

A STUDY OF ELECTRIC ARC WELDING AND
ACETYLENE WELDING.

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Introduction.

This study was made for the purpose of determining which method of welding made the strongest weld and with the hope that something may be brought to light which would make possible a weld which could be guaranteed to be as strong as the metal.

In view of the rapid spread of the use of the welding process during the past five years, it may be stated that practically all steel industries make use of at least one or more welding equipments, with the majority of them using the arc-welding process. The welding process was formerly looked upon as a repair method but it is now becoming evident that it is not only a repair method but an efficient production process in some industries.

This study differs from the mass of writing on welding due to the fact that the welds of the two processes were studied with care, consideration given to the nature of the break, comparison of the structure of the grain was noted and the welds were inspected at the break to see why they broke.

Acknowledgment is gratefully made to Mr. W.C. Kinane, of the Knoxville Boiler Works, for his esteemed council, advice and the use of their welding equipment given to me in working this thesis.

General Survey of the Field.

Arc welding was first made use of by de Meritens in 1881 for uniting parts of a storage battery plate. The work piece was connected with the positive pole of a source of current capable of maintaining an electric arc. The negative pole was a carbon rod directed by the hand of the operator so as to first maintain contact then secure the proper distance to maintain the arc. This method was improved by Bernardos and Olszewski, Slavienoff, Coffin and others. The Slavienoff modification was the greatest improvement of all. He placed a metal electrode in place of the carbon rod. The metal electrode gradually melts and furnishes fused drops of metal for filling the vacant spaces. This was better than the carbon rod because the carbon that was in the space caused the weld to be hard and brittle, also causing cracks in the filling.

In 1886, Thompson caused a weld to be made by electric resistance of the metal. The metals to be united are held in clamps and pressed together in firm contact. A current is made to traverse the joint, bringing it to a welding temperature. The metal is united by forcing the pieces together.

To date the arc welding process has been improved on very much. The welding is done similar to the Slavenoff process. The welder furnishes a desired amount of current thru the wire electrode which in turn when touching the metal causes an arc and also causes the wire to fuse, filling the space with molten metal.

About ten years ago it was discovered that acetylene dissolved under pressure in acetone in cylinders filled with porous material drew attention to the gas users, and by using a special blowpipe an oxy-acetylene flame was produced. This is better than the oxy-hydrogen flame and it can be used for the direct welding of steel and for several other metallurgical processes.

There are still more improvements to make on the welding processes, especially the arc welding process as it is in greater demand. It is the question of securing a weld that is as strong as the metal.

The welding processes now used point to the approaching demand for a guaranteed weld, as the welding that is being done now reduces the time, price and labor. As more experiments are completed it is probable that valuable information will be discovered and speed the development of a substantial welding process.

Statement of Purpose.

A comparison of the tensile strength of the arc weld and the acetylene weld is made. The reason why the arc weld has the greater tensile strength is discussed. Most of the steel industries or industries that deal with steel or some form of steel are partial to the arc welder.

General Theory.

This period is called the age of steel, and the big news today is that joints are being eliminated from steel construction. The first heavy duty steel frame building, electrically welded instead of riveted, was completed a short while ago at Canton, Ohio, with 14,694 inches of welded joints. The welding was done in a fifth less time than riveting would have required. It is claimed that the joints are 35% stronger than riveted joints. The bombing plane, Cyclops, which was completed recently, is a rivetless metal construction. In the latest type of wire wheels on autos the spokes are no longer laced into the rim, but welded to it. The drop center tire is another instance of the trend away from joints. There are numerous cases where welding plays an important part as in welding tanks, airplane bodies, castings, etc.

Almost everyone will agree that at best a joint is a possible sort of weakness, and that we are getting away from joints, but that weakness cannot be eliminated by skimping along with an arc, or torch over unavoidable joints.

Welding is not allowed by the American Society of Mechanical Engineers code for high pressure boilers, nor is it allowed by the Interstate Commerce Commission. The Boiler Code of the A.S.M.E. permits the use of fusion welding only. "In cases when the stress or load is

carried by other construction which conforms to the requirements of the code and when the safety of the structure is not dependent of the weld."

Welding is not used anywhere or recommended for power boilers, or on any locomotive. The fusion process by nature causes a brittle zone somewhere between the white hot edge and the cold surface; the critical molecular condition may be recognized by the pigeon wing temper along this line of possible fracture in the future. This condition may be removed by annealing, but how can one anneal a skyscraper or a 100 ft. x 25 ft. tank.

Fusion welding is performed without the use of force, or pressure and the finished product consists of two or more pieces cemented together by a zone of cast metal which has not been subjected to the refining influence of mechanical working.

In fusion welding it is difficult to avoid overheating, or burning of the metal, and often the weld is porous and contains slag and oxides. The weld may appear to be of the best quality and it will have such defects as to have coarse grains, lacks the quality of ductility, has little resistance to alternating stress and shock. There is no known method of inspection to determine these weaknesses, other than a test to destruction.

The safety of a weld depends partly on its tensile strength. The tensile strength may be high and still be weak in its resistance to alternating stresses or shocks.

During the period July 1, 1915, to June 30, 1926, inclusive, there were 563 accidents due to fireloxx crown sheet failures which resulted in the death of 356 persons and an injury of 886 others, or an average of .63 killed and 1.57 seriously injured per accident. Of the 563 crown sheet failures referred to, there were 158 cases in which welded seams were involved, of which 122 or 77.2% failed while 22.8% did not fail. During this period fusion welded seams were involved in 28% of total crown sheet failures, while 51% of the persons killed in crown sheet accidents were killed when fusion welded seams were involved. 16.3% of riveted seams failed where 72.2% of the fusion welded seams failed under exactly the same conditions.

Welding has a bright future ahead and if we are to profit by the experience of others we must give careful consideration to the result of all practices and methods.

Description of Apparatus and Method Used.

The apparatus used was a complete acetylene welding equipment, an electric arc welder, boiler plating test pieces, Riehle 100,000 lb. tension or compression machine, welding wire, microscopic lense and kodak.

A complete acetylene welding apparatus consists of an oxygen cylinder, with hose connected to regulators on top of oxygen cylinder, a cylinder of acetylene with hose connected to regulators on top of the cylinder. The two hoses are connected together at the torch. Correct mixture of the gas is obtained at the regulators. The correct flame (called the neutral flame) for welding is produced by burning the correct mixture of oxygen and acetylene. The clear, well defined white cone indicates that the flame is correct. Welds made with it should be thoroughly fused and free from burned metal or hard spots.

The electric arc welding set used was an "Alternarc" welder. The primary has the following ranges:

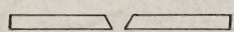
Volts 220 - 240

Cycles 60

Amps 80 - 40

The secondary has a current range from 50 to 250 amperes. K.W. = 7.5. It is type S.V. The terminal wires were connected to the handle in which a welding wire was

inserted. A hood was used to protect the eyes from the glaring arc.

Fifteen test pieces (See Fig.1 and 2) were welded by the acetylene welding process and tested by the Riehle tension machine to determine their tensile strength. Fifteen test pieces were welded by the electric arc process and tested in like manner and their results recorded. The test pieces consisted of three thicknesses $3/16"$, $1/4"$ and $5/16"$, all of which were 2" wide. Five of each of these were welded by the acetylene process and the other five were welded by the arc welding process. The test pieces were cut at the end so as to make a 60° single V weld (), and welded on each side.

Observations.

All of the pieces tested except one did not show a yield point. The welded joints broke without any noticeable elongation while the acetylene welded test pieces elongated considerably before they broke. The electric arc welded joints had a greater tensile strength according to the results obtained.

Some of the test pieces were put under a microscope and a study made of the granular structure of the strong weld and a weak weld. The strong weld had a uniform structure of small grains while the weak weld had an irregular granular structure, small pinholes caused by oxidation and impurities, and in some places the metal was only pasted on the side of the test piece.

The test pieces all broke at the weld.

The welding wire used was tested for its tensile strength and compared with the tensile strength of the welded joints.

Tests and Calculations.

(Tensile strength of test pieces = 55,000 lbs.per sq.in.)

Arc Weld		Acetylene Weld	
Size = 3/16" x 2"	:Lbs.per :sq. in. :Tensile :Strength	Size = 3/16" x 2"	: Lbs.per : sq.in. : Tensile : Strength
1	: 57,300	:1	: 52,300
2	: 49,600	:2	: 53,750
3	: 62,800	:3	: 47,300
4	: 68,400	:4	: 54,300
5	: 54,900	:5	: 49,000
Average	: 58,600	Average	: 51,330
Size 1/4" x 2"	:	Size 1/4" x 2"	:
1	: 52,700	:1	: 43,000
2	: 45,000	:2	: 39,000
3	: 57,800	:3	: 47,900
4	: 59,200	:4	: 54,800
5	: 65,000	:5	: 50,700
Average	: 55,940	Average	: 47,080
Size 5/16"x 2"	:	Size 5/16"x 2"	:
1	: 40,900	:1	: 34,500
2	: 50,700	:2	: 36,000
3 Poor weld. (Porous Structure)	: 39,000	:3	: 37,600
4	: 45,800	:4	: 46,600
5	: 50,750	:5	: 38,700
Average	: 45,430	Average	: 38,680

Welding Wire.

Average composition = Carbon 0.16%; Manganese 0.56%;

Phosphorous 0.032%; Sulphur 0.024%;

Silicon 0.016%.

Dia. = .130	:	Tensile Strength
	:	Lbs. per sq. in.
1	:	98,500
2	:	97,000
3	:	96,300
4	:	107,500
5	:	97,800
6	:	100,000
Average	:	99,517

The arc welded joints had the following efficiency:

$$\begin{aligned}
 3/16" \times 2" &= \frac{58,600}{55,000} \times 100 = 106.0\% \\
 1/4" \times 2" &= \frac{55,940}{55,000} \times 100 = 101.7\% \\
 5/16" \times 2" &= \frac{45,430}{55,000} \times 100 = 90.7\%
 \end{aligned}$$

The acetylene welded joints had the following efficiency:

$$\begin{aligned}
 3/16" \times 2" &= \frac{51,330}{55,000} \times 100 = 93.4\% \\
 1/4" \times 2" &= \frac{47,080}{55,000} \times 100 = 85.6\% \\
 5/16" \times 2" &= \frac{38,680}{55,000} \times 100 = 70.4\%
 \end{aligned}$$

Conclusions.

From the results obtained it is a fact that the arc welded joints have a higher tensile strength than the acetylene welded joints. This is due to the cause that the arc welded joint is not subject to the great heat that the acetylene welded joint is, which tears down the granular structure of the metal, also there are more impurities injected in the acetylene welded joint when it is fused.

The reason why most of the industries that use welding apparatus are partial to the arc welding process may be stated that the arc welding process gives a stronger joint as seen from results obtained, also it is cheaper than the acetylene welding process. Arc welding utilizes power more efficiently than gas welding because the electric current is transformed directly into heat and the heat is developed within the metals to be welded. In gas welding heat is generated by the burning of gas which was originally produced by electricity. The process of transforming electric current into heat is indirect and wasteful. Also the heat is developed at a point outside the weld and a large part of the heat of the flame is lost.

Gas welding is frequently used in repair shops when welding is incidental to the general repair business. This is because the first cost of equipment for gas welding

is cheaper than the arc welding equipment.

"Arc Welding" by Lincoln Electric Company states that when the amount of welding is more than three linear feet per day, arc welding is more economical than acetylene welding.

The weak point in welded joints is that there is no way of knowing what they will stand in terms of shocks, stress and shear. The only way at present to determine their strength is the test to destruction.

From the conclusions obtained it may be said that the arc welding process is superior to the acetylene welding process in all respects. The average arc weld is stronger than the average acetylene weld and it is more economical.

Figures.

Figure No.1 is a photograph of one of the arc welded test pieces after being broken.

Figure No.2 is a photograph of one of the acetylene welded test pieces after being broken.

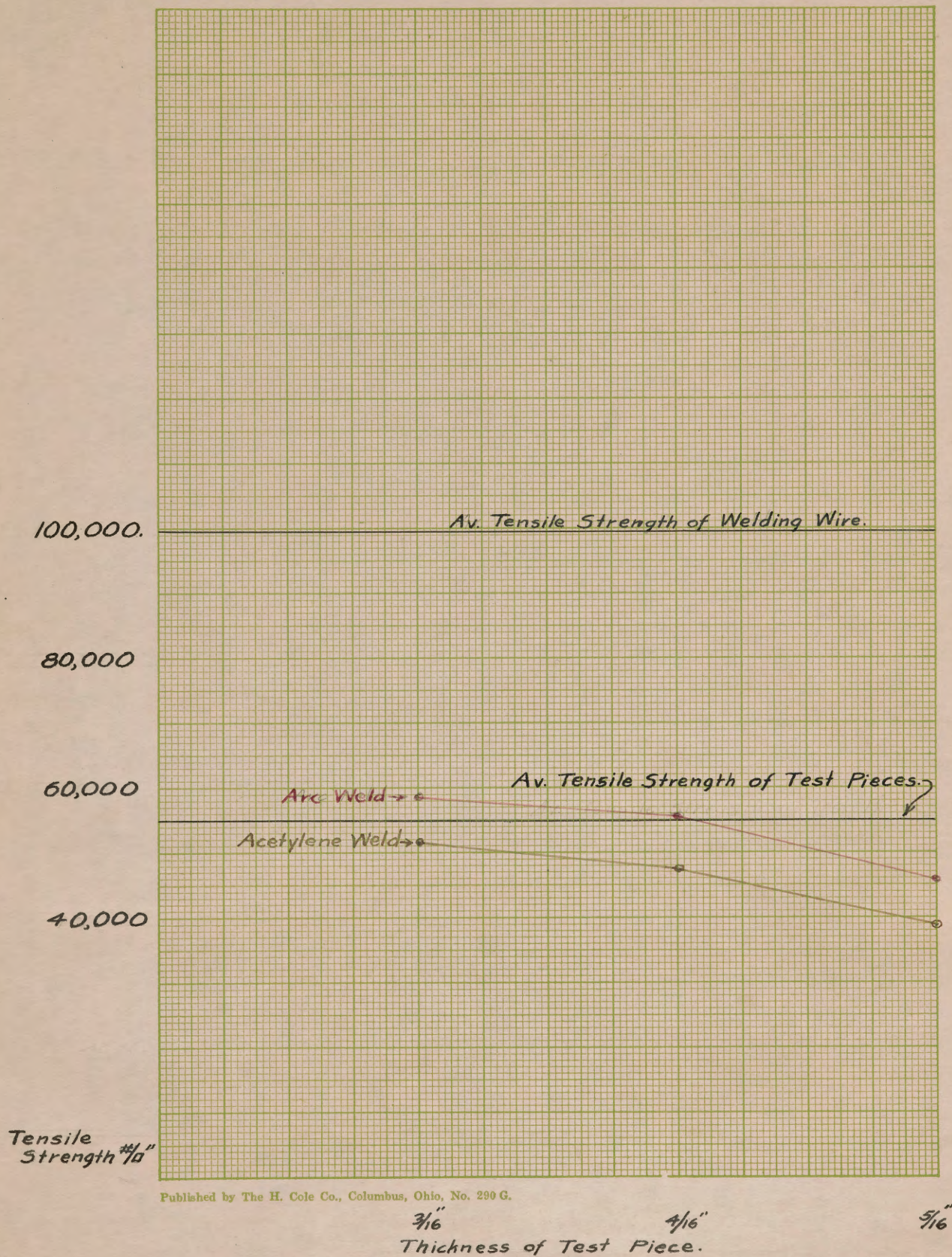
Figure No.3 is a graph showing the relation between the average tensile strength of welding wire and the average tensile strength of the boiler plating to the average tensile strength of the arc and acetylene welds of different thicknesses.

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2. Arc welding in The Steel Industry.
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Note: The above consists of pamphlets put out by the Westinghouse Electric & Manufacturing Company.

7. The Encyclopaedia Britannica.
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9. Manual of Instructions for Welding Operators.
 - (a) Oxy-acetylene welding.
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11. Arc Welding (The New Age in Iron and Steel)
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12. A Tiny Tilt in the Tribune by Harper Leech,
with articles by A.G.Pack on Fusion Welding.



Published by The H. Cole Co., Columbus, Ohio, No. 290 G.

Fig. 3.



Fig. 1



Fig. 2

Approval.

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

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