The ancient world's primitive methods of iron manufacture were finally focused, as far as the European countries are concerned, on the so-called Catalan Forge. This was first devised and used in Catalonia, Spain. It differs but little from the ordinary blacksmith forge and has its air blast furnished by bellows or, if possible, by a water fall through the medium of a trompe, an ingenious device in which water falls through a pipe and carries air bubbles into an air-tight receptacle. Pressure is obtained by the air being carried downward in the falling water. The trompe is responsible for so many ancient iron works being located near streams and adjacent to water falls.

Large clinker deposits in Britain indicate that the Romans used this method there. That it was crude and expensive is known from the fact that these clinkers were later smelted and the metal that the Romans were unable to get was extracted at a profit. Recent experiments with the old Roman methods indicate that iron could not be produced in this way at a cost of less than one thousand dollars per ton.

The Catalan Forge prevailed through the middle ages and up to the time that the Germans developed from it the crude form of the blast furnace. Until then iron was not smelted but merely formed into a lump of the crude metal which was then hammered into usable shapes. The German forge was
built up to a height of from ten to fifteen feet and was called a "Wolf Oven" from the resulting form of the product. The output of the oven was from one hundred to one hundred and fifty tons per year.

The next stage was an enlargement of the "Wolf Oven" to a greater height and a change in its name to "Blow Oven." The greater heat of the flame succeeded in melting the metal so that it could be cast. This furnace was improved and perfected during the fifteenth and sixteenth centuries and resulted in an English furnace in 1600 which was described as being thirty feet high, as operating continuously and as making cast iron under the name of "Sow" or "Pig" iron. These names are derived from the custom of allowing the molten metal to run into a main trench and side trenches which caused the cast metal to resemble a family of small pigs feeding.

The iron industry was impeded in Europe by the fact that it resulted in deforestation of the territory in which it was conducted, since charcoal was the only fuel that was then thought to be of any use. As America was plentifully supplied with forests, the industry flourished in this part of the world.

Sir Walter Raleigh's successful expedition had brought back glowing accounts of iron ore from Virginia as early as 1585. In 1608, the year after Jamestown was settled, seven tons of iron were smelted in Bristow from Virginia ore. In
1620, an iron furnace was started on the James River, approximately sixty miles from Jamestown, but disease, death, financial difficulties and the Indian Massacres of 1682 caused its failure. In 1640, John Winthrop, Jr., son of the Governor of Massachusetts, with ten other Englishmen founded "The Company of Undertakers of the Iron Works" with a capital of 1000 pounds Sterling, and, within a year, were making iron at Lynn, Massachusetts. In three years the output was three thousand tons per week. However, the Company soon got into trouble over the devastation of adjacent forests and the overflowing of land by water that was backed up by their dam. In forty years their plant had closed. This plant was followed by others in the state and, for the century following 1620, Massachusetts was the chief iron maker among the colonies.

The industry grew and spread over New England and finally reached New York where the famous Sterling Forges in Orange County were established. It was in these furnaces that the chain, which was stretched across the Hudson to block the English, was made. By the end of the eighteenth century this one plant was producing twenty thousand tons of iron per year.

In 1743, Pennsylvania, now the leader of the world in making iron and steel, had thirty-four bloomeries in the vicinity of Philadelphia alone. The Pennsylvania industry, however, differed from that of the other states in that it
changed shortly after 1730 from blooming mills to furnaces that made pig iron almost exclusively. The industry spread from Pennsylvania to the states of Delaware, Maryland, Virginia and North Carolina.

The pioneer furnace of the Mississippi Valley was established at Bourbon, Kentucky, in 1791. This western furnace produced about three tons of iron per day and served a great need in that unsettled region. From Bourbon came the cannon balls, grape shot and chain shot for General Jackson in his historic destruction of the British at New Orleans in 1815.

Thus we can see that this industry in its undeveloped stage was fairly wide-spread throughout the old world and the new. It was now ready for the fundamental changes in the manufacturing process that lifted it out of its dark ages and into its present prominent position in the civilized world. The first of these changes was that of the substitution of coke for the charcoal that had heretofore been used as a fuel.

The fuel used for the smelting of iron had to burn easily, furnish great heat and be hard physically so as to bear up the burden of ore upon it; otherwise, it would be crushed down and the fire would be smothered. Charcoal was an ideal fuel but the quantities required were so great that it was relatively short-lived in every locality.

This pressure was soon felt in small England and, as
early as the reign of Queen Elizabeth, Parliamentary action was taken to prohibit the locating of blast furnaces in certain counties. This action drove the industry from one county to another, following the vanishing forests. The scarcity of charcoal had caused the relative decline of the industry in that country.

Germany with larger forest resources encouraged the industry and, in 1749, was exporting twenty thousand tons of iron to England, while England herself was making only eighteen thousand tons.

As early as 1619, Eud Dudley had succeeded in making partly burned coal serve the purpose of charcoal in his blast furnace but this proved to be unprofitable. His equipment was broken up by outraged charcoal dealers who saw in its improvement the threatened ruin of their business.

Bituminous coal itself was unsuitable for the purpose as in burning it formed a soft mass and choked the fire. In 1740, Abram Darby finally succeeded in using coke successfully but, due to the lack of development in coke making, this did not yet revolutionize the iron industry. However, it came just in time to save the industry in England as charcoal was running low there. The English coal deposits were very close to the iron deposits, a condition that greatly facilitated the use of coke in the manufacture of iron in that country.

In America there was an abundant supply of charcoal and so the use of this fuel continued in this country for fifty
years after it had been replaced by coke in England. However, the change from charcoal to coke came at the time when the railroads were just getting started and were becoming a sizeable factor in American industry. This was fortunate for the iron industry in that it permitted the ready use and acceptance of anthracite coal as a fuel.

The first actual introduction of anthracite coal to an iron works occurred in 1812. Five wagon loads were brought into Philadelphia, two were sold at cost and the remaining three were given away. One of the purchasers attempted to make a fire with the fuel and a half-day of disappointed labor resulted. It would not kindle, the workmen gave up in disgust, slammed the door shut and went to lunch. This gave the anthracite coal the necessary undisturbed kindling time and, when the workmen returned, they found the furnace glowing with white heat. Thus anthracite coal was introduced to the industry.

The first successful smelting of iron with anthracite coal was by a Doctor Geissenhaimer in 1836 and, by 1840, this fuel had become a factor of consequence to the industry. In 1849, the standard for iron quotations became one ton of anthracite iron rather than a ton of coke iron. However, due to the fact that it was obtainable in any quantity in only one state in this country and comprised but a small part of the total coal resources of the country, the leadership of anthracite coal as a fuel was short-lived.
It was not long before coke from bituminous coal became common and, as this type of coal exists in wide-spread areas, it naturally became the predominant fuel used in the iron industry.

In 1835, ninety-five years after the great English successes with coke, the Franklin Institute of Philadelphia offered a medal "to persons who shall manufacture in the United States the greatest quantity of iron from ore during the year, using no fuel other than bituminous coal or coke." This medal was never claimed but, in the same year, a furnace at Huntington, Pennsylvania, had succeeded in running a month continuously on coke. For a while iron made from coke and that made from anthracite ran side by side but, from 1865 to 1880, railroads had advanced greatly and western Pennsylvania, the center of the coke industry, came into its own. In addition two new centers, one in Colorado and the other in Alabama, developed.

The first step in the modernization of the iron industry was now complete. It had outgrown the old use of charcoal, had tried the use of anthracite coal and had found coke from bituminous coal to be the best fuel for its purpose. It was now ready for the second step in its development, the modernization of the process of manufacturing the iron.

In 1784, an Englishman, Henry Cort, had aided the industry greatly by the discovery of the puddling furnace and grooved rolls to assist in the purification of the iron.
Cort's scheme consisted of having a basin-like hearth full of molten pig iron, across which rushed the flames and burning gases from a fire from behind a low partition. This flame burned out the objectionable carbon, which was contained in the iron, the process being hastened by stirring the molten metal with a rake. After the carbon was burned out the iron rolled about, a viscous, spongy lump of nearly pure iron with every pore filled with molten lava. Cort's grooved rolls easily purified this iron by squeezing it and ejecting the impurities.

Seven years after this invention, fifty thousand tons of puddle iron were produced annually. In 1815, Samuel Baldwin Rogers invented a new lining for the puddling furnace which greatly increased its efficiency.

The efficiency of the process was further increased and the cost decreased by the introduction of the hot blast by J. B. Neilson. The output of the furnace was doubled with no increase in fuel by increasing the temperature of the air to approximately 600 degrees Fahrenheit before it was ejected into the furnace.

These improvements in the manufacturing methods reduced the cost of iron and so increased the demand for the product. Anchor ropes on ships, formerly made of hemp, were now made of wrought iron. Water pipes in cities and rails, formerly made of wood, were now made of wrought iron. The uses of the metal grew rapidly and, by the middle of the eighteenth century, there was a growing demand for a metal stronger than
iron. Steel was known and was good but was most costly. How comes the change that has made possible our modern civilization, a process for the economical manufacture of steel.

Steel is simply a mixture of pure iron with from four-tenths of one per cent to one and a half per cent of carbon. Cast iron is pure iron with from three to ten times as much carbon, while wrought iron is pure iron with practically all of the carbon taken out. Steel making is a process of mixing carbon with pure iron in proper proportions. This could not be done in a puddling furnace, because of the lack of a means of controlling the carbon content.

Steel had been made by putting wrought iron into a closed retort with carbon in the form of charcoal and then bringing it to a red hot heat with no air being available to burn the carbon. The iron was allowed to remain in this red hot carbon bath for days with the carbon gradually penetrating the iron. When time enough had elapsed, the iron was taken out, a rough, ragged bar, called "blister" steel. This steel was of a fine quality and was used for cutlery and the finest edged tools. It was too costly for any other purpose.

In 1858, Bessemer invented a process for producing cheap steel. Tons of molten iron were run into a great pear-shaped retort and air under pressure was then blown through holes in the bottom. The oxygen of the air united with the carbon in the iron and the heat from this generated a tem-
perature high enough to keep the iron hot. After about twenty minutes of this, the carbon was completely burned out of the iron, leaving it with the quality of wrought iron. This was then converted into steel by adding measured quantities of Spiegel iron or Ferro-manganese. As the amount of iron in the retort and the carbon content of the Spiegel iron were known, the carbon in this retort of steel was now under perfect control. The flame was cut off when the changing color indicated that the carbon was gone. The manganese thus added gave to the steel a toughness much needed to make it stand the strain to which it was to be subjected.

This process came just in time to meet the demand for cheap iron and steel that came with the industrial and railroad expansion immediately following the Civil War in this country. However, it did not fulfill all demands as the process was so quickly performed that proper control over the steel was impossible and flaws were likely to occur.

A remedy was sought by the Messrs Siemens, who took out patents on the open hearth process in 1856 but, due to the lack of sufficient heat, it proved unsuccessful. Approximately eight years later, a Frenchman named Martin perfected this process by applying to it the so-called regenerating device. The flames after passing over the steel melting hearth were carried over a brick framework, which was heated and, after an interval, the gas fuel was cut off and entered the furnace through the other stove, which was
previously heated. While this was being done the waste gases were heating a second stove on the other side of the furnace. This process had a fuel supply that was entirely independent of the iron and could go on as long as was desired. It was under perfect control and samples could be taken out and examined at any time. If too much of any one element was present, other elements could be added to reduce the excess. Unlike the Bessemer process, this one took from eight to ten hours and was, consequently, more costly but produced steel of more uniform strength.

Open hearth steel is used for boilers and other uses where steel of greater reliability is required. For such uses as railroad iron and structural girders a small flaw, which might be fatal to an engine or boiler, would make but little difference and so for such uses Bessemer steel is used, it being cheaper.

The steel comes from the Bessemer or open hearth converters molded into a great billet, like a piece of a large wooden beam. This is carried, red hot, to a so-called soaking pit, where it is heated until it is ready to start on its journey through the mills. In one direction, successive rollers squeeze, crush and lengthen it into steel rails, in which form it emerges a thousand feet away. Other sets of rolls make the billet into flat beams for bridges. A third set, also starting near the soaking pits, sends the billet out of the distant door of the steel mill in the form of
great, flat plates for making boilers, tanks and stacks. Other rolls form the billet into square rods which are chopped into pieces called "billets" or "blooms," which serve as raw materials for other mills making wire and nails or manufacturing steel of any other of a thousand forms. Thus steel passes out into the great world of manufacture.
So far, we have briefly sketched the use of iron and the development of iron manufacture from the early primitive methods to the modern methods of preparing steel. We must now turn to the methods of joining used in steel construction work and trace the development of those processes that are to be tested and compared in this paper. We shall first consider riveted plate work.

Riveting is exceedingly old. From all indications rivets were first used in ship building. When iron began to replace wood as the material for ship building, iron rivets replaced the copper dowels and wrought iron spikes used in the old wooden boats. Records show that, as early as 1820 in the United States, iron rivets were being made by machine. They were doubtless made by hand for some few years previous to this. At first, these rivets were made of wrought iron but, around 1867, soft steel was investigated and found to better serve the purpose.

The first soft steel rivets placed on the market in the United States were made by the Severance Manufacturing Company, the pioneer in the industry. As the rivets had to be soft and, at the same time, strong in order to be driven successfully, open hearth steel was found to be better for rivets than the unreliable Bessemer product.
Other than the afore-mentioned change from iron to steel rivets have suffered no great change since their origin. Many improvements, however, have been made in the art of heating and driving rivets. The first rivets were driven by hand with heavy hammers and it was not until 1900 that steel and air were used in the operation. About that time, pneumatic hammers or, as they are known to the workers, air guns came into general use. These are driven by steam or compressed air which acts intermittently against a small, solid piston. The piston is forced down and strikes a rivet set which, in turn, transmits the blow to the rivet and thus battens down its end to form the head. Other pneumatic and hydraulic devices to drive any known size of rivet have been designed for use in both field and shop work. Among these is the "Bull Riveter," which is capable of exerting a pressure of from one hundred and fifty to two hundred tons on the rivet head.

One of the latest developments in riveting devices is the electric hammer in which an electric magnet or solenoid replaces the compressed air used in the pneumatic type. Another type now used is one in which the piston is driven by an electric motor, to which has been attached an eccentric pin. These electric machines have successfully driven rivets from one-fourth inch to one and one-fourth inches in diameter. The smaller sizes are generally driven cold, while those of larger size must necessarily be heated to be driven successfully.
The strength of riveted joints has been reduced to a definitely calculable basis and for that reason they are generally used wherever definite strength is imperative. This is cited as an advantage over welded joints as one bad rivet in the joint does not necessarily spell failure for it, while a short space of bad welding is serious since welding is either excellent, approximating one hundred per cent efficiency, or is very weak. Another advantage is that riveted joints can easily be tested for strength by hammering while welded joints are hard to judge from the outside appearance.

The use of this method of joining is wide-spread. Practically all of the ships are of riveted construction. Then too, in the 60's, the American Architects established a new school or architecture with the modern sky scarpers, all of riveted construction. The thousands of bridges across rivers, supporting their load of human lives and standing the stresses imposed by vibration and expansion, stand as a mighty tribute to the art of riveted construction. The contribution of riveting to the progress and safety of humanity may be seen in every direction.
A second method used in joining in steel construction work is electric welding.

The application of electrical energy has occupied the minds of some of the foremost inventors during the past fifty years, and the developments that have taken place in this branch of engineering have been remarkably rapid. Some of the greatest manufacturing industries in the world have been built up on the basis of the inventions made in the electrical field. One of the many uses of electrical energy in the metal working trades is found in its application to electric welding. The electric welding process passed out of the experimental and into the practical stage many years ago, but still is rather vague in the minds of most people. The part it plays in present day industries is of great importance and without the methods of electric welding many products would have to be manufactured in an entirely different way and, in many cases, at a greatly increased cost.

Electric welding is simple; the parts that are to be welded together are heated to a melting temperature by means of an electric current. The parts are then brought together by a slight pressure and are joined through the fusing of their metals.

There is no definite date available as to when electric
welding was first used. It appears, however, to have been used for the first time in 1881 by De Meritens for welding together parts of storage battery plates. In this case the work was connected to the positive pole of the electric current and an electric arc generated with a carbon electrode. The heat generated by the arc fused the lead of the storage battery plate and thus welded it.

The idea had been conceived by Dr. Elihu Thomson as early as 1877, but it was years later that he designed and constructed the apparatus for his process. Between 1883 and 1885, he worked out plans for a welding apparatus based upon his earlier ideas. At this time he had at his command an alternating current dynamo which he had built. He constructed a welding transformer with welding clamps or holder for the piece to be welded.

The first machine, an experimental one, was built in 1886 and was followed by a larger one the next year. The apparatus consisted of two arms or clamp-holding bars, one of which was movable and swung on a joint which was insulated by interposing washers and a tube of insulating material, allowing a free movement of the arms but no passage for the current. Heavy cables, which were many times the section of the wire to be welded, connected the arms with the terminals of the apparatus producing the current. The work to be welded was held in place by means of clamps which held it firmly so that its abutting ends projected slightly. A
mechanism consisting of a spring, insulated by means of an insulator, acted upon by a screw, brought the work into contact as it heated. Heavy copper contacts were provided to automatically conduct the heat through the arms after the joint between the two wires had been made. This device prevented excessive fusing.

Thomson's process was based upon the principle that a poor conductor of electricity offered so much resistance to the flow of an electric current that it was heated, the degree of heat depending upon the volume of current and the resistance of the conductor. The pieces to be welded, when clamped into position, completed an electric circuit which was inadequate to carry the heavy current through them without heating. As the heat of the metal increased, the resistance increased, and the union or weld was thereby accelerated. The heat was confined to the metal between the clamps or bars and weld heat was reached so quickly that there was but very little time for the wasting of current by radiation or conduction.

Thomson's process is an electric resistance-welding process and is one of the two ways in which an electric current may be utilized for heating metals to a welding temperature. In resistance-welding the parts to be welded are brought to a welding heat by the passage through them of an electric current on such voltage and amperage that the resistance to the flow of the current is great enough to produce sufficient heat at the points or surfaces to be welded. When these
points or surfaces are brought together they will be joined by the fusing of the metals.

There is another resistance-welding process, known as the "percussion" method, in which the parts to be welded are heated instantaneously by the sudden discharge from a condenser and then forced together with a rapid blow. The sudden rush of current momentarily melts the portions of work that are to be joined and, by forcing them together at this moment, a good weld is secured. This process is of recent development, having been originated by L. W. Chubbs, of the Westinghouse Electric and Manufacturing Company at East Pittsburgh, Pennsylvania, in 1905.

While conducting tests on electrolytic condensers, Mr. Chubb noticed that wires could be connected to aluminum plate by the condenser spark. This joint was not strong but, in tests using condensers with larger capacities, it was found to be possible to make stronger joints. The first apparatus consisted of two hinge arms with wire grips in their ends to hold the wires to be welded. After being released the arms were drawn together and, at the instant of contact, the condenser was discharged. The force of the impact welded the ends together. Later, the construction of the apparatus was changed to resemble a small pile driver. The latter method afforded an easier means of study and was found to be more successful from the point of operation. Direct current was used, whereas alternating current is used in resistance welding. This process is used primarily in
welding aluminum wires and can be used in welding two metals together regardless of their different characteristics.

A distinctive feature of the resistance-welding process is that the interior of the metal is raised to a welding temperature before the surface reaches this heat, thus ensuring a good weld throughout when the surface outside indicates a good weld. In welding in a forge the opposite condition occurs; a perfect weld may be indicated on the surface, but this weld may cover an imperfect joint inside.

The advantages claimed for the resistance process are briefly; a homogeneous weld is obtained, finished work may be welded without serious damage to the surface, impurities are forced out of the joint, the process is rapid, the cost of labor is reduced and the operation is in plain view as it proceeds so that defective welds may be easily prevented.

There is another type of welding, known as arc-welding, wherein an electric arc is drawn between two electrodes, or between the work and one electrode. This arc is brought into such a position relative to the work that the heat from the arc melts the metal to be welded and enables the parts to be united.

This type may be subdivided into four different processes which are named after the men who are accredited with their discovery. They are the Zerenener, the Bernardos, the Slavianoff and the Strohmenger-Slaughter.

In the Zerenener arc-welding process, two electrodes, so arranged in a holder that they form a "V", are employed. An
arc is drawn between them, which arc is caused to impinge upon the metal surfaces to be welded by a powerful electromagnet so placed that the arc is forced toward the work. This causes the arc to act in a manner similar to the flame of an oxy-acetylene torch. The process is also known as "the electric blow pipe method," on account of the peculiarity of the impinging arc, and was invented about thirty years ago. No current passes through the work. It is based on the fact that two rods of carbon, or other electrodes, connected to the poles of a generator, will have a flame playing between them, the flame being known as an electric arc. The size of the arc is varied by several methods, among which are, varying the distance between the electrodes and changing the electric current.

The Zerener process is used to a limited extent for comparatively small work on steel and brass, and for welding small corners in tubes and tanks. It is, however, inefficient and complicated, and requires great skill to be applied properly. Therefore, it is not used as extensively as are the other processes.

The Bernardos electric arc-welding process is, perhaps, the best known of the welding methods, and, until recently, was the most extensively used. It is especially adapted to large and heavy work. In this process the arc is drawn between the metal of the work and a single carbon or graphite electrode. The arc is drawn by touching the electrode to the work and withdrawing it to the proper distance, in a
manner similar to that in which an arc light is lighted. The temperature of the arc is approximately 6200 degrees Fahrenheit and this heat is confined to a comparatively small space directly in contact with the arc. It is commonly known as the carbon electrode process.

At first, the carbon electrode was used as the positive terminal with the work as the negative. This proved to be unsuccessful, however, as part of the carbon from the electrode was carried into the work, thus making it very hard and brittle. In reversing the electrodes this condition was corrected and it was found that, with the electrode as the negative terminal, a greater portion of the heat was concentrated in the work which was the positive terminal.

The carbon rod used varies in size from three sixteenths of an inch to one and one-half inches in diameter, depending upon the size of the work to be welded. The electrodes are held in an insulated holder which is manipulated by the workman’s hands. The pieces of metal to be welded are melted on their faces together with a small iron rod which acts as a solder and flows in between the pieces.

This system, when properly adapted to the work to be done, is practical, simple and efficient.

The Slavianoff electric arc-welding process is commonly called the metallic arc-welding process, because of the fact that a metal electrode is used instead of the carbon. This metal electrode eliminates the introduction of carbon into
the work and thus produces a softer and stronger weld. The arc is drawn by touching the work with a metal electrode and drawing it away in the same manner as in the Bernardos system. The metal electrode acts as a solder by gradually melting away and entering the weld.

The arc is smaller than in the Bernardos process and, consequently, this process is slower. This, however, is of small importance on small work. As the arc itself will carry the metal from the electrode to the work, it is possible to use this method for welding on a vertical wall or in overhead work and hence the process is largely used in overhead repair work, in fireboxes, for welding fluxes in boilers and, in general, when repairs must be made in place.

All of the welded specimen referred to later and used in the tests conducted are welded by the Slavianoff process.

The last of the arc-welding processes is the Strohmeenger-Slaughter. The parts to be welded together are placed in the required position and an electrode, consisting of a soft iron rod, covered all over, except at the extreme ends, with a flux suitable for the metal to be welded, is laid upon and along the welding lines. This flux also serves as an insulator. The work acts as an electrode as in the Bernardos and Slavianoff processes. An arc is drawn as in these processes, thus causing the electrode to melt. The flux from the electrode, on being melted, coats the weld and, at the same time, prevents oxidation. This process is claimed to be successful in the welding of rails and for
building up worn places, but it is not so generally used as are the other processes.

The extensive use of welding in any work is comparatively recent as its application to the metal working industry was not realized as soon as its possibilities would seem to have merited. As a result, a considerable portion of the life of the early patents passed by without much attention being given to the process. A too conservative attitude prevented the use of the process and it did not come into general use until it was greatly aided by the general growth of stations for generating and transmitting electrical energy.

The process as originally applied and developed was carried on with very few appreciable changes. There were, of course, some marked improvements in design of apparatus, construction of welding transformers adapted to particular uses, but a great deal of this was foreseen from the start and taken care of in many cases.

As a matter of history, since the original patents for electric welding were taken out by Dr. Thomson, one firm alone, a manufacturer of welding apparatus, has taken out over one hundred and fifty patents, under which this firm is now manufacturing their machines. Other firms have taken out large numbers of patents also. The patent records at the present time contain by far the largest amount of available information on the subject of electric welding.
All sorts of special machines have been built for special work but all consist principally of a transformer for changing the current to the low voltage and high amperage required to produce the necessary resistance, clamps for holding the work, a means of forcing these clamps together and a control apparatus for regulating the flow of the current.

The resistance-arc-welding process is employed for regular butt and lap welding, as well as for a number of special welding methods that have been developed. These are known as "spot," "joint," or "projection" and "ridge" welding. The resistance process is applicable to manufacturing work rather than to repair work and is used extensively in duplicate work in such industries as the manufacture of automobiles and bicycles and, lately, in the manufacture of aeroplanes.

The arc-welding process is used almost entirely in plants engaged in the fabrication and erection of products of steel plate, such as tanks, stacks, boilers, breechings and light structural work. Because of the fact that it is difficult to determine by inspection whether or not a weld has been properly made, welding is not used to any great extent for high pressure work. However, a careful operator can obtain a weld strength nearly equal to that of the plate itself. Arc-welding is used to a very large extent on mammoth pipe lines for oil, water, or gas and is used very
extensively in nearly all sorts of steel repair work.

Arc-welding has recently been used to excellent advantage in the welding of small steel buildings. Comprehensive tests are now being made on such construction by such firms as the General Electric Company and these tests are expected to furnish valuable data for future designs. Several buildings of moderate size have recently been built largely of welded construction and, in every instance, savings over similar buildings of riveted construction have been made. The great savings are being made in the metal and fabrication costs. Erection costs have nearly always exceeded those of riveted buildings.

Between 1915 and 1920, ships of welded construction were being built in England. In 1918, a one hundred and fifty foot, five hundred ton coasting ship, named the Fullagar, was launched. A one hundred and twenty-five foot, completely welded, cross-channel barge for use between England and France was launched in 1917. Since then several more barges of this type have been built in England.

A large gas company in Australia recently completed at Fitzroy a two million cubic foot gas holder of welded construction throughout, except for fit-up rivets. In Melbourne, in the same country, another gas tank, two hundred feet in diameter, was welded up complete. In both cases savings over riveted construction were achieved. However, the welding of this type of structure is in its infancy with rapid develop-
ments being made.

The American Society of Mechanical Engineers in connection with the American Welding Society is now conducting studies of welded construction on pressure vessels in an effort to gain reliable information for future design.

Fifty-six hundred pounds per square inch is the allowable working stress for fusion welded joints as specified in the code for unfired pressure vessels, published by the Society of American Engineers. This value is very conservative and many prominent engineers think that it should be changed for different kinds of joints and for different uses. Some changes will undoubtedly be made in the code when the tests now under way are completed.

One United States firm concentrating on welding has been very successful with a patented process called "Smith-weld," which is used for welding all sorts of pressure vessels, some up to six hundred and fifty pounds per square inch pressure and made of steel three inches thick. One oil cracking unit, weighing seven hundred thousand pounds, was "Smith-welded." Oil and gas pipe lines are now made by this process at the rate of from eight to ten miles per day. One automobile frame plant produces eight thousand finished welded frames per day. Many similar products are being successfully made by welding and at a smaller cost than would be possible by using any other method of joining.
The two processes already discussed, riveting and welding, have recently been combined to form a third, but its application is limited as there are but few cases that either riveted or welded construction alone will not serve the purpose. Riveting and welding are combined in such cases where the vessel must stand a high pressure and still be absolutely tight as in high pressure gas holders. Rivets on large pitch are used in welded tank work quite extensively to facilitate fitting up. When this is done, however, the weld is depended upon to furnish the strength to the joint.

Several large tank builders have combined the two processes in order to save building the first rings of large tanks on blocks and then testing them in this position, which is usually done to facilitate caulking under test. However, the process of building up the first ring on blocks and then lowering it to the foundation after completion is costly. Since it is very easy to secure a tight joint by welding, these tanks are sometimes built directly upon the foundations with but a few rivets for fitting up and then the entire bottom is welded on the inside. The expense of caulking, of driving a great number of rivets and of lowering tanks after completion is saved by combining riveting and welding in such work.
The large gas holder used in the tests for this paper were of combined riveted and welded construction and proved to be very successful.

It is known that in welding a riveted joint some of the rivets will be loosened by the heat of the weld so that it is usually necessary to weld around each rivet to insure an absolutely tight job.
PART V.

STAYBOLTED PLATE WORK

We have now come to our last method of steel plate construction, the staybolting process, which is used to tie together the inner and outer shells of jacketed vessels. Just when this method was first used is not known but men not of the old school in boilermaking inform us that, as early as 1895, staybolts were used in the Mississippi Valley.

The staybolt is a round bar, procurable in lengths approximately 36" long, threaded continuously from end to end, and with one end squared to facilitate screwing in place. The holes in the two shells of the vat or tank being stayed occur directly opposite each other and are tapped with a continuous thread. The staybolt is screwed into these holes and cut off so that the ends project slightly. These projecting ends are battered down very much as is a rivet head, and, in this way, the staybolts are made tight as well as strong. Standard staybolt stock varies in size from five-eighths of an inch to one and five-eighths inches in diameter and is usually made from a very soft but reliable steel that will endure the necessary severe service. Some manufacturers still adhere to the use of wrought iron staybolts but these are few.

With the ordinary solid staybolt, the only way a broken bolt could be discovered, except, of course, by taking it
out, was by tapping the end of the bolt lightly with a hammer and with this method only a skilled workman was able to tell. Consequently, the "tell-tale" or hollow staybolt was devised. This hollow staybolt is identical with the original solid bolt except that a small hole, approximately three-sixteenths of an inch in diameter was drilled completely through the bolt. These, of course, were not as strong as solid bolts, but, by their use, any sort of a failure in the bolt is easily detected.

A great use of staybolts has been made in the many jacketed vessels employed in the meat packing industry and in the grease and soap industries. Such vessels resemble ordinary tanks and are either rectangular or circular in appearance but differ in construction in that they have two shells with a small space between them properly sealed in which either steam or hot water is circulated. The material being treated rests inside the inner shell of the tank and is heated by the steam or hot water in the jacket. Staybolts tie these two shells securely together and withstand the pressure of the steam or water in the jacket. These vessels and various types of boilers for the generation of steam would be impossible were it not for staybolted construction.
CHAPTER II

PRODUCTS OF STEEL PLATE CONSIDERED
1. WELDED GAS HOLDER - DRAWING 1-W.

Furnish Made up at our Plant:

1 - Gas Tank; 10'6" inside diameter x 46'10½" long in the shell; of 3/8" steel throughout, with all seams electrically welded, using the double "V" weld; tank is to be equipped with two 10" x 16" manholes, two 2" flanges and two 4" flanges, all located as shown on drawing attached, and is to be given one coat of good paint on the outside before shipment; on completion tank is to be tested under 90 lbs. of hydrostatic pressure.

2. WELDED STACK - MADE UP IN SECTIONS AT THE PLANT - DRAWING 2-W.

Furnish Made up in Sections at our Plant:

1 - Steel Stack; 40" in diameter x 110'0" high overall; the first 40' to be of 5/16" steel, the next 40' to be of 1/4" steel, and the top 30' to be of 3/16" steel; all seams in stack are to be electrically welded, and the sections are to be provided with a flanged connection for bolting together in the field; stack is to have two sets of four eyebolts each for guy wire connections, and to be reinforced where
3. WELDED BREECHING - MADE UP IN SECTIONS IN PLANT - DRAWING 3-W.
Furnish Made Up in Sections at our Plant:
1 - Breeching; 48" x 48" x approximately 46'8" long overall; breaching to have one 90 degree elbow and to be made of No. 10 gauge steel throughout; to have one cleanout door in one end; breaching to be of welded construction throughout, except for field joints, which will be flanged for a bolted or riveted connection; outside of breaching to be given one coat of good heat-resisting paint before shipment; see The Darby Corporation blue print No. CCS-101-29; breaching to be made up in four sections.

4. WELDED ACID TANK - MADE UP AT OUR PLANT - DRAWING 4-W.
Furnish Made Up at our Plant:
1 - Acid Tank; 5'0" in diameter x 18'0" long; made of
3/4" steel in the shell, and of 7/8" steel in the heads; all seams in the tank to be electrically welded, using the double "V" weld; tank is to be made up complete at our plant, with all openings and fittings as shown on attached blue print, and given one coat of good paint on the outside on completion.

5. WELDED BRINE TANK - MADE UP IN PLANT - DRAWING 5-W.
Furnish made up at our plant:
1 - Tank; 8'0" long x 4'0" wide x 4'0" deep; of 1/4" steel throughout; tank to have a 2 1/2" x 2 1/2" x 1/4" angle around the top on the outside, and to be equipped with two 2" flanges, located as directed; tank is to be made up complete at our plant, of electric welded construction, and given one coat of good paint on the outside before shipment.

6. WELDED WATER STORAGE TANK - ERECTED IN FIELD - DRAWING 6-W.
Furnish and build in place on foundation provided:
1 - Steel Tank (open top) 15'9" in diameter x 28'4" high; the bottom plates to be 1/4" thick, flanged for welding; the first bottom ring to be of 1/4" plate; balance of plates to be 3/16"; all plates to be rolled and punched at approximately 24" centers
for 1/2" bolts for bolting up; we are to weld the seams in the field; top to be finished with 2" x 2" x 1/4" angles rolled to proper diameter; we are to furnish two 3" steel boiler flanges for inlet and outlet connections; also one 6" double flange, one 20" manhole, complete, one steel outside ladder; we are to locate manhole and flanges on job and weld same to tank; we are to furnish required 1/2" bolts for assembly; tank to be given one coat of good paint on outside on completion.

7. AIR TANKS - WELDED - MADE UP IN PLANT - DRAWING 7-W.
Furnish Made up at Our Plant:

20 - Air Tanks; 16" outside diameter x 42" long overall; made of 3/16" steel in the shell; of 5/16" steel in the heads, which are to be dished; all seams are to be electrically welded; tanks are to be equipped with standard openings, as shown on attached blue print, and are to be subjected to a hydrostatic test of 210 lbs. per square inch on completion, after which they are to be given one coat of good paint on the outside.

8. WELDED WATER STORAGE TANKS - DRAWING 8-W.
Furnish Made up at Our Plant:

2 - Vertical Tanks; 10'0" in diameter x 20'0" high;
made of 1/4" steel throughout; tanks are to have 2" x 2" x 1/4" angle around the top on the outside, but are not to have covers; each tank is to be equipped with inside and outside ladder, and is to be given one coat of good paint inside and outside before shipment; tanks are to be made up complete at our plant, with all seams electrically welded.

9. WELDED DIGESTERS - MADE UP IN PLANT - DRAWING 9-W.
Furnish Made up at our Plant:
16 - Garbage Disposal Cookers or Digesters; shell of 3/8" and heads of 1/2" flange steel of 55,000 to 65,000 tensile strength; top and bottom heads both to be dished to a radius equal to the diameter or 6'; digesters to be 6' in diameter x 16' high on the outside over heads, all longitudinal and girth seams of shell to be welded electrically in a manner satisfactory to some standard insurance company; digesters to be fitted with charging and discharging openings and pipe connections, conforming with that indicated on the blue print attached hereto; pipe coils to be furnished but not installed. The discharge door frame is to be mounted as nearly in line with the upper surface of the perforated grate as is possible; the grate referred to is to be of 1/2" boiler plate and
punched with approximately 1/2" holes, on about 1\(\frac{1}{2}\)" centers, not laid out exact; all castings to be of the best grade of gray iron and to be made straight and true to pattern; all castings to be riveted to digesters; the two pipe flanges and one small dome casting to be riveted to each digester, with 1/8" copper gaskets between themselves and shell or head plate, where they are to be attached; all castings to be caulked and made tight from the outside; digesters to be made up as shown on blue print; drop forge eyebolts and yoke pins to be used in all instances where same are indicated on blue print. All digesters to be given one coat of good paint when completed. Upon completion of these digesters at our plant, same are to be tested at 150 lbs. hydrostatic pressure.

10. WELDED FREEZING TANK - ERECTED IN FIELD - DRAWING 10-W;
Furnish and Build in Place on Foundation Provided:
1 - Freezing Tank; 30'0" long x 23'0" wide x 51" deep;
of 1/4" steel, except the bulkhead and agitator trough, which are to be of No. 10 gauge steel;
tank is to have a 2\(\frac{1}{2}\)" x 2\(\frac{1}{2}\)" x 1/4" angle around the top on the outside, together with vertical bracing angles and cross ties to properly support the tank when full of brine; all material to be
fabricated at our plant, and built in place on foundation provided, with all seams electrically welded.
PART II

RIVETED

1. RIVETED GAS HOLDER DRAWING 1-R
Furnish Made up at our Plant:

1 - Gas Tank; 10'6" inside diameter x 46'10½" long in
the shell; made of 3/8" steel throughout; with
all round-about seams, lap-joint, single riveted,
and all longitudinal seams, lap-joint, double
riveted; all seams are to be caulked inside and
outside, and are to be made tight when tested under
a hydrostatic pressure of 90 lbs. per square inch;
tank is to be equipped with two manholes and stan-
dard flanges, all as shown on attached drawing,
and to be given one coat of good paint on the out-
side before shipment.

2. RIVETED STEEL SMOKE STACK - MADE UP IN SECTIONS IN
THE PLANT - DRAWING 2-R.
Furnish Made up in Sections at our Plant:

1 - Steel Smoke Stack; 42" in diameter x 120'11" high
overall; the first 35 feet to be of 5/16" steel,
the second 35 feet of 1/4" steel, and the balance
of 3/16" steel; stack is to have a base plate,
reinforcing angles and guy bands, all as shown and
detailed on attached drawing; stack is to be made
up at our plant in approximately 40' sections; all seams, lap-joint, single riveted, and given one coat of good paint on the outside before shipment.

3. RIVETED BREECHING - MADE UP IN SECTIONS IN PLANT - DRAWING 3-R.

Furnish Made up in Sections at our Plant:
1 - Breeching; 3'0" wide x 6'0" high; made of No. 10 gauge steel; having an overall length of approximately 30'0"; breeching is to be reinforced with 2\(\frac{3}{4}\)" x 2\(\frac{3}{4}\)" x 1/4" angle completely around the outside on 4'0" centers; breeching is to be of riveted construction, with all seams lap-joint, single riveted, and is to have two uptakes for boiler connection and one cleanout door; the sections are to have an angle iron connection for bolting together in the field; breeching is to be made up at our plant in sections convenient for erection, and given one coat of good paint on the outside on completion.

4. RIVETED COMPRESSION TANK - MADE UP IN PLANT - DRAWING 4-R.

Furnish Made up at our Plant:
1 - Compression Tank; 4'6" in diameter x 11'9" high
in the vertical shell, which is to be of 3/4" steel; the dished heads are to be of 7/8" steel; all longitudinal seams to be quadruple riveted, double butt-strap joint; all girth seams to be double riveted, lap-joint; tank to be made up complete at our plant, with all openings and fittings as shown on attached blue print, and to be given one coat of good paint on the outside on completion.

5. **RIVETED BRINE TANK - MADE UP IN PLANT - DRAWING 5-R.**

Furnish Made up at our Plant:

1 - Tank; 8'0" long x 5'0" wide x 3'0" deep, of 1/4" steel throughout; tank to have 2" x 2" x 1/4" angle around the top, and to be equipped with one 1½" and one 2" flange, located as you may direct; with all seams lap-joint, single riveted, and given one coat of good paint on the outside upon completion.

6. **RIVETED WATER STORAGE TANK - DRAWING 6-R.**

Furnish and Build in Place on Foundation Provided:

1 - Tank; 31'6" in diameter x 25'7" high in the shell, having an approximate capacity of 150,000 gallons; bottom of tank to be made of 3/16" steel; the first ring of shell of 1/4" steel, the second ring of 13/64" steel, and top three rings of 3/16" steel;
tank is not to have a roof; tank to have 3" x 3" x 3/8" angle around top on the outside, and to be equipped with 20" cast iron, bolted cover manhole, one ladder, one swing line, one gauge, one 6", one 4", and one 2" flanges; all located as directed; material to be fabricated at our plant and built in place on foundation, with all seams lap-joint, single riveted, with the exception of the vertical seams in the shell, which are to be lap-joint, double riveted; all rivets 7/16" diameter; tank to be riveted up complete, with all seams caulked and made tight, and given one coat of good paint on the outside upon completion.

7. RIVETED AIR TANKS — MADE UP IN THE PLANT — DRAWING 7-R.

Furnish Made up at our Plant:

78 - Air Tanks; 16" outside diameter x 42" long overall; made of 3/16" steel in the shell; of 5/16" steel in the heads, which are to be dished; all seams are to be lap-joint, single riveted, and to be caulked and made tight, tanks are to be equipped with standard openings, as shown on attached blue print, and are to be subjected to a hydrostatic test of 210 lbs. per square inch on completion, after which they are to be given one coat of good paint on the outside.
8. RIVETED WATER STORAGE TANK - MADE UP IN THE PLANT -
DRAWING 8-R.

Furnish Made up at our Plant:

1 - Tank; 10'0" in diameter x 17'6" high; made of
3/16" steel throughout; tank to have a 2" x 2" x
1/4" angle around the top on the outside, and a
2\(\frac{3}{4}\)" x 2\(\frac{3}{4}\)" x 1/4" angle around the bottom on the
inside for connecting the bottom to the shell;
tank is not to have a cover; all girth seams and
seams in the bottom are to be lap-joint, single
riveted; all vertical seams, lap-joint, double
riveted; tank is to be equipped with an inside
and outside ladder, is to be made up complete at
our plant, and given one coat of good paint on the
outside before shipment.

9. RIVETED RENDERING TANK - DRAWING 9-R.

Furnish Made up in our Plant in Two Sections:

16 - Rendering Tanks; 6'0" in diameter x 16'0" long in
the shell; shell to be made of 1/2" steel, with
upper cylinder to lap inside of lower cylinder;
longitudinal and girth seams to be lap-joint, double
riveted, with 7/8" rivets, 2\(\frac{3}{2}\)" pitch; all lap-joints
to be caulked both inside and outside with fuller
and fine tool.

Top head to be 5/8" steel, dished 9-5/8", and to
have an oval manhole, 18" x 22", cut in the heads for cast iron frame and manhole cover. Manhole frames to be riveted on the inside of the heads with 7/8" rivets.

Shell to have two pressed steel flanges, riveted near center, as per blue print; one hole thread for 1/2" pipe in the top head, half way up from the side of the tank, and 2" pressed steel flange to be riveted in center of head. Bottom head to be cone-shaped of 5/8" steel, and to be made in four segments, riveted together with lap-joint, double riveted, 7/8" rivets, 3/16" pitch.

Casting to be riveted to bottom of cone with 12" opening for 19" flange. Twelve 7/8" holes to be drilled in flange on about 16-3/4" diameter circle. Standard drilling in flange to receive 12" valve; also 2" standard pipe thread in front of casting.

Tank to be made up in our plant in two sections - top ring and head making one section, and one ring and bottom making the second section, to facilitate erection.

10. RIVETED BRINE TANK - DRAWING 10-R

Furnish and Build in Place on Foundations Provided:

1 - Freezing Tank; 31' long x 24' wide x 51" deep; of 1/4" steel; tank is to have one bulkhead and
agitator trough of No. 10 gauge steel, and is to have 2 1/2" x 2 1/2" x 1/4" angle around the top on the outside, together with three vertical bracing angles; also 2 1/2" x 2 1/2" x 1/4" angles on each side and three cross ties of 3/8" x 2" flat mild; all seams of tank to be lap-joint, single riveted, and to be caulked and made tight; tank to be erected complete on foundation.
PART III

WELDED AND RIVETED

1. RIVETED AND WELDED GAS HOLDER - MADE UP IN PLANT - DRAWING 1-WR.

Furnish Made up at our Plant:

1 - Gas Tank; 10'6" inside diameter x 46'10½" long in the shell; of 3/8" plate throughout; with all round-about seams single riveted, lap-joint, and all longitudinal seams double riveted, lap-joint; all joints are to be welded as shown instead of caulked; the tank is to be equipped with two 10" x 16" manholes, two 2" flanges and two 4" flanges, all located as shown on approved drawing; tank to be made up complete at our plant, and given one coat of good black graphite paint on the outside before shipment.

4. RIVETED AND WELDED ACID TANK - MADE UP IN PLANT - DRAWING 4-WR.

Furnish Made up at our Plant:

1 - Acid Tank; 4'6" in diameter x 20'0" long; made of 1" tank steel quality plate, with heads of flanged quality steel; longitudinal seams are to be double riveted, lap-joint; girth seams, single riveted, lap-joint; all rivet holes to be sub-
punched and reamed to size; all seams are to be electrically welded on the caulking edge on the inside and caulked on the outside; all rivet heads are to be welded on the inside; tank is to be made up complete at our plant, with all fittings and openings as shown on attached blue print and subjected to a hydrostatic test of 150 lbs. per square inch on completion.

7. **RIVETED AND WELDED AIR TANKS - MADE UP IN THE PLANT - DRAWING 7-WR.**

Furnish Made up at the Plant:

50 - Air Tanks; 16" in outside diameter x 42" long overall; made of 5/16" steel in the shell; of 5/16" steel in the heads, which are to be dished; all seams are to be lap-joint, single riveted, and are to be electrically welded on the caulkimg edges outside; tanks are to be equipped with standard openings; as shown on attached blue print, and are to be subjected to a hydrostatic test of 210 lbs. per square inch on completion, after which they are to be given one coat of good paint on the outside.

9. **RIVETED AND WELDED RENDERING TANKS - MADE UP AT OUR PLANT IN TWO SECTIONS - DRAWING 9-WR.**
Furnish Made up at our Plant:

10 - Hendering Tanks; 6'0" in diameter x 16'0" long in the shell; shell to be made of 1/2" steel, with the upper cylinder to lap inside of lower cylinder; longitudinal and girth seams to be lap-joint, double riveted, with 7/8" rivets on 3 1/2" pitch; all inside seams and rivet heads are to be electrically welded, and all outside seams are to be caulked with fuller and fine tool.

Top head to be 5/8" steel, dished 3-5/8", and to have an oval manhole, 18" x 22", cut in the heads for cast iron frame and manhole cover. Manhole frames to be riveted on the inside of the heads with 7/8" rivets.

Shell to have two pressed steel flanges, riveted near center, as per blue print; one hold thread for 1/2" pipe in the top head, half way up from the side of the tank, and 2" pressed steel flange to be riveted in center of head. Bottom head to be cone-shaped, of 5/8" steel, and to be made in four segments, riveted together with lap-joint, double riveted, 7/8" rivets, 3 1/2" pitch.

Casting to be riveted to bottom of cone with 12" opening for 19" flange. Twelve 7/8" holes to be drilled in flange on about 16-3/4" diameter circle. Standard drilling in flange to receive 12" valve.
also 2" standard pipe thread in front of casting.

Tanks to be made up in our plant in two sections - top ring and head making one section, and one ring and bottom making the second section, to facilitate erection.
PART IV
STAYED PLATE WORK

1. RIVETED - JACKETED DRAIN PANS - MADE IN OUR PLANT - DRAWING 1-S.

Furnish Made up at our Plant:

2 - Steam Jacketed Drain Pans; 7'0" long x 3'5" wide x 3'0" deep; having a 2" steam jacket covering the entire bottom and extending up on the sides for a distance of 1'; this jacket to be staybolted to the shell with 5/8" staybolts, threaded, with the heads riveted over; pans are to have a 2\(\frac{1}{2}\)" x 2\(\frac{1}{2}\)" x 5/16" angle around the top on the outside, and to be equipped with one 2" and two 2" flanges, located in accordance with attached drawing; all seams in the pans are to be lap-joint, single riveted, and to be caulked and made tight; pans are to be given one coat of good paint on the outside on completion.

2. WELDED - JACKETED DRAIN PANS - MADE UP AT OUR PLANT - DRAWING 2-S.

Furnish Made up at our Plant:

2 - Jacketed Drain Pans; 7'0" long x 3'5" wide x 3'0" deep; having a 2" steam jacket covering the entire bottom and extending up on the sides 1'; this
jacket to be staybolted with 5/8" rods, welded to the shell and to the jacket; pans are to have a 2¼" x 2½" x 5/16" angle around the top on the outside, and are to be equipped with two 2" and one 3" flanges, all located in accordance with attached drawing; pans are to be made of 1/4" plate throughout, and are to be given one coat of good paint on the outside on completion; all seams in the pans are to be electrically welded.

3. WELDED AND STAYBOLTED MIXER - DRAWING 3-S.

Furnish and build in place on foundations provided:

1 - Mixer; 7'4" in inside diameter x 12'6" long overall; the shell of mixer is to have a steam jacket, with 1½" steam space on the outside; jacket is to be staybolted on 11½" centers, with 7/8" rods welded to the shell and to the jacket, as designed for a working pressure of 25 lbs.; the shell of mixer to be made of 3/8" steel and heads of 1/2" steel; both heads are to be reinforced with 4" x 4" x 1/2" angles, both horizontal and vertical, as shown on attached drawing; all seams in mixer to be electrically welded inside and outside where possible; we are also to furnish four (4) 12" channels, 20.7$ per foot, each 14'0" long, to be used in supporting the mixer; we are also to furnish one (1) 3-15/16"
diameter shaft; 16'0" long with 10" of 1" keyway, one end only, with stuffing boxes and brackets for supporting bearings; we are also to furnish five (5) bands of 6 x 1/2" flat mild bar for supporting the mixer; all material to be fabricated at our plant, and built in place on foundations provided, Kansas City.

4. RIVETED AND STAYBOLTED MIXER - DRAWING 4-3.

Furnish and build in place on foundations provided:

1 - Mixer; 7'4" in inside diameter x 12'6" long overall; the shell of mixer is to have a steam jacket, with 1 1/2" steam space on the outside; jacket is to be staybolted on 11 1/2" centers with 7/8" staybolts, threaded, with heads riveted over, as designed for a working pressure of 25 lbs.; the shell of mixer to be made of 3/8" steel and heads of 1/2" steel; both heads are to be riveted to the shell; we are also to furnish four (4) 12" channels, 20.77 per foot, each 14'0" long, to be used in supporting the mixer; we are also to furnish one (1) 3-15/16" diameter shaft; 16'0" long with 10" of 1" keyway, one end only, with stuffing boxes and brackets for supporting bearings; we are also to furnish five (5) bands of 6 x 1/2" flat mild bar for supporting the mixer; all material to be fabricated at our plant,
and built in place on foundations provided, Kansas City.
SIDE ELEVATION OF TANK
1 Req'd

NOTES:
- Tank to be of welded construction throughout
- Test at 80 lbs hydrostatic pressure
- Paint one coat of Black Chalk

THE DARBY CORPORATION
END ELEVATION

DETAIL OF DOUBLE 'V' WELD

NOTES:
Tank of welded construction throughout.
Tank to be made up complete in shop.
To be given one coat of Black Oxide Paint
on outside when completed.

HEAD TO SHELL
DOUBLE 'V' WELD

PLAN OF ACID TANK
NOTES:
Welded construction
Paint one coat on outside

2" Tank flg.
1'-0"
4'-0"

2½ x 2½ x 4' L

2" Tank flg.
1'-0"
Outside Ladder
3/4" Bars with 3/8"
Rungs 12" CtcG.

2 x 4" L
Weld
16"
6"

20" Manhole
5" Flange
6" Del. Flange
Weld

Paint
One Field Coat Black Oxide.
Seams Welded Inside & Outside.
NOTES:
All Seams Electrically Welded.
Test tank to 210 lbs. per sq. in.
Hydrostatic Pressure.
Prime one shop coat Black Oxide.
Notes:
1. All Seams Solid Butt Welded
2. All Angles Stitch Welded.
3. Paint One Coat Black Asphaltum On Outside On Completion

THE DARBY CORPORATION.
NOTES:

Riveted Construction

1/12 throughout

Paint one coat outside

THE DARBY CORPORATION
DETAIL OF SEAMS

3/4 F.S. Flange Riveted to Head.

Caulk

16. O. D. O.

3'-6"

3/8 Forged Steel Fly.

7/8 Head riveted to shell. 3/8 Rivets. 1 1/2 Grs.

1/8 F.S. Flange

Caulk

NOTES:
All Seams and Flanges caulked to withstand test of 210 lbs. per sq. in. hydrostatic pressure.
To be given one shop coat of Black Oxide Paint.

7 - R
THE DABBY CORPORATION
NOTES:

All seams double,

Lap joint single riveted,

Bulkheads and agitator trough 10 Ga.,

Caused watertight,

To be erected on foundation.

2 x 14 L

2 1/2 x 24 x 1 1/2 L

2 x 1 1/2 Flat M.S. Bars

10-R

THE DARBY CORPORATION
NOTES-
All Seams and Flanges riveted & welded to withstand test of 210 lbs. per sq. in. hydrostatic pressure.
To be given one shop coat of Black Oxide Paint.

7WR

THE DARBY CORPORATION
Small drawing for meters
Material 3/8" Black iron

2 3/4" x 3/8" x 1/8" LS

2 3/4" x 1/2" x 3/16"

All seams single, riveted, lap joint

Screen 18 Ga. 3/8 Perforation 1/16"

3/8" Stud Tank Flange

Staybolts threaded, heads riveted over

5" Drum welded

1 S

THE DARBY CORPORATION
PANS WELDED THROUGHOUT

SMALL DRAIN PAN FOR MELTERS
MATERIAL 3/4" BLACK IRON
CHAPTER III

INSPECTION AND COSTING METHODS
PART I.
INSPECTION

In the consideration of the methods of testing to be used in inspecting the various specimens submitted, it is necessary to keep in mind the fact that all the products are specimens of typical manufacture. The purpose in the design of each specimen was to create a product satisfactory for use under the ordinary operating conditions to be encountered. The purpose, therefore, of all tests has been to determine the practicability of the particular design under inspection, for satisfactory performance.

All materials were inspected daily in the process of shop fabrication as well as field erection where included in the work done. The details in the specifications covering the methods of fabrication and assembling were under constant supervision by the regular plant inspectors. Daily reports on each job were turned in on the standard form as shown in exhibit 29.

On completion, each specimen was subjected to the final test and inspection for approval in accordance with requirements set out hereinafter. All pressure vessels were tested tight at one and one-half times the allowable working pressure for which they were designed.
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**DATE**

**INSPECTOR**

**SUPT.**
REQUIREMENTS FOR FINAL APPROVAL

WELDED SPECIMENS

1. **WELDED GAS HOLDER - MADE UP IN PLANT.**
   
   Designed for working pressure of 60 lbs. Test under air pressure of 90 lbs. and apply hammer test. Tank must hold pressure for six hours with a loss in pressure not to exceed 1/2 lbs. per square inch.

2. **WELDED STACK - MADE UP IN SECTIONS AT THE PLANT.**
   
   Examine welding closely to see that neat job is done and all joints are sealed.

3. **WELDED BREECHING - MADE UP IN SECTIONS IN PLANT.**
   
   Examine all welding closely to see that a neat job is done and that all joints are sealed.

4. **WELDED ACID TANK - MADE UP IN PLANT.**
   
   Designed for working pressure of 100 lbs. with an allowance for corrosion. Test under hydrostatic pressure of 150 lbs. subjecting welded seams to hammer test while tank is under pressure.

5. **WELDED BRINE TANK - MADE UP IN PLANT.**
   
   Test full of water and make tight by caulking or welding. Welded seams subjected to hammer test with tank full of water.

6. **WELDED WATER STORAGE TANK - ERECTED IN FIELD.**
   
   Test bottom and first ring with water, making tight before lowering on foundation on completion. Test tank
full of water and make tight by caulking small pin holes or re-welding.

7. **AIR TANKS - WELDED - MADE UP IN PLANT.**

   Designed for working pressure of 140 lbs. per square inch. Test under hydrostatic pressure of 210 lbs. per square inch and apply hammer test on all seams. Make tight with either caulking or additional re-welding.

8. **WELDED WATER STORAGE TANKS.**

   Test full of water and make tight by caulking or welding.

9. **WELDED DIGESTERS - MADE UP IN PLANT.**

   Designed for working pressure of 100 lbs. per square inch tested at 150 lbs. per square inch under hydrostatic pressure and applied hammer test with tanks under pressure. Small pin holes may be either caulked or re-welded.

10. **WELDED FREEZING TANK - ERECTED IN FIELD.**

    Test bottom with 12" of water and make tight before lowering. Great care must be taken in lowering the tank which is done with a number of chain blocks. Test tank full of water and make tight by caulking on the outside.
RIVETED SPECIMENS

1. RIVETED GAS HOLDER - MADE UP IN PLANT.
   Designed for working pressure of 60 lbs. per square inch tested under air pressure at 90 lbs. per square inch and made absolutely tight using soap bubble testing. Test must hold pressure for six hours with a loss in pressure not to exceed 1/2 lb. per square inch.

2. RIVETED STEEL SMOKE STACK - MADE UP IN SECTIONS IN PLANT
   Inspector to examine closely to see that sheets fit up tight and that good rivets are driven to give smoke tight job.

3. RIVETED BREECHING - MADE UP IN SECTIONS IN PLANT.
   Examined closely by inspector to see that sheets are laid up closely for smoke tight job and that any bad rivets are re-driven.

4. RIVETED COMPRESSION TANK - MADE UP IN PLANT.
   Designed for working pressure of 250 lbs. per square inch, test under hydrostatic pressure of 375 lbs. per square inch and make tight by caulking. Also apply final test with tank 2/3 full of water with internal pressure of 280 lbs. per square inch.

5. RIVETED BRINE TANK.
   Test full of water, making tight outside by caulking.

6. RIVETED WATER STORAGE TANK.
   Make shop inspection on fit-up of bottom and first ring for fair holes and general layout. In erecting,
test bottom and first ring making completely tight by caulking before lowering on foundation. Make daily inspection of rivets driven during completion of erection. Test finally full of water and make tight by caulking, eliminating all pin holes and featheredges.

7. **RIVETED AIR TANKS - MADE UP IN PLANT.**

   Designed for working pressure of 140 lbs. per square inch. Test under hydrostatic pressure of 210 lbs. per square inch and make tight by caulking.

8. **RIVETED WATER STORAGE TANK - MADE UP IN PLANT.**

   Test full of water, making tight by caulking outside.

9. **RIVETED RENDERING TANK.**

   Designed for working pressure of 100 lbs. per square inch. Test under hydrostatic pressure of 150 lbs. per square inch and make tight by caulking. Examine closely for bad rivets which must, necessarily, be replaced.

10. **RIVETED BRINE TANK - BUILT IN PLACE IN THE FIELD.**

    Test bottom with 12" of water and make tight before lowering. Great care must be taken in lowering the tank which is done with a number of chain blocks. Test tank full of water and make tight by caulking on the outside.
WELDED AND RIVETED SPECIMENS

1. RIVETED AND WELDED GAS HOLDER - MADE UP AT PLANT.
   Designed for working pressure of 60 lbs. per square inch. Test under air pressure at 90 lbs. per square inch. Tank must hold pressure for six hours with loss in pressure not to exceed 1/2 lb. per square inch.

4. RIVETED AND WELDED ACID TANK - MADE UP IN PLANT.
   Designed for working pressure of 100 lbs. with allowance for corrosion. Test under hydrostatic pressure of 150 lbs. Make tight with outside caulking.

7. RIVETED AND WELDED AIR TANKS - MADE UP IN PLANT.
   Designed for working pressure of 140 lbs. Test under hydrostatic pressure of 210 lbs. Make tight by caulking or re-welding.

9. RIVETED AND WELDED RENDERING TANKS - MADE UP OUR PLANT.
   Designed for working pressure of 100 lbs. Test under hydrostatic pressure of 150 lbs. Make tight by outside caulking.
STAYED SPECIMENS

1. **RIVETED JACKETED DRAIN PANS - MADE UP IN PLANT.**

To be tested under hydrostatic pressure of 15 lbs. per square inch. Make tight by caulking leaking rivets or staybolts paying particular attention to any bad stay bolts which must necessarily be replaced.

2. **WELDED JACKETED DRAIN PANS - MADE UP IN PLANT.**

To be tested absolutely tight with hydrostatic pressure of 15 lbs. per square inch and hammer test applied. Small leaks in the welding of the seams or stay rods may be either caulked or welded. Any bad stay rods must be cut out and replaced.

3. **WELDED AND STAY BOLTED MIXER.**

Designed for working pressure of 25 lbs. To be tested tight under Hydrostatic test of 40 lbs. per square inch. Use hammer test with the mixer under normal working pressure. Small leaks in the stay rods may be either caulked or welded, but any bad stay rods must be cut out and replaced. Job should be absolutely dry, under 40 lb. per square inch water pressure, before final approval.

4. **RIVETED AND STAY BOLTED MIXER.**

Check shop fabrication closely. Mixer designed for working pressure of 25 lbs. per square inch. Test with hydrostatic pressure of 40 lbs. per square inch. Make tight by caulking leaking rivets or staybolts, paying
particular attention to any bad staybolts, which must, necessarily, be replaced.
TIME RECORDING:

The time card as shown in Exhibit 30 is the record of the time spent by each man in the plant on the different individual jobs. This card is filled out by the workman substantially, as shown in the exhibit, giving such information.

---

### EXHIBIT 30

<table>
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**RATE** 75¢  **TOTAL** 8 6.00

**MAN'S NAME** John Burns

**MAN'S NO.** 40

**DATE** 5-2-29  **FOREMAN** E.
as his name and number, the job order and the type of work done, for instance, welding, riveting, beveling, shearing, together with the amount of time spent on each individual operation. The cards are approved by the plant foreman daily and turned in to the cost department for recording. At the office the number of hours each man works for the entire day is taken off of the card and posted in the time book, at the same time the workman’s rate is put on his time card, with the total number of hours and the amount of wages due the employee for that day at the bottom of the card. The cards are then checked over and a recap sheet made, on which the amount of time spent that day on each job by all shop men and the labor cost for that job are recorded. See Exhibit 31. The hours and the cost are then posted from this sheet onto the cost card, on which a complete record of the cost of the job is kept, as shown in Exhibit 32.

The outside time card, shown in Exhibit 33, is a little different form from the plant time card in this respect—that it is a larger sheet and is made up in tablet form. This card is designed to give the same information as the plant time card, with the addition of provisions for describing the work done, together with customer’s name and address for completing the records. The extensions on this sheet are made in the same manner as on the plant time card and the recap sheet. Posting of the time on the cost card
is done in exactly the same manner as that followed in handling the plant time card. On an order where the price is based on the time spent and material used in doing the work the workman takes two copies of this outside time sheet with him, and one copy is retained by the customer for his record, while the other is signed by the customer and then returned to the office for filing.

**MATERIAL ACCOUNTING:**

When an order goes into the plant, it is first sent to the layout, who estimates the size and number of sheets, angles and other materials to be used in the completion of the order. The daily material report is then filled out, recording the order number, together with the amount of all materials used on the particular job in progress, as displayed in Exhibit 34. These reports are then turned into the office, where they are posted on the stock records and onto the cost card, as shown in Exhibits 35 and 32. Any materials that we do not stock and which are ordered direct are posted on the cost card from dealer's invoice, and are not sent to the office on a material slip from the plant.

The total cost of the job, which includes the labor, materials, freight, drayage, overhead and the various other expenses incurred, is then summed up in the spaces provided on the cost card, as shown in Exhibit 35. This cost is then subtracted from the selling price of the job to show the
profit or loss.
May 2, 1929.

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Men must be allowed time from the time they leave the shop until they return. Railway fare and board charged on all out of town jobs. All Sunday and holiday work and all work after 5:00 P.M. and 12 M. Saturday to be charged for at the rate of double time.

### THE DARBY CORPORATION
KANSAS CITY, KANSAS

HARRY DARBY, JR.
PRESIDENT

**DATE** 3-18-29

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<td>H</td>
<td>9</td>
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**REMARKS**

NAME Bailey-Reynolds Chandelier Co.,

ADDRESS 15th & Grand Ave.

SIGNED BY James Smith

FOREMAN
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**REMARKS**

Gaulking top ring, erecting spider, indicator board, overflow pipe, and bolting on clips for roof.

NAME: Bailey-Reynolds Chandelier Co.,  
ADDRESS: 15th & Grand Ave.  
SIGNED BY: D. JONES.  
FOREMAN: James Smith
### DAILY MATERIAL REPORT

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<td>2</td>
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<td>2</td>
<td>11&quot; x 15&quot; Manholes complete</td>
</tr>
<tr>
<td>2</td>
<td>11&quot; x 15&quot; Manhole Saddle Plates 84&quot; dia. circle</td>
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<td>4</td>
<td>Heads flanged and dished 9/16&quot; pl. 84&quot; O. D.</td>
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<td>Pls. 80&quot; x 20# x 267&quot; flanged (2) on bench 8 to punch</td>
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<tr>
<td>2</td>
<td>Pls. 64&quot; x 17.65# x 80&quot; flanged (1) on bench and (1) to shears</td>
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<tr>
<td>2</td>
<td>Pls. 40&quot; x 17.65# x 80&quot; flanged (1) on bench (1) to shears</td>
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**POSTED BY**

ON COST RECORDS: S  
ON STOCK RECORDS: R

H. Faust  
LAY OUT MAN

Latimer  
SUPT.
### Colgate-Palmolive-Peet Co.

#### 1 - Conveyor Trough

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**COST SUMMARY**

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<td>4 43</td>
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**TOTAL**

| Gain | 17 72 |

**MADE BY**

**BILL BY**

**CHECKED BY**

**FOLIO 2482**

**AMT. 173.83**

**E-2807**
OVERHEAD CHARGES

To figure the plant overhead on a job, add the number of plant hours on the cost card, multiply the number of plant hours, as in Exhibit 35, by the rate or constant figure determined at the beginning of each month to be used for arriving at the total amount of plant overhead. When there are any outside field hours on the work in question, the matter is handled in the same manner, except that a much lower rate or constant figure is used to determine the proper amount to charge for outside overhead. These two totals are added together, placed on the cost card and summed up with the cost of the job. These totals are accumulated at the end of the month and should equal the total amount of actual plant overhead accumulated on the general books of the corporation. If there happens to be any variation, it should be very small and should be adjusted in the following month.

This rate or constant figure for determining plant overhead is worked out by dividing the average amount of monthly plant overhead by the average number of estimated productive hours. To determine the total amount of actual plant overhead at the end of each month, the following items are chargeable to this account: Building Repairs, Transportation, Fuel, Machinery Depreciation, Gas, Insurance Earned, Freight Counsellor, Lights, Miscellaneous Expense, Non-Productive Labor, Plant
Salaries, Plant Supplies, Power, Rent, Machinery Repairs, Taxes, Tool Room Expense, Shop Expense and Water. Some of these items are fixed charges, for instance, Taxes, Rent, Depreciation, etc. Casualty insurance is estimated for current month and then adjusted, if necessary, in the following month. The other items are actual amounts that accumulate during the month.

Office overhead and sales expense are deductible from the net profit determined at the end of the month from the plant operations.
CHAPTER IV

RESULTS
WELDED SPECIMENS

1. WELDED GAS HOLDER, MADE UP IN PLANT:

On completion, one crack from strain developed. This was, however, satisfactorily closed by replacing the welding. The hammer test showed no defects with the air pressure of ninety pounds per square inch applied. Tank held this pressure for six hours with no noticeable loss.

The cost of this job was $4.19 per cwt.

2. WELDED STACK, MADE UP IN SECTIONS IN PLANT:

All joints well sealed and general appearance of the work good. Welding neat and the job thoroughly satisfactory in every respect.

The cost of this job was $4.56 per cwt.

3. WELDED BREATHER, MADE UP IN SECTIONS IN PLANT:

All joints were well sealed and the work neatly done, even under a light hammer test, no defects developed. The job as a whole was satisfactory.

The cost of this job was $5.83 per cwt.

4. WELDED ACID TANK, MADE UP AT OUR PLANT:

Tank tested out perfectly tight under hydrostatic pressure and showed no ill effects whatever
after the hammer tests were applied. No cracks from strain developed at anytime in the process of fabrication.

The cost of this job was $8.81 per cwt.

5. WELDED BRINE TANK, MADE UP IN PLANT:

Tank tested perfectly tight, except for one small pin hole, which required caulking. Otherwise tank was satisfactory and the work well done.

The cost of this job was $8.54 per cwt.

6. WELDED WATER STORAGE TANK, ERECTED IN FIELD:

Shop fabrication satisfactory and all field tests on bottom and completed job showed a few leaks easily corrected by caulking. This material went together nicely and job was completed in a thoroughly workmanlike manner.

The cost of this job was $6.17 per cwt.

7. 90 - WELDED AIR TANKS, MADE UP IN PLANT:

Only three tanks failed to test out perfectly under the hammer tests with the pressure applied. The three defects were minor, and only required a little additional welding. Tanks very neat and workmanlike in appearance.

The cost of this job was $15.49 per cwt.
8. **WELDED WATER STORAGE TANKS, MADE UP IN PLANT:**

Some trouble was encountered with about six inches of the seam connecting the bottom to the shell, making it necessary finally to chip off old welding and re-weld. On completion, the tanks tested good.

The cost of this job was $4.97 per cwt.

9. **WELDED DIGESTERS, MADE UP IN PLANT:**

The work was nearly perfect on each tank, and on final test no leaks developed, even when seams were hammered with pressure applied. This was an unusual piece of workmanship.

The cost of this job was $5.12 per cwt.

10. **WELDED FREEZING TANK, ERRECTED IN FIELD:**

On test of bottom, one bad leak required some additional welding. On completion and final test, job was satisfactory and dry with no leaks whatever.

The cost of this job was $6.14 per cwt.
RIVETED SPECIMENS

1. RIVETED GAS HOLDER - MADE UP IN PLANT.

At 50 lbs. pressure it was found necessary to replace one rivet, after which final test of 90 lbs. was applied and the pressure held for six hours with no noticeable loss. There was some additional caulking required before the time pressure test was applied.

The cost on this job was $2.48 per cwt.

2. RIVETED STACK-MADE UP IN SECTIONS IN PLANT.

This job was satisfactory, except that on assembling at the point where a change in pattern occurred, it was necessary to ream about half the holes on one round-about seam to make them fair. On completion the job passed final approval.

The cost on this job was $4.93 per cwt.

3. RIVETED BREECHING - MADE UP IN SECTIONS AT PLANT.

Shop fabrication was satisfactory and assembly completed in a very neat and workmanlike manner. It was deemed advisable to close up, by welding, some of the corner joints on the angle iron connections for bolting the sections together, which was done before final approval.

The cost on this job was $6.43 per cwt.
4. RIVETED COMPRESSION TANK - MADE UP IN SHOP.

On completion, under hydrostatic test, job was nearly perfect. Only two rivets requiring a little additional caulking. The pressure was held satisfactorily on the air and water test with no noticeable loss.

The cost on this job was $9.28 per cwt.

5. RIVETED BRINE TANK

Tested satisfactorily, except that additional caulking was required around the 2" flange.

The cost on this job was $6.67 per cwt.

6. RIVETED WATER STORAGE TANK.

Shop fabrication was satisfactory. In field, bottom and first ring tested out satisfactorily with a little additional caulking at two scarfing points. On completion it was found necessary to cut out and redrive seventeen rivets in the top ring, after which the tank was accepted.

The cost on this job was $5.97 per cwt.

7. 75 - RIVETED AIR TANKS - MADE UP IN PLANT.

Shop fabrication passed through in fine shape with all pieces matching templates. Seven tanks required from one to four rivets replaced. All others were made tight satisfactorily with very little extra
caulking under test.

The cost on this job was $18.12 per cwt.

8. RIVETED WATER STORAGE TANK - MADE UP IN PLANT.

Completed test showed seventeen rivets and one caulking edge near scarfing point leaking slightly, which were corrected satisfactorily by additional caulking. The cost on this job was $6.03 per cwt.

9. 16 - RIVETED RENDERING TANKS.

Fabrication was carried through in satisfactory manner. On completion six tanks were accepted on hydrostatic test of 150 lbs. per square inch, five tanks had less than ten leaking rivets, which only required additional caulking for acceptance, and the other five tanks had from ten to seventeen leaking rivets, all of which took up satisfactorily by caulking and were accepted. Two tanks had leaks around caulking strip between bottom casting and cone bottom, which required a small amount of caulking.

The cost on this job was $5.68 per cwt.

10. RIVETED BRINE TANK - BUILT IN PLACE.

Shop fabrication was satisfactory. In field, on testing bottom it was found necessary to replace six rivets, after which it was satisfactory and was lowered on foundation. On completion tank tested tight
except for a little additional caulking on fifteen rivets.

The cost on this job was $7.08 per cwt.
1. RIVETED AND WELDED GAS HOLDER MADE UP IN PLANT:

The welding on this job was exceedingly well done and was just heavy enough to seal the caulking edges properly. Because of this extra care, only seventeen rivets in this large tank required additional caulking before final acceptance. Under the air test, the pressure was held for six hours with no loss whatsoever recorded on the gauge. The job as a whole was entirely satisfactory.

The cost of this job was $4.67 per cwt.

4. RIVETED AND WELDED ACID TANK, MADE UP IN PLANT:

The inside welding loosened twenty-three rivets, largely due to the extreme plate thickness, requiring more heat for the fusion. One rivet had to be cut out and replaced. Final test thoroughly satisfactory and job passed for approval.

The cost of this job was $9.82 per cwt.

7. 50 - RIVETED AND WELDED AIR TANKS, MADE UP IN PLANT:

Considerable difficulty was experienced with loosening of rivets, due to the welding heat encountered, and a few rivets in every tank required additional caulking under test. However, the caulking
edges welded, were very satisfactory, giving practically no trouble with pin holes.

The cost of this job was $18.75 per cwt.

9. 10 - RIVETED AND WELDED RENDERING TANKS:

Shop fabrication was satisfactory. On completion, six tanks had from ten to twenty rivets that had been loosened by the electric welding on the inside; these required considerable caulking to make tight. One casting developed a bad sand hole, requiring considerable work in filling out. The other tanks were entirely satisfactory under a hydro-static test, and all were passed for final approval.

The cost of this job was $5.95 per cwt.
STAYED SPECIMENS

1. RIVETED JACKETED DRAIN PAN:

Shop fabrication was satisfactory. Under test all seams and rivets were tight but thirteen stay bolts in the two tanks required caulking. It was necessary to replace one staybolt in one tank before they were passed for final approval.

The cost of this job was $7.09 per cwt.

2. WELDED JACKETED DRAIN PANS - MADE UP IN PLANT:

Shop fabrication was satisfactory and job tested out perfectly tight with no caulking or additional welding required. No defects developed under the hammer test with pressure applied.

The cost of this job was $6.47 per cwt.

3. WELDED STAYBOLTED MIXER - BUILT IN PLACE:

On completion this job tested nearly perfect with no leaks whatsoever in the seams even with the hammer test with pressure applied. Only three stay rods required a little additional welding before the job was passed for final approval.

The cost of this job was $6.76 per cwt.
4. RIVETED AND STAYBOLTED MIXER – BUILT IN PLANT:

Shop fabrication was satisfactory. On completion considerable difficulty was encountered in caulking the joints tight at the ends of the mixer where we have three thicknesses of metal. Seven staybolts required additional caulking and it was necessary to replace one bolt. The job passed final inspection in good shape and was dry at test.

The cost of this job was $7.55 per cwt.
CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS
In consideration of the test results set out in Chapter IV on which our comparisons and conclusions will be based, we will make comparisons in the following manner:

Under Parts I and II we have tested eleven products, and in these two groups Specimens No. 1 under Part I will be compared with Specimens No. 1 in Part II, and so on throughout the list.

In Part III we have tested four products, which will be compared with the Specimens numbered identically under Parts I and II.

In Part IV four tests have been made, but this work is, of course, not comparable to that covered in any of the other chapters.

These specimens will be compared as follows: No. 1 against No. 2, and No. 3 against No. 4.

SPECIMENS NOS. 1.

These Gas Holders are always used by some large industry, where considerable other valuable properties, as well as labor, are constantly employed. They constitute a hazard as pressure vessels alone, without any consideration to their explosive contents. The welded job shows a saving of 29¢ per cwt. over the straight riveted, and of 49¢ per cwt. over the welded and riveted construction. In spite of the savings which the tests show could be affected by building these tanks of welded construction throughout, it is our
recommendation that the combined riveted and welded design be used. This eliminates any question of the strength of the design for the pressure specified and the welded design insures a completely tight job excellent for service conditions. In addition to this, in unloading and setting the tanks at the site, they are certain to receive some rough handling, and the straight riveted job is very likely to develop a number of leaks, while the recommended construction of the combined riveted and welded will remain tight, unless subjected to some unusual treatment.

SPECIMENS NOS. 2.

The welded Stack showed a saving of 37% per cwt. over the riveted, which, however, we do not believe is enough to justify this construction. On stacks of this size and larger it is nearly always necessary after a number of years of service to replace the top 20 or 25 ft., which has been corroded out by the condensing vapors, and this replacement can be handled much more economically on the riveted design. A large stack, naturally, constitutes a considerable hazard, in view of the almost certain damage to life and property in case of collapse in storms. There is no question of the strength of the riveted joint, which is not the case with welded construction. It is not essential for successful operation to have the joints absolutely tight. We, therefore, believe the most desirable
design for large stacks is riveted construction, with the edges caulked to give a reasonably tight job. Conditions are different in the case of stacks smaller than approximately 36" diameter by 60 ft. high, in which case the welded construction is more desirable. The smaller stacks being built of lighter material are, as a rule, replaced as a whole. This small stack is highly competitive, and the saving in cost is frequently a deciding factor in securing the business. In case of collapse there is little likelihood of great damage.

**SPECIMENS NOS. 3.**

The work on these Breechings tested out very much as would be expected, showing a saving of 60¢ per cwt. for welded over riveted construction. The welded design is, undoubtedly, preferable, since a far tighter job is possible, greatly increasing the conditions of draft. The breeching, properly braced, is under no particular condition of strain, and any irregular sections or transition pieces frequently encountered in this work can be built much more economically of welded construction.

**SPECIMENS NOS. 4.**

For Pressure Vessels of this nature, with high working pressures and severe operating conditions, we are inclined to favor the combined riveted and welded construction, especially when it is necessary to use plates in thicknesses from 3/4" up. Failure of
a pressure vessel of this nature means almost certain disaster to any persons or property in the immediate vicinity. It is our recommendation that for this particular class of work the riveted construction, with seams and rivets welded on the inside be specified. The cost of this design, as shown in the test, exceeded the straight riveted job by 54¢ per cwt., and the straight welded job by $1.01 per cwt., but since this work is nearly always of a special nature, and these vessels are frequently important parts in the operation of some process work, the additional cost should not stand in the way of securing the best job possible.

**SPECIMENS NOS. 5.**

The welding of Small Brine Tanks, similar to these specimens, is practically universal at the present time. The saving in cost of $1.13 per cwt. is, of course, the dominant factor in this preference, but, in addition, in operation the welded tanks are proving most satisfactory. So many different sizes are required that considerable waste is encountered in the using of stock plates for the riveted construction, while with the welded tanks the plates can be pieced out to good advantage without detracting seriously from the appearance.

**SPECIMENS NOS. 6.**

The Water Storage Tanks give us the first comparison which includes erection work done in the field. The saving in cost of 80¢
per cwt. in the welded over the riveted job is of essential impor-
tance in this class of work. When for all conditions of
operation there is no important preference for either type of con-
struction, it is our opinion that the welded job should be speci-
fied for this class of work, and that it will give the least
amount of trouble throughout a period of long service. The practice
of welding storage tanks is rapidly spreading, and is being given
a special impetus in the oil field work, which will, undoubtedly,
be almost entirely welded construction in the next two or three
years. An important point in the success of field welding is the
necessity of keeping the welding surfaces clean and free from
rust. It often may be necessary to wire-brush the surfaces ahead
of the welder.

SPECIMENS NO. 7.

The test results on these small welded Air Tanks, naturally,
showed a considerable saving for the welded construction, it being
$2.63 per cwt. cheaper than the straight riveted job, and $3.29
cheaper than the riveted and welded construction. In consideration
of the size and operating conditions for these tanks, it is our
opinion that the welded construction is the most practical design,
since the labor is the greatest item of cost in such tanks. It
is evident that by using the welded design the thickness of the
metal could be increased considerably without making a large ad-
dition in the cost, increasing materially at the same time the
The welded Water Storage Tanks show a saving of $1.06 per cwt. over the riveted construction, which is a most important consideration on highly competitive work of this type. When for all conditions of operation there is no important preference for either type of construction, it is our opinion that the welded job should be specified for this class of work, and that it will give the least amount of trouble throughout a period of long service.

The conditions in operation of Rendering Tanks make it highly essential to have the tanks designed in such a manner that the inside can be thoroughly and easily cleaned. In constant use the rivet heads are eaten away, and this rendering matter has a tendency to get in between the lapped seams, either eating out the rivets or the plate or perhaps both. The riveted and welded construction is, of course, preferable to the straight riveted job, even considering the additional cost of 25¢ per cwt. However, since these tanks are designed for a working pressure of 100 lbs. and are normally operated at approximately 75 to 80 lbs. pressure, it is the opinion of the writers that it is thoroughly safe and consistent with the best practice to build these tanks of welded construction throughout.
the welded over the riveted and welded job, and 56¢ per cwt. for the straight riveted job. In addition to this saving in cost, the welded design gives a perfectly smooth interior surface, easily cleaned and provides no ledges or irregularities for this corroding matter to lodge on. Our recommendation for this type of products, under similar operating conditions, is the straight welded design.

SPECIMENS NOS. 10.

The welding of Large Brine and Freezing Tanks has also become more or less standard practice, since the depth of the tank ordinarily does not exceed 51", and if properly braced, no particular breathing in the shell plates is encountered. The saving in cost of 94¢ per cwt. realized by building the tank of welded construction is, of course, an important point in favor of this design, in addition to the decided advantages of welded over riveted construction for holding such fluids as brine, since a small leak will cause considerable damage and inconvenience. Welding of this class of work practically eliminates the shop fabrication costs.
CONCLUSIONS AND RECOMMENDATIONS FOR
SPECIMENS SET OUT IN PART IV.

SPECIMENS NOS. 3 AND 4.

The results of these tests show a saving of 77¢ per cwt. for the welded construction as against the riveted. For this work the welded construction was by far the most satisfactory and will give the best service in operation. One of the big savings in any staybolted job in the welded construction is the elimination of the difficult O.G.'d work to make the riveted joint. Tapping of staybolt holes is also eliminated in the welded job. We have experienced very little difficulty with any properly designed welded-staybolted vessel.

SPECIMENS NOS. 1 AND 2.

The welded Drain Pans show a saving of 62¢ per cwt. as against the riveted construction, which we consider very good, because of the small weight of the job. The actual saving in cost is, of course, more than indicated by the "per cwt." figure, since there is a very considerable saving in the weight of material used. This welded-staybolted work tests out in fine shape and eliminates that additional caulking on the riveted staybolts, which is always encountered. Since they were subjected to a hammer test under pressure, we consider them entirely satisfactory and highly desirable for this class of work. For working pressures under 75 lbs. per
square inch we recommend the use of the welded design throughout.
BIBLIOGRAPHY

Bird, H. M.; 1884; "Creators of the Age of Steel"; New York; Scribner and Sons.

Collins, Hubert E.; 1908; "Boilers"; New York City; McGraw Hill Book Company.


Hamilton, Douglas T. & Erik Oberg; 1921; "Electric Welding"; New York City; New York Industrial Press.

Jeans, J. J. 1846; "Steel, Its History, Manufacture, Properties and Uses";

Oberg, Valdemar Erick; 1881; "Story of Iron and Steel"; New York City; D. Appleton and Company.

Sping, La Verne W., A.B.; 1917; "Non-Technical Chats on Iron and Steel"; New York City; Frederick A. Stoker Co.
Tieman, Hugh Phillip; 1979; "Iron and Steel"; New York City; McGraw Hill Book Company.

Walker, J. Bernard; 1926; "Story of Steel"; New York City; Harper and Brothers.

The Iron Age; April 5, 1928; "All Welded Gas Holder Takes 258 Tons of Plates and Shapes"; Page 941.

The Iron Age; October 6, 1927; "American Welding Society Discusses Progress in Welding"; Pages 120-939-940.

The Iron Age; November 15, 1928; "Business Building Has Welded Frame"; Page 1224.

The Iron Age; November 8, 1928; "Mass Production Welding Operation".

The Iron Age; November 1, 1928; "Present Status of Structural Steel Welding"; Page 1090.

The Iron Age; March 3, 1927; "Structural Welding and Riveting Discussed"; Pages 145-646.

The Iron Age; April 9, 1925; "Welding vs Riveting in Large Structures"; Page 1051.
Iron Trade Review; January 3, 1929; "Improvements in Fabrication Marked in 1928"; Pages 84, 26, 27.

Machinery; January 1927; "Riveting and Welding Processes; Pages 350, 351.

Machinery; June 1926; "Riveting vs Welding"; Page 792.

Mechanical Engineer; June 1926; "Autogenously and Electrically Welded Boilers and Containers; Page 605.

Mechanical Engineering; "Procedure Control in Pressure Vessel Welding"; February 1928.

Mechanical Engineering; February 1927; "Stresses in a Large Welded Tank Subjected to Repeated High Test Pressure"; Page 117.

Proceedings of American Society of Mechanical Engineers; New York; 1924; "Bibliography on Riveted Joints".

Power; September 28, 1926; "Are Welded Pressure Vessels Safe?"; Page 493.

Power; April 5, 1927; "Boiler Shell Joints, Rivets, Welds and Dovetails"; Page 527.

Power; July 24, 1928; "Design of Pressure Vessels for the Petroleum Industry"; Page 164.

Power; May 5, 1927; "Design and Construction of Pressure Vessels.

Power; December 28, 1928; "Lively Discussions on Pipe Welding"; Page 999.

Power; October 19, 1928; "Welded Pressure Vessels"; Page 603.