Design for
OXWELDING

A LONG successful record of chemical equipment designed for oxwelding and built with the advice and assistance of Linde Process Service is reflected in the following quotation from a chemical firm's specifications for six large aluminum tanks:

"Welding is to be by the oxy-acetylene process using Oxweld Aluminum Welding Rod and Oxweld Aluminum Flux. Special care is to be taken as the tank is to contain acid. The approval of each welder must be obtained through a qualification test from The Linde Air Products Company before welding is done."

Before planning equipment this firm has regularly obtained from Linde the latest data on performing the specific welding job and specifications have been drawn to require techniques, materials, and testing methods proved in the vast experience of Linde Process Service. In this way the soundest, strongest, most economical fabrication is assured.

You can have this in your equipment too, by simply taking advantage of Linde Process Service. The nearest Linde Sales Office will be glad to explain this service to you. Phone or write now.

Continuing previous records for service, Linde advised on the correct type of oxwelded joints and the welding materials for building these 3000-gal. aluminum tanks. Every seam was leakproof under hydrostatic test. All welders were rigidly qualified by Linde.

THE LINDE AIR PRODUCTS COMPANY
Unit of Union Carbide and Carbon Corporation
126 Producing Plants 859 Warehouse Stocks
IN CANADA, DOMINION OXYGEN CO., LTD. TORONTO

You are cordially invited to visit the numerous exhibits sponsored by the Corporation in both the Basic and Applied Sciences in the Hall of Science at Chicago's 1934 A Century of Progress Exposition. Here you will see how users of products and processes developed by Units of Union Carbide and Carbon Corporation benefit from a most unique coordination of scientific research with manufacturing, sales and service facilities.

Sales Offices:
Atlanta
Baltimore
Birmingham
Boston
Buffalo
Butte
Chicago
Cleveland
Dallas
Denver
Detroit
El Paso
Houston
Indianapolis
Kansas City
Los Angeles
Memphis
Milwaukee
Minneapolis
New Orleans
New York
Philadelphia
Phoenix
Portland, Ore.
Salt Lake City
San Francisco
Seattle
Tulsa

You are invited to visit these facilities and learn how they serve you.
AMERICAN WELDING SOCIETY

SEPTEMBER

Contents

Technical Papers, Items and Reports

A Welder, by Kuhler (Courtesy Metal & Thermit Corporation) .................. Frontispiece
First Large Stainless Clad Pipe Is Arc Welded, by A. F. Davis .................. 2
An Examination of Welds Made under Field Conditions for High-Pressure, High-
Temperature Steam Station Piping, by A. E. White, D. H. Corey and C. L. Clark .. 3
A Discussion of the Methods for Qualifying Operators of Welding Equipment under
A. S. M. E. Boiler and Pressure Vessel Codes, by Wm. D. Halsey .............. 11
Note on the Fatigue Testing of Welds, by J. H. Zimmerman .................... 13
Sprayed Molten Metal Coatings, by E. V. David ............................... 16
Welded Rail Joints—Main Track—Steam Railroads, by H. S. Clarke ............. 21
Alternating Current Arc-Welding Transformer and Circuit Characteristics, by A. M.
Candy ............................................ 23
Qualification of Welding Equipment Operators, by Harry W. Pierce ........... 26
Acceptance of A.C. Welding, by C. J. Holslag ................................. 28
Current Welding Literature .................................................. 29

Society and Related Activities

Fall Dinner ..................................................... 30
Section Activities .............................................. 30
William Hastings Bassett .............................. 30
The Institution of Welding Engineers .................. 31
Achievement Medal ......................................... 31
New Movie Shows Construction of Oil and Gas Pipe-Lines .................... 31
Acetylene Association Meeting .......................... 31
Course on Metal Radiography .................................... 31
The Feature Course of Six Lessons .......................... 31
How to Enroll for the Course ..................................... 31
Program Fourteenth Fall Meeting A. W. S .................. 32

ISSUED MONTHLY

Copyright, 1934, by the American Welding Society
Subscription $4.00 per year in United States and possessions; $4.50 in Canada; Foreign
Countries, $5.50.
Entered as second-class matter January 15, 1939, at the post-office at Easton, Pa., under the
Act of March 3, 1879.
Man and Machine—This Grotesque Figure, an Arc Welder, and the Welding Machine behind Him Are Forming 315,000 Tons of Stainless Clad Steel into an 1800-Ft. Pipe for the New Milwaukee Sewage Disposal Plant.

Arc Welding Is Speeding the Construction of This Stainless Steel Clad Pipe—the First of Its Kind Ever Built. The Diameter Varies from 5 to 2 Ft.

First Large Stainless Clad Pipe Is Arc Welded

By A. F. DAVIS*

THE largest order for two-ply stainless clad steel ever placed is being fabricated by arc welding into an 1800-ft. pipe at Milwaukee, Wisconsin.

This unusual pipe, 2 ft. to 5 ft. in diameter and \( \frac{1}{4} \) in. thick, will carry compressed air from rotary turboblowers to aeration tanks at the Milwaukee Sewage Disposal Plant on Jones Island. It is being built by the Cream City Boiler Company, Milwaukee, Wisconsin, fabricators of alloy metal equipment, who will also do the field welding. This is the first time that stainless clad steel has been used for this type of work.

The pipe is a main air header which will convey air under pressure for activating raw sewage. Welded stainless steel construction was decided upon because of the low internal coefficient of friction which it provides and which will be maintained for life. Due to this low internal friction, the pipe was designed several inches smaller than cast-iron pipe for the same purpose. With this decrease in diameter, it is possible to install the pipe in existing structures. Cast-iron pipe would have required expensive changes to the buildings. Arc welding also proved the most economical and the fastest means of fabrication.

Most sections of the pipe are 54 ft. long. These are made up of nine plates \( \frac{1}{4} \) in. thick. Each single plate is formed and placed in a special welding clamp for making the longitudinal seam. This is a plain butt weld, made with 18-8 stainless steel electrodes on the inside and with heavily coated mild steel electrodes on the outside. Welding speed is about 50 ft. per hr.

Nine of these plate shells are then welded together to form one section. The circumferential joints are butt welds. The plates have previously been sheared square and are placed with a \( \frac{3}{32} \) in. gap between the edges.

About 1325 ft. of the pipe is 5 ft. in diameter. The rest is 48, 36, 30 and 24 in. The contract required the fabrication of several special elbows, T's and fittings.

Expansion joints are made of 10-gage solid stainless steel. All flanged connections are so made that only stainless steel is exposed to the action of the material carried by the line.

All welding of the stainless inside of the pipe is being done with \( \frac{5}{32} \) to \( \frac{3}{16} \) in. special electrodes for stainless steel manufactured by our Company. Welding of the steel side of the pipe is done with \( \frac{5}{32} \) in. and \( \frac{3}{16} \) in. covered electrodes supplied by the same company.

Approximately 315,000 lb. of \( \frac{1}{4} \) in. two-ply stainless steel and 9000 lb. of 10-gage solid stainless steel are required for the project.

The total cost of the job is approximately $107,000. It is scheduled for completion by the first of December.

* Vice-President, The Lincoln Electric Company.
An Examination of Welds Made under Field Conditions for High-Pressure, High-Temperature Steam Station Piping

By A. E. WHITE, D. H. COREY and C. L. CLARK

THE Detroit Edison Company is now engaged in rebuilding a portion of its Connors Creek Power House, originally designed and built to operate at a steam pressure and temperature of 225 lb. per sq. in. and 650° F., respectively. New equipment is being installed and old equipment is being altered, to permit operation of the new section at 650 lb. per sq. in., 850° F. This increase in steam pressure and temperature has necessitated the installation of completely new steam generating equipment and steam and water piping systems.

Fusion welding, by the direct-current, metallic-arc process, is being employed in piping erection to a much greater extent than has been the previous practice of this Company. Notable additions to the list of services for which welding is being employed are main and auxiliary superheated steam piping systems operating at 650 lb. per sq. in., 850° F. and boiler feed piping systems operating at 1000 lb. per sq. in., 385° F. The main superheated steam piping is especially noteworthy in that there are no flanged joints between the superheater outlet header and the inlet end of the turbine stop valve, all valves except the turbine stop valve being of the welding-end type.

The decision to adopt fusion welding to the extent which has been indicated was arrived at only after extensive investigations had indicated that sound, reliable welds could be produced under field conditions by welders employed by the Company’s Construction Bureau. Preliminary tests were directed toward determining the most satisfactory form of bevel, the proper clearance, proper electrode sizes and the effect of such operations as peening and stress-relieving.

Following those tests, the two welds here reported upon were made and submitted to the Department of Engineering Research, University of Michigan, for various destructive tests. These welds embodied all of the desirable and necessary items which had been investigated previously. They were made under conditions duplicating, as closely as possible, actual field-welding conditions using the materials which were then proposed and subsequently adopted for use in the rebuilding program.

Base Material Involved

Two welds are involved: a pipe-to-pipe weld and a pipe-to-casting weld. The necessity for the two welds is apparent when it is recalled that it was proposed to use welding-end valves. The pipe used in the investigations was 16-in., Grade B, Schedule 80 (A. S. A. Tentative Standard), seamless steel pipe, of the following analysis:

<table>
<thead>
<tr>
<th>Element</th>
<th>Per Cent by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>0.33</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.75</td>
</tr>
<tr>
<td>Silicon</td>
<td>0.06</td>
</tr>
<tr>
<td>Aluminum</td>
<td>0.04 (Metallic)</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.06</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.01</td>
</tr>
<tr>
<td>Sulphur</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Fig. 1—Pipe Section Prepared for Welding
The casting used was a 16-in. ring of the same wall thickness as the pipe, and of the following analysis:

<table>
<thead>
<tr>
<th>Element</th>
<th>Per Cent by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>0.24</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.62</td>
</tr>
<tr>
<td>Silicon</td>
<td>0.36</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.82</td>
</tr>
<tr>
<td>Nickel</td>
<td>1.19</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>0.40</td>
</tr>
</tbody>
</table>

It then appeared, and was subsequently established, that these analyses would be representative of the materials chosen for the pipe and valve bodies, respectively, for Connors Creek.

**Welding Procedure**

Two 9-in. lengths of the material to be welded were beveled and assembled for welding in the manner shown in Fig. 1. The two pieces so assembled were then securely clamped in a jig in such a manner that the longitudinal axis was horizontal and approximately four feet above the floor. Thus the completion of the weld required welding in the three positions, flat, vertical and overhead.

The electrodes used were those which had been used by this Company for some time for pipe welding. They were mild steel electrodes (0.10 to 0.15 C.) having a coating of the organic type producing the so-called shielded-arc deposit.

Current and voltage adjustment of the welding generator was left to the discretion of the welder. Following the deposition of each bead of weld metal, the welder to chip his own weld is not tolerated for this class of work, because of the danger of inducing arm fatigue and consequent unsteadiness of hand.

In completing the pipe-to-pipe weld, 7 beads were deposited using \( \frac{3}{32} \)-in. diameter electrodes and 7 beads using \( \frac{3}{16} \)-in. diameter electrodes. The time required for completion of the weld was approximately 16 hrs. The pipe-to-casting weld required one bead of \( \frac{3}{32} \)-in. diameter electrodes and 11 beads of \( \frac{3}{16} \)-in. diameter electrodes. The time required was approximately 20 hrs.

The welds were stress-relieved by heating a circumferential band containing the weld to a temperature of 1100° F., holding at that temperature for one hour, and cooling in still air. Electric heating by induction, with which the Company was then experimenting, was used.

**Specimen Identification**

Before proceeding with the presentation of the test results, the authors wish to call attention, briefly, to the system of specimen identification used. Each specimen is identified by two numbers. The number preceding the dash identifies the specimen as part of the pipe-to-pipe weld (14) or the pipe-to-casting weld (13). The number following the dash fixes the specimen with respect to its position in the weld as made. The extreme top or flat welding position was assigned the number "48," the sides or vertical welding positions,

<table>
<thead>
<tr>
<th>Material</th>
<th>Specimen Number</th>
<th>Tensile Strength, Lb./Sq. In.</th>
<th>Yield Stress, Lb./Sq. In.</th>
<th>Proportional Limit, Lb./Sq. In.</th>
<th>Elongation % in 2 In.</th>
<th>Reduction of Area, %</th>
<th>Location of Fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Pipe (0.30% C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipe</td>
<td>73,000</td>
<td>40,000</td>
<td>32,500</td>
<td>30.5</td>
<td>50.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipe</td>
<td>73,100</td>
<td>40,000</td>
<td>33,750</td>
<td>33.0</td>
<td>60.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipe</td>
<td>73,100</td>
<td>40,000</td>
<td>32,500</td>
<td>33.0</td>
<td>60.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipe</td>
<td>73,007</td>
<td>40,000</td>
<td>32,915</td>
<td>32.2</td>
<td>60.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cast Alloy H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specimens from 16 In. Ring Cast for Welding Tests</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Casting</td>
<td>103,200</td>
<td>70,750</td>
<td>58,000</td>
<td>13.0</td>
<td>21.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Casting</td>
<td>101,000</td>
<td>70,750</td>
<td>58,000</td>
<td>13.0</td>
<td>21.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Casting</td>
<td>100,450</td>
<td>71,000</td>
<td>54,000</td>
<td>13.0</td>
<td>23.70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cast Alloy H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specimens from Actual Cast Valves</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Casting</td>
<td>87,900</td>
<td>59,750</td>
<td>45,800</td>
<td>24.5</td>
<td>45.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Casting</td>
<td>87,750</td>
<td>58,400</td>
<td>40,800</td>
<td>20.6</td>
<td>40.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cast Alloy H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specimens from Actual Cast Valves</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Casting</td>
<td>87,900</td>
<td>59,750</td>
<td>45,800</td>
<td>24.5</td>
<td>45.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Casting</td>
<td>87,750</td>
<td>58,400</td>
<td>40,800</td>
<td>20.6</td>
<td>40.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cast Alloy H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welded Pipe-to-Pipe Specimens</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welded pipe-to-pipe</td>
<td>14-4</td>
<td>65,450</td>
<td>42,500</td>
<td>37,500</td>
<td>15.0</td>
<td>31.5</td>
<td>Junction</td>
</tr>
<tr>
<td>Welded pipe-to-pipe</td>
<td>14-25</td>
<td>66,100</td>
<td>42,500</td>
<td>40,000</td>
<td>19.0</td>
<td>33.1</td>
<td>Junction</td>
</tr>
<tr>
<td>Welded pipe-to-pipe</td>
<td>14-23</td>
<td>66,200</td>
<td>42,500</td>
<td>37,500</td>
<td>14.0</td>
<td>29.4</td>
<td>Weld</td>
</tr>
<tr>
<td>Welded Cast(alloy)-to-Pipe Specimens</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welded casting-to-pipe</td>
<td>13-27</td>
<td>69,950</td>
<td>42,750</td>
<td>37,500</td>
<td>14.5</td>
<td>17.0</td>
<td>Junction</td>
</tr>
<tr>
<td>Welded casting-to-pipe</td>
<td>13-23</td>
<td>62,100</td>
<td>40,000</td>
<td>32,500</td>
<td>7.0</td>
<td>15.9</td>
<td>Junction</td>
</tr>
<tr>
<td>Welded casting-to-pipe</td>
<td>13-48</td>
<td>63,900</td>
<td>41,750</td>
<td>35,500</td>
<td>22.0</td>
<td>63.3</td>
<td>Weld</td>
</tr>
<tr>
<td>Welded Cast(alloy)-to-Pipe Specimens</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welding Procedure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Yield point rather than yield-stress value.
Metallographic Structure of Welded Pipe-to-Pipe Section

Before Holding at 850°F for 1000 Hours Under Stress of 7000 Pounds per Square Inch.
Table 2—Short-Time Tensile Tests at 850° F. on 0.30C Seamless Pipe, Cast Alloy H and Welded Specimens of the Two

<table>
<thead>
<tr>
<th>Material</th>
<th>Specimen Number</th>
<th>Tensile Strength, Lb./Sq. In.</th>
<th>Yield Stress, Lb./Sq. In.</th>
<th>Proportional Limit, Lb./Sq. In.</th>
<th>Elongation % in 2 In.</th>
<th>Reduction of Area, %</th>
<th>Location of Fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Pipe (0.30% C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipe</td>
<td>13-20</td>
<td>52,100</td>
<td>28,750</td>
<td>15,000</td>
<td>20.0</td>
<td>57.0</td>
<td>Weld</td>
</tr>
<tr>
<td>Welded pipe-to-pipe</td>
<td>14-22</td>
<td>49,900</td>
<td>25,750</td>
<td>16,000</td>
<td>19.0</td>
<td>43.1</td>
<td>Weld</td>
</tr>
<tr>
<td>Welded casting-to-pipe</td>
<td>13-46</td>
<td>49,100</td>
<td>25,000</td>
<td>16,000</td>
<td>20.3</td>
<td>50.3</td>
<td>Junction</td>
</tr>
</tbody>
</table>

* Specimens taken from ring cast for welding tests.

"12" and "36," the extreme bottom or overhead welding position, "24." Intermediate positions were assigned intermediate numbers. Division of the second part of the specimen number by four gives the "clock" position of the specimen in the original complete weld, making it easy to visualize the welding position represented by each specimen.

Results

The tests considered were an X-ray and metallographic examination, tensile and impact tests at both room temperature and 850° F., creep tests at 850° F., and temper-embrittlement tests. In the majority of cases, this series of tests was conducted on all four types of materials considered, that is, original pipe, original casting, welded pipe-to-pipe and welded casting-to-pipe sections.

X-Ray Examination.—A complete X-ray examination of both the pipe-to-pipe and pipe-to-casting welds was made. Of the pipe-to-pipe weld, 60 per cent of the circumference was entirely free from defects, as was 25 per cent of the pipe-to-casting weld. The degree of porosity observed in the remaining sections of these welds was considerably less than the maximum allowed by the A. S. M. E. Boiler Code for Class 1 fusion welding. Metallographic Examination.—The results from the metallographic examination of the pipe-to-pipe and casting-to-pipe welds are given in Charts 1 and 2. Chart 1 shows the original structure of the pipe, the structure in the zone between the pipe and the weld and the structure in the weld proper. Chart 2 shows the structure in the original casting, the zone between the casting and the weld and the weld proper. These structures were taken from the welded casting-to-pipe section.

The photomicrographs show the original pipe to possess a somewhat coarser grain than is sometimes found in pipe material. The structure, however, is well broken down, although with suggestions of fair grain size. The structures shown in the weld proper were exceedingly fine-grained and are believed to be above the average for welded material in so far as their uniformity is concerned.

Short-Time Tensile Properties.—The results of the short-time tensile tests at room temperature and at 850° F. are given in Tables 1 and 2. The yield stress and proportional limit values were obtained from stress-strain curves which were determined with an optical extensometer system reading to 2.8 millionths of an inch per inch of 2-in. gage length. The yield stress is defined as the stress required for a permanent deformation of 0.2%.

The tensile properties of the original pipe material at room temperature are in line with those that would be expected from a steel of this chemical composition. The tensile strength was approximately 73,000 lb., the yield stress 40,000 lb., the proportional limit 32,915 lb., the elongation in 2 in. 32.2% and the reduction of area 60.0%.

The tensile properties of the cast material, as received for the welding tests, were not entirely satisfactory in that the ductility was not of the desired degree. While material of the same chemical composition was subsequently used for the valves, as installed, the heat-treatment had been changed somewhat, and the resulting ductility greatly improved, as shown in the table.

The physical tests on the welded pipe-to-pipe specimens and on the welded casting-to-pipe specimens were surprisingly satisfactory. They showed good tensile strength, good yield stress, good proportional limit values and excellent ductility as measured by elongation and reduction of area. In only one test was the ductility, as measured by the per cent elongation, low and in but three tests was the reduction of...
area not up to what it should be. In two of the specimens from which these values were obtained there was evidence of slight porosity which would account for these low ductility values. In the third specimen, the fracture showed sound metal, although there might have been unsound sections invisible to the eye. There is, however, in none of these tests anything which should cause concern.

The short-time tensile tests at 850°F require no comment. They show satisfactory material and satisfactory properties except that the ductility of the cast alloy is somewhat low. No cast samples, heat-treated to give improved ductility, such as were tested at room temperature, were available for tests at 850°F. It is believed, however, that the steps which were taken to improve the ductility of this alloy at room temperature will likewise improve it at 850°F.

Impact Resistance.—Impact tests were made at 80 and 850°F on the original pipe material, welded pipe-to-pipe, casting material and welded casting-to-pipe. These tests were made in a Charpy impact testing machine with a keyhole notch being used. The data obtained are given in Table 3.

Table 3—Charpy Impact Resistance at 80° and 850° F. of 0.30C Pipe, Welded Pipe-to-Pipe, Alloy Casting H and Welded Casting-to-Pipe

<table>
<thead>
<tr>
<th>Material</th>
<th>Specimen Number</th>
<th>Charpy Impact, Ft.-Lb.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe Material</td>
<td>34</td>
<td>36</td>
</tr>
<tr>
<td>Pipe Material</td>
<td>36</td>
<td>35.3</td>
</tr>
<tr>
<td>Welded Pipe-to-Pipe</td>
<td>14-5</td>
<td>39.5</td>
</tr>
<tr>
<td>Welded Pipe-to-Pipe</td>
<td>14-13</td>
<td>42.5</td>
</tr>
<tr>
<td>Welded Pipe-to-Pipe</td>
<td>14-37</td>
<td>45.0</td>
</tr>
<tr>
<td>Cast Material*</td>
<td>25.0</td>
<td></td>
</tr>
<tr>
<td>Cast Material*</td>
<td>31.0</td>
<td></td>
</tr>
<tr>
<td>Cast Material*</td>
<td>30.0</td>
<td>28.7</td>
</tr>
<tr>
<td>Welded Casting-to-Pipe</td>
<td>13-4</td>
<td>38.0</td>
</tr>
<tr>
<td>Welded Casting-to-Pipe</td>
<td>13-33</td>
<td>40.0</td>
</tr>
<tr>
<td>Welded Casting-to-Pipe</td>
<td>13-36</td>
<td>41.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material</th>
<th>Test Temperature = 850°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe Material</td>
<td>18.0</td>
</tr>
<tr>
<td>Pipe Material</td>
<td>18.0</td>
</tr>
<tr>
<td>Pipe Material</td>
<td>19.0</td>
</tr>
<tr>
<td>Welded Pipe-to-Pipe</td>
<td>14-6</td>
</tr>
<tr>
<td>Welded Pipe-to-Pipe</td>
<td>14-29</td>
</tr>
<tr>
<td>Welded Pipe-to-Pipe</td>
<td>14-33</td>
</tr>
<tr>
<td>Cast Material**</td>
<td>17.5</td>
</tr>
<tr>
<td>Cast Material**</td>
<td>22.0</td>
</tr>
<tr>
<td>Cast Material**</td>
<td>19.0</td>
</tr>
<tr>
<td>Welded Casting-to-Pipe</td>
<td>13-5</td>
</tr>
<tr>
<td>Welded Casting-to-Pipe</td>
<td>13-12</td>
</tr>
<tr>
<td>Welded Casting-to-Pipe</td>
<td>13-31</td>
</tr>
</tbody>
</table>

* Specimens taken from actual cast valves.
** Specimens taken from 16-in. ring cast for welding tests.

The values obtained show that these materials have a satisfactory resistance to creep for the purpose intended. These tests, of course, were made after the specimens had been drawn 1 hour at 1100°F. It should be pointed out that these creep values would doubtless be somewhat lower if the specimens had been originally heated to a temperature such as 1300°F and held for an appreciable time at that temperature. It is believed, however, that these creep values will not undergo changes of any great magnitude if the material is heated to only 850°F. At least no marked change will take place during the life of installation.

Temper-Embrittlement.—Temper-embrittlement may be defined as the loss of impact resistance at room temperature due to prolonged heating at some particular elevated temperature. The exact nature of the changes occurring in the steel to produce this loss is not as yet clearly understood, but has been attributed by some to a precipitation of either carbides or nitrides in a sub-microscopic state.

Two methods have been employed for determining the susceptibility of a metal to temper-embrittlement. One of these consists in heating the material at the temperatures in question for a prolonged period of time under stress, with the impact resistance being compared before and after this treatment. The other is a short-time method which consists in the comparison of the impact resistance of duplicate specimens, one of which is air-cooled, and the other water-quenched from the same temperature.

Prolonged Heating Tests.—In order to determine whether or not the original pipe or casting material, as well as welded sections of the pipe-to-pipe and casting-to-pipe material, would develop temper-embrittlement when subjected to prolonged stress at elevated temperatures, specimens of each type were held at 850°F for 1000 hrs. under a stress of 7000 lb. per sq. in. Sections taken from these specimens were then subjected to impact tests at room temperature and to a metallographic examination. The results of the impact tests are given in Table 4, while the resulting metallographic structures at 1000 diameters are shown in Charts 4 and 5 for comparative purposes. Metallographic pictures are also included of the materials before the prolonged test at 850°F. These are given in Charts 3 and 5.
Metallographic structure of welded pipe-to-pipe section.
After holding at 800°F for 1000 hours under stress of 7000 pounds per square inch.

Metallographic structure of welded pipe-to-casting section.
Before holding at 800°F for 1000 hours under stress of 7000 pounds per square inch.

Metallographic structure of welded pipe-to-casting section.
After holding at 800°F for 1000 hours under stress of 7000 pounds per square inch.
Table 4—Influence of Heating for 1000 Hrs. at 850° F. under a Stress of 7000 Lb. per Sq. In. on the Resulting Charpy Impact Resistance

<table>
<thead>
<tr>
<th>Material</th>
<th>Specimen Number</th>
<th>Charpy Impact Resistance before Prolonged Test</th>
<th>Average Impact Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welded pipe-to-pipe</td>
<td>14-18</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>Welded pipe-to-pipe</td>
<td>14-19</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Welded pipe-to-pipe</td>
<td>14-20</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Welded casting-to-pipe</td>
<td>13-18</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>Welded casting-to-pipe</td>
<td>13-19</td>
<td>42.5</td>
<td></td>
</tr>
<tr>
<td>Welded pipe-to-casting</td>
<td>13-20</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>Welded pipe-to-casting</td>
<td>13-21</td>
<td>32.3</td>
<td>35.3</td>
</tr>
</tbody>
</table>

The values obtained from the impact tests after the prolonged heating at 850° F. under stress, Table 4, were of the same order of magnitude as those shown by the materials before the test. (See Table 3.) This clearly indicates that under the test conditions, the materials exhibited no tendency toward temper-embrittlement.

The metallographic examination showed the structures to be the same before as after the prolonged tests at 850° F., thus indicating that neither of the original materials nor the welded sections of these materials exhibited a visible tendency toward carbide precipitation.

Short-Time Tests.—This test was conducted by heating impact specimens of the various materials at 850° F. for one-half hour and then air-cooling one lot and water-quenching the other; also, by taking additional specimens and heating them for 48 hrs. at the temperature in question (850° F.) and then air-cooling one set and water-quenching the other. If the samples which are water-quenched show values decidedly under those obtained from air-cooling the material is considered to be subject to temper-embrittlement. Results obtained from these tests are given in Tables 5 and 6.

In all cases, the drop in impact value due to water-quenching as set forth in the susceptibility ratio was not sufficient to justify any conclusion that these materials were subject to temper-embrittlement. That the impact value of the water-quenched samples in the case of the specimens held for 48 hrs. at 850° F.

Table 5—Temper-Embrittlement Tests at 850° F. on 0.30C Pipe, Welded Pipe-to-Pipe, Alloy Casting H and Welded Casting-to-Pipe

<table>
<thead>
<tr>
<th>Material</th>
<th>Specimen Number</th>
<th>Charpy Resistance Air-Cooled</th>
<th>Specimen Number</th>
<th>Charpy Resistance Water-Quenched</th>
<th>Susceptibility Ratio*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe material</td>
<td>13-29</td>
<td>36.0</td>
<td>13-10</td>
<td>32.5</td>
<td>0.864</td>
</tr>
<tr>
<td>Pipe material</td>
<td>13-14</td>
<td>36.0</td>
<td>13-9</td>
<td>32.0</td>
<td>0.892</td>
</tr>
<tr>
<td>Pipe material</td>
<td>13-18</td>
<td>34.0</td>
<td>13-11</td>
<td>32.5</td>
<td>0.822</td>
</tr>
<tr>
<td>Welded pipe-to-pipe</td>
<td>14-12</td>
<td>41.0</td>
<td>14-8</td>
<td>39.7</td>
<td>0.889</td>
</tr>
<tr>
<td>Welded pipe-to-pipe</td>
<td>14-18</td>
<td>41.0</td>
<td>14-28</td>
<td>39.7</td>
<td>0.907</td>
</tr>
<tr>
<td>Welded pipe-to-pipe</td>
<td>14-24</td>
<td>41.0</td>
<td>14-30</td>
<td>39.7</td>
<td>0.892</td>
</tr>
<tr>
<td>Welded pipe-to-casting</td>
<td>13-8</td>
<td>41.0</td>
<td>13-16</td>
<td>39.7</td>
<td>0.892</td>
</tr>
<tr>
<td>Welded pipe-to-casting</td>
<td>13-20</td>
<td>41.0</td>
<td>13-17</td>
<td>39.7</td>
<td>0.892</td>
</tr>
<tr>
<td>Welded pipe-to-casting</td>
<td>13-22</td>
<td>41.0</td>
<td>13-18</td>
<td>39.7</td>
<td>0.892</td>
</tr>
<tr>
<td>Welded pipe-to-casting</td>
<td>13-24</td>
<td>41.0</td>
<td>13-19</td>
<td>39.7</td>
<td>0.892</td>
</tr>
</tbody>
</table>

Table 6—Temper-Embrittlement Tests at 850° F. on 0.30C Pipe, Welded Pipe-to-Pipe, Alloy Casting H and Welded Casting-to-Pipe

<table>
<thead>
<tr>
<th>Material</th>
<th>Specimen Number</th>
<th>Charpy Resistance Air-Cooled</th>
<th>Specimen Number</th>
<th>Charpy Resistance Water-Quenched</th>
<th>Susceptibility Ratio*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe material</td>
<td>13-29</td>
<td>36.0</td>
<td>13-10</td>
<td>32.5</td>
<td>0.864</td>
</tr>
<tr>
<td>Pipe material</td>
<td>13-14</td>
<td>36.0</td>
<td>13-9</td>
<td>32.0</td>
<td>0.892</td>
</tr>
<tr>
<td>Pipe material</td>
<td>13-18</td>
<td>34.0</td>
<td>13-11</td>
<td>32.5</td>
<td>0.822</td>
</tr>
<tr>
<td>Welded pipe-to-pipe</td>
<td>14-12</td>
<td>41.0</td>
<td>14-8</td>
<td>39.7</td>
<td>0.889</td>
</tr>
<tr>
<td>Welded pipe-to-pipe</td>
<td>14-18</td>
<td>41.0</td>
<td>14-28</td>
<td>39.7</td>
<td>0.907</td>
</tr>
<tr>
<td>Welded pipe-to-pipe</td>
<td>14-24</td>
<td>41.0</td>
<td>14-30</td>
<td>39.7</td>
<td>0.892</td>
</tr>
<tr>
<td>Welded pipe-to-casting</td>
<td>13-8</td>
<td>41.0</td>
<td>13-16</td>
<td>39.7</td>
<td>0.892</td>
</tr>
<tr>
<td>Welded pipe-to-casting</td>
<td>13-20</td>
<td>41.0</td>
<td>13-17</td>
<td>39.7</td>
<td>0.892</td>
</tr>
<tr>
<td>Welded pipe-to-casting</td>
<td>13-22</td>
<td>41.0</td>
<td>13-18</td>
<td>39.7</td>
<td>0.892</td>
</tr>
<tr>
<td>Welded pipe-to-casting</td>
<td>13-24</td>
<td>41.0</td>
<td>13-19</td>
<td>39.7</td>
<td>0.892</td>
</tr>
<tr>
<td>Welded pipe-to-casting</td>
<td>13-26</td>
<td>41.0</td>
<td>13-20</td>
<td>39.7</td>
<td>0.892</td>
</tr>
</tbody>
</table>

* Ratio of impact value of water-quenched specimen to that of air-cooled specimen.
was higher than that of the air-cooled specimen may be largely attributed to the nature of the samples themselves.

**Conclusions**

On the basis of the results obtained from the metallographic examination of the proposed pipe material for the main steam lines of the Connors Creek Station, the following conclusions may be drawn:

1. The X-ray examination showed that the welded sections were of a satisfactory quality.
2. The metallographic examination of the welded pipe-to-pipe and the welded casting-to-pipe sections showed the welds to be of an excellent type. The grain size was unusually fine in the welded sections, due doubtless to the method of welding employed.
3. The short-time tensile tests at room temperature and 850° F. showed all of the materials to possess a suitable combination of strength and ductility. The results obtained from the welded specimens were surprisingly good.
4. The impact values for all the materials tested were satisfactory.
5. The creep tests indicated the original pipe material as well as the welds to possess a sufficient resistance to creep. In fact, even under a stress of 15,000 lb., an elongation of but from 1.1 to 1.3% would be expected in 100,000 hrs.
6. The temper-embrittlement tests may be said to be negative.

In conclusion, it is believed that the plain-carbon steel of the type tested and the Alloy H castings will render satisfactory service under the proposed operating conditions. These materials can be satisfactorily welded so as to produce the desired continuity of service without introducing operating hazards. This statement is made, of course, on the assumption that all the materials will be carefully inspected during production and installation.

---

**Qualifying Operators of Welding Equipment under A.S.M.E. Boiler and Pressure Vessel Codes**

By WM. D. HALSEY†

THE A. S. M. E. Boiler Construction Code today refers specifically to four types of vessels; namely, those built in compliance with the Code for Fusion Welded Power Boilers, those built under the requirements of Par. U-68 of the Unfired Pressure Vessel Code (formerly known as Class 1 Pressure Vessels), those built in compliance with the requirements of Par. U-69 of the Unfired Pressure Vessel Code (formerly known as Class 2 Pressure Vessels) and those built in compliance with the requirements of Par. U-70 of the Unfired Pressure Vessel Code (formerly known as Class 3 Pressure Vessels). The Code for boilers and for U-68 vessels does not specify any exact procedure for determining the ability of the operators employed in welding the vessel. It is true that the Code does specify that a sample of welding must be made for each pressure vessel and this welding must be done by exactly the same technique as followed in the construction of the vessel. In most cases, weld samples must be made as a continuation of the longitudinal seam of the vessel. It also is true that the inspector may designate which operator, of those to be employed on the vessel, shall make the test weld and a recent interpretation case by the Boiler Code Committee stated that the inspector has the right to call for tests of any individual operator on a power boiler or U-68 vessel at any time. Aside from these provisions, however, the Code does not specifically state that all operators employed in the welding must be qualified by any set procedure. On the other hand, the Code does specify that all longitudinal and circumferential seams on power boilers and U-68 vessels must be radiographed and the soundness of the seams so examined must meet a certain standard.

In contrast to the above the Code requires that all operators of welding equipment to be employed in fabrication of U-69 or U-70 vessels shall make welds by the same process of welding to be used in fabricating the vessel and these test welds must meet certain requirements. Two types of tension tests are called for in addition to free-bend and nick-break tests. To qualify an operator a minimum of 8 and a maximum of 24 test specimens are required and plate thicknesses from \( \frac{1}{4} \) in. to a maximum of \( \frac{3}{4} \) in.

In the construction of power boilers and U-68 vessels, all the welded seams must be fabricated by the same technique of welding as that used for the test plates and it is assumed that the physical properties shown by the test plates are representative of the physical properties of the welded seams provided those seams are free from defects. The fact that such seams are free from defects is determined by radiographic examination. For U-69 and U-70 vessels the Code states, in effect, that the technique of welding for any particular vessel must be determined upon in advance of welding that vessel, and the individual operators must then be tested to determine their ability to make a weld which will meet the Code requirement for tensile strength, ductility and soundness, the latter quality to be determined by the nick-break method, although radiographic examination for the test plates may be used in lieu of the nick-break.

If we examine somewhat more closely the requirements of the A. S. M. E. Code for power boilers and U-68 vessels, it will be clear that the testing for tensile strength, ductility and specific gravity is done for the purpose of determining whether the process of welding used will produce satisfactory results. The acceptability of the welds on the vessel made by several individual operators is not specifically determined by such operators having previously demonstrated they could make a weld that would have the required tensile strength and ductility, but rather, the acceptability of the work of those men is determined by the radiographic examination. In other words, certain tests having
shown that the welding process will produce a weld having proper tensile strength and ductility, all that is further needed to be known for each individual operator is that he has produced a sound weld.

The writer has stated upon numerous occasions that quality welding depends upon two fundamental principles. First, a technique or procedure of welding that has been carefully tested to know that it will produce acceptable results and second, operators trained to exactly follow that technique of welding and subsequently tested to determine their ability to follow the procedure and to obtain results. We cannot require the most experienced operator to use inadequate equipment or improper materials and expect that he can obtain acceptable results nor can we place the most highly developed technique of welding in the hands of one who is wholly inexperienced in its application and expect to gain the desired end.

There has been in the past a most widespread practice to let each operator of welding equipment determine what materials he desired to use and determine how he would make a weld. If such methods are to be followed it is essential to know that every individual welder can by his pet procedure obtain welds that will have adequate tensile strength, in addition to ductility and soundness. On the other hand, if it can be definitely known that a certain exact procedure of welding will, within reasonable certainty, produce welds that have the desired characteristics, the only examination that need be made of individual operators is as regards their ability to obtain proper fusion and a clean weld.

The statement of the technique, specification or procedure for welding should cover exactly all variables which may have a bearing upon the physical properties of the welded joint. When such a specification for welding has been decided upon, numerous welds in various plate thicknesses should be made in accordance with that specification and such welds should then be tested. What those tests should be will depend largely upon the kind of information desired. They should include at least a determination of the tensile strength of the welded joint using the reduced section tensile test coupon, a determination of the free-bend ductility and a determination of the soundness either by nick-break methods or by X-ray examination. In addition to these tests it may be desirable to examine the tensile strength and ductility of the weld metal itself. Tests of specific gravity and impact strength may also be included. Macrographic and micrographic studies are undoubtedly of great value.

Having determined that a given fixed technique of welding will produce the desired results, it is then necessary to determine that the individual operators of the equipment are willing to and will follow the exact technique. If they are unwilling to do so, they should be shown wherein departures from the technique will produce poor results and, if there is an utter lack of desire to cooperate, their services should be dispensed with. When a welder has demonstrated that he can follow the technique of welding, some simple tests should then be made to determine his ability to obtain fusion with the base metal and also to obtain a clean weld.

While the free-bend test has been used primarily to determine the ductility of a weld, it may also be used in examining an operator's ability to obtain fusion with the base metal and for that reason should be included in the tests for qualifying an operator of welding equipment.

The nick-break test has been used to determine the operator's ability to obtain a clean weld. However, the present type of nick-break specimen, while permitting an examination of the degree of porosity in the weld metal and the operator's ability to obtain a weld sound at the root, does not permit examination of the operator's ability to obtain thorough fusion with the base metal.

The writer has examined numerous X-ray films of welded joints and it is apparent that a common defect is a slag inclusion along the side wall of the joint. The writer, therefore, suggests a new type of nick-break specimen in which the nick would be made along the line of fusion instead of at right angles to the plate surface and through the root of the weld. It is believed that such a test will prove of great advantage not only in testing the ability of an operator but also in showing him wherein it is necessary to keep his work clean and to follow the specified procedure for welding.

The writer has made a number of nick-break tests with the nick on the line of fusion and has discovered defects which otherwise would not have been found except by X-ray examination.

In addition to the free-bend and the nick-break tests, a reverse bend test is of value. This is particularly true in the case of single butt welds in determining the operator's ability to obtain fusion through the entire thickness of material.

From the hundreds of qualification tests of operators that the writer has made or reviewed, he is satisfied that an operator's ability may be satisfactorily determined by a test weld in the maximum plate thickness for which such operator is to qualify and subjecting this test weld to free bend, back bend, right angle and fusion line nick-break tests. Such tests require no elaborate equipment and can be made quickly at small cost. It should be clearly understood, however, that the writer proposes this method of qualifying an operator only where an exact procedure of welding has been developed, proved and exactly followed in welding the test plates.

Whatever the writer may have said in this paper regarding the A. S. M. E. Boiler or Pressure Vessel Code is not to be taken in any way as a criticism of that Code. It is best that such a Code be ultra-conservative and that it be rigid in its requirements. In adopting the procedure for qualifying an operator, as such procedure now appears in the Pressure Vessel Code, the Boiler Code Committee decided upon a method which seemed best suited to that purpose. However, the Boiler and Pressure Vessel Codes, while they are prominent features of a great work, are not considered by the Boiler Code Committee to be so sacred and fixed that they may not be changed. The writer had no small part in developing the methods of qualifying operators that now appear in the A. S. M. E. Code and he is satisfied that the Boiler Code Committee will gladly listen to any suggestions for change provided those suggestions maintain the high standards of safety desired.

Today there are almost as many methods of qualifying a welder as there are people who have given thought to the matter. It is the writer's belief that in developing the various methods of qualifying an operator, the methods used have often been those for qualifying or testing a process of welding rather than qualifying an operator. Methods of investigating a process should be exhaustive. Methods of qualifying an operator who follows that point, it is of little value.

It is the writer's belief that the AMERICAN WELDING SOCIETY should be the authority to whom all can look for a statement as to what constitutes a qualified operator and the methods that should be used to qualify an operator, and he strongly recommends to the AMERICAN WELDING SOCIETY that consideration be given to this matter.
Note on the Fatigue Testing of Welds

By J. H. ZIMMERMAN

The use of welding in connection with the fabrication of highly stressed machine parts, shafts, frames, etc., is steadily increasing. In many such applications the joints or weld metal may be subjected to stress reversals or repetitions of stress of such character as to warrant serious consideration of the danger of failure by repeated stress or fatigue. In furthering the applications of welding in such instances by correspondingly minimizing the possibility of progressive failures in service, the need for exact knowledge of the behavior of welded joints under conditions of repeated stress becomes at once apparent.

Unfortunately, in most cases, the isolated endurance or fatigue limit of a single metal is of no use to the designer. He seldom knows his actual working stresses with sufficient accuracy to design up to the endurance limit without applying the well-known "factor of safety" which might better be called a factor of ignorance. But, given the endurance limits for two materials, other things being equal, in selecting the one showing the greatest resistance to repeated stress distinct progress toward the improvement of the product has been made. Similarly, a welded joint may be made up with any number of procedures but there must be one certain technique or one best procedure combination which will leave the joint in the best possible condition to resist fatigue.

There are two general methods of fatigue testing. These may be briefly described as "full-scale" tests and "specimen" tests. In the first instance full-scale members or joints are subjected to repeated loads in a way closely approximating actual conditions of service and in the second case a series of small machined specimens is subjected to repeated stress cycles of a known magnitude. In the full-scale member test the object of testing is to determine the maximum load to which the member may be subjected for an infinitely large number of repetitions without failure. In the specimen type of test the fatigue or endurance-limit of the metal or joint is the objective. This value may be defined as the maximum stress to which a material may be subjected for an infinitely large number of cycles without failure.

In many respects the ideal fatigue test involves the use of full-scale test specimens but practical limitations have minimized the use of this method. Notable work in this respect has been carried out in the Research Laboratories of the Westinghouse Electrical and Manufacturing Company. However, the average investigator finds this type of test to be entirely too expensive from the standpoint of the preparation of specimens and the size of testing equipment and it is fair to say that well over ninety per cent of the published fatigue investigations have been conducted on the smaller machined specimens. It is in this type of test specimen, therefore, that we find our greatest interest.

Comparative sketches of certain specimens in wide use have been presented by Professor Thornton and there is no need to present detailed sketches of these specimens here with the exception of a type which has been adopted by the writer and which is, in his opinion, a logical one, particularly for the testing of welds. In Fig. 1c is shown the original specimen design as recommended for the R. R. Moore Fatigue Machine. Figure 1b has been used at the Massachusetts Institute of Technology because of the simplified machining and the specimen illustrated in Fig. 1c has been selected for all tests of welded joints.

It will be noted in Professor Thornton's paper and in the subsequent discussion as published in the JOURNAL OF THE AMERICAN WELDING SOCIETY that one of the features involved in the selection of a specimen is the uniformity of stress distribution in the weld metal and in the zones adjacent to the deposit. It is agreed by all investigators that the entire welded joint should be subjected to a

---

*Paper to be presented at Fall Meeting, A. W. S., October 1-5, 1934, New York. Contribution to the Fundamental Research Committee, A. B. W.
†Assistant Professor of Mechanical Engineering, Massachusetts Institute of Technology.
uniform or very nearly uniform stress. In this connection the specimen shown in Fig. 1c is ideal.

A second point that may be taken into consideration in the selection of a specimen is the presence of shear stresses as existent in a cantilever type specimen. These may or may not be important but regardless of the effect of these shear stresses, it is the opinion of the writer that some complication in the interpretation of results can be done away with by their elimination. It will further be noted in Fig. 1c that the specimen has been designed for test in a rotating beam-type machine in which the specimen is subjected to a uniform bending but is at the same time subjected to no shear during the rotation.

As a final consideration in the selection of a test specimen the matter of surface finish cannot be overlooked. It has been shown by many investigators that the condition of the surface of a test specimen is of extreme importance. In practically every specimen that has been in use the direction of the final machining, grinding or polishing marks has been circumferential. It will be noted in Fig. 1c that the specimen recommended by the writer is finished in such a manner as to leave the final surface markings in a longitudinal direction. In this type of finish the effect of surface conditions is reduced to an entirely negligible value.

As a means of determining the actual performance of specimens of the M. L. T. type, five series of tests were conducted. All specimens were prepared from the same 3/16-in. ship plate, the properties of which were as follows:

- Tensile strength: 72,500 lb. per sq. in.
- Yield point: 38,000 lb. per sq. in.
- Elastic limit: 35,000 lb. per sq. in.
- Elongation in 2 in.: 33.0%
- Reduction of area: 49.1%

In the preparation of the welded specimens two plates 6 in. x 18 in. were welded with a double 90° vee butt weld on the long dimension. A 2-in. length was discarded from each end and the remainder was sliced into 3/4-in. widths. These 3/4-in. x 3/4-in. x 12-in. pieces with the weld at the center were then machined to specimens as shown in Fig. 1c.

In order to establish a general fatigue efficiency of welded joints in this preliminary work, four types of welds were employed. Types I and II were arc welded using heavily coated electrodes. Types III and IV were oxyacetylene welded. All welds were made manually and the four types were made in four different shops by experienced and presumably competent welders who were instructed to produce the best possible joint. The speci-
The logical attack on stresses of this general type is through the use of full-scale test specimens or in certain cases which lend themselves to two-dimensional analysis, by photelastic investigations.

It may also be proper to include under the heading of macro-stresses the well-known residual or locked-up stresses, the analysis of which is usually somewhat complicated. With reference to stresses of this nature, however, there appears to be some justification for stating that residual stresses as induced by welding may not always detract from the strength of the joint. It is quite possible that in certain designs these stresses may be put to good use, as for example in the case of the auto-trettaged gun barrel which is deliberately over-loaded and expanded in order to introduce residual stresses.

In the study of micro-stresses the small scale machined test specimen fulfills a real need. By micro-stresses is meant any of the numberless stresses with which the designer is unfamiliar and over which he has no control. These stresses exist irregularly in microscopic volumes of the material only, but they are of sufficient magnitude in many instances to cause the formation of minute cracks which in turn expand and progress under repeated stressing until finally rupture occurs. Examples of these may be cited in the cases of concentrations due to microscopic blow holes, inclusions or scratches and these may be guessed at fairly accurately. Such stresses, however, as those which probably exist at the boundaries between grains of dissimilar constitution or dissimilar atomic orientation may only be speculated upon.

It is probable that in most fatigue failures minute cracks originate at many points simultaneously and that these spread to ultimately combine with corresponding intensification. Evidence of this may be seen in the illustration presented by Professor Otto Graff in the Journal for August 1933, page 30. By reducing the number of base points for these cracks, the welder can improve the fatigue resistance of the deposited metal.

In conclusion it seems reasonable to state that in eliminating all possible sources for the concentration of stresses both the design of a joint and the design of a test specimen are improved. Similarly in eliminating all porosity and unsoundness the fatigue strength of weld metal may be correspondingly improved, and it is the writer's opinion that the fatigue test employing small, well-designed and carefully machined specimens is probably one of the best tools for determining the actual quality of deposited or adjacent metal in a welded joint.

### Bibliography

R. R. Moore (McCook Field), "Fatigue of Welds," JOURNAL AMERICAN WELDING SOCIETY, April 1927, p. 11.


C. H. Jennings (Westinghouse), "Discussion of Peterson and Jennings Paper 'Fatigue Tests of Weld Metal'," JOURNAL AMERICAN WELDING SOCIETY, October 1931, p. 158.


Peterson and Jennings (Westinghouse), "Fatigue Tests of Welded Joints," JOURNAL AMERICAN WELDING SOCIETY, September 1931, p. 5.


---

<table>
<thead>
<tr>
<th>Stress, Lb. per Sq. In.</th>
<th>1000's of Cycles</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>34,800</td>
<td>835</td>
<td>Failed</td>
</tr>
<tr>
<td>36,200</td>
<td>2,583</td>
<td>Failed</td>
</tr>
<tr>
<td>35,150</td>
<td>3,147</td>
<td>Failed</td>
</tr>
<tr>
<td>34,900</td>
<td>217</td>
<td>Failed at Flaw</td>
</tr>
<tr>
<td>34,500</td>
<td>5,333</td>
<td>Failed</td>
</tr>
<tr>
<td>34,050</td>
<td>10,400</td>
<td>Unbroken</td>
</tr>
<tr>
<td>34,000</td>
<td>26,010</td>
<td>Unbroken</td>
</tr>
<tr>
<td>35,950</td>
<td>15,293</td>
<td>Unbroken</td>
</tr>
<tr>
<td>33,400</td>
<td>10,481</td>
<td>Unbroken</td>
</tr>
<tr>
<td>32,650</td>
<td>17,323</td>
<td>Unbroken</td>
</tr>
<tr>
<td>32,500</td>
<td>12,911</td>
<td>Unbroken</td>
</tr>
</tbody>
</table>

### Table 2—Endurance Ratios

<table>
<thead>
<tr>
<th>Material</th>
<th>Endurance Limit, Lb. per Sq. In.</th>
<th>Endurance Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unwelded Plate</td>
<td>34,000</td>
<td>0.47</td>
</tr>
<tr>
<td>Type I Weld</td>
<td>22,000</td>
<td>0.30</td>
</tr>
<tr>
<td>Type II Weld</td>
<td>19,200</td>
<td>0.27</td>
</tr>
<tr>
<td>Type III Weld</td>
<td>20,400</td>
<td>0.28</td>
</tr>
<tr>
<td>Type IV Weld</td>
<td>19,000</td>
<td>0.25</td>
</tr>
</tbody>
</table>

as for example in the case of an under-cut, over-sized fillet and in the case of the over-reinforced butt weld.
Sprayed Molten Metal Coatings

By E. V. DAVID

Introduction

CORROSION is one of the arch enemies of modern civilization and causes destruction of property estimated at many times that resulting from fires. This is due to the fact that ferrous metals (iron and steel) constitute those which are by far the most widely used in industry but, unfortunately, are also those most actively attacked by corrosion. Non-ferrous metals (brass, bronze, nickel, etc.) are, as a class, much less liable to corrosion. However, they are more costly and have less strength and fatigue-resistance. Ordinarily, therefore, engineers much prefer to use iron and steel wherever the surfaces can be effectively protected.

Efforts to prevent corrosion of ferrous metals have taken the form of protective coatings and also of alloying the steel or iron with chromium, nickel or other elements, to make the metal itself rust-resistant. The stainless steels have so far proved too expensive for general use, however, so that protective coatings are still the principal means to combat corrosion.

Paints and varnishes are the cheapest and most widely known and used preservative coatings, but provide only temporary protection in most cases. Bituminous, asphaltum and cement are employed to a lesser extent. A number of other protective processes have been developed, such as galvanizing, sheradizing, electropolating, enameling, lead coating and sprayed molten metal coating, the latter being the process which is to be discussed.

In addition to corrosion-resistant coatings, industry has need for heat-resistant coatings, decorative coatings, coatings to add dimension or weight to worn or mismatched parts, coatings to conduct electric currents, fire-resistant coatings and others.

**MetaLayer Process.**—Sprayed molten metal coatings may be applied by different methods, one of which is known as the MetaLayer process. This process provides a satisfactory means of applying the various types of metal coatings already mentioned. By this method, any of the commercial metals may be melted, atomized and sprayed in fine molten particles on to any surface, to form an adherent, or separable, metal coating. The coating may be built up to any desired thickness on any material, whether metallic, fibrous, vitreous, conducting, insulating or inflammable. Parts of any size or shape may be metal-coated, regardless of location. The application may be made before, during or after fabrication of the part, either in the shop or in the field.

This process uses no pigments, solvents, fluxes or other vehicles. Commercial metallic wire is the only raw material. While it has a field of its own in mechanical work, for which the other coating processes cannot be employed successfully, it may also be used to advantage as an adjunct for them and, therefore, should not be considered as their competitor.

The process makes it practical to secure on any surface, at low cost, the desirable qualities of the more expensive metals, while using the cheaper and usually cheaper.
stronger material for the bulk or mass of the product. Another unique feature of the process is that one portion of a surface can be coated with one metal and other parts of the same surface with other metals. Alternate layers of as many different metals as desired may be applied, one on top of the other. Non-ferrous metals may be applied to ferrous metals and vice versa. Sprayed metal coatings as applied are instantly cold, hard, dry and ready for use. No waiting time or extra handling time is required.

With this process, metal coatings can be applied when wanted and as wanted, up to any thickness desired. Metals with high melting temperatures may be sprayed on base metals or on previously applied coatings having low-melting temperatures. Even wood, fabrics or the thinnest paper may be metal coated without charring.

Metal is sprayed with a self-contained, portable spray gun. This hand tool melts, atomizes and sprays any commercial metal to form coatings on surfaces of any size and shape and of practically any material. Thus, the process may be said to carry out regular foundry practice of melting and pouring metals. The molten metal is in fine particles, however, and is "poured" by a jet of compressed air on the surface to be coated. This method gives a unique control of results and is able to meet and satisfy requirements and demands of great importance.

The metal to be sprayed is supplied in the form of wire, of standard Brown & Sharpe gage.

Capacity.—With the standard spray nozzle held perpendicular to the surface being coated and 5 in. distant from it, the molten metal spray covers a circle approximately 2 in. in diameter. A single pass over a surface sprays a metal coating of from one to two thousandths of an inch in thickness, depending on the metal being sprayed. Each additional pass increases the thickness of the coating by a like amount, until any desired total thickness is obtained. The operator experiences no difficulty in properly guiding and advancing the gun over the surface, as his vision enables him to distinguish clearly between the coated and uncoated portions, as well as between each succeeding pass applied.

Wires of 13, 15, 19 and 20 Brown & Sharpe gage are sprayed with equal efficiency, it being merely necessary to install the proper wire tip in the gun in each case. Wire feed speeds are adjustable to suit all materials. High-melting temperature wires used are of smaller diameter and are fed at lower speeds, while low-melting temperature wires used are of larger diameter and are fed at higher speeds. Intermediate diameters and feed speeds are used for wires of medium-melting temperature. Metals of any melting temperature up to that of tantalum (5250° F.) can be sprayed. Wire feed speeds used range from 10 ft. per minute or less for high melting-point wire to 34 ft. per minute or more for low melting-point wire. Weight of wire used ranges from about 1/2 lb. per hour for iron to about 40 lb. per hour for lead. Weight of metal coatings sprayed ranges from about 1.2 lb. per hour for iron to about 18 lb. per hour for lead. Area metal coated to six thousandths of an inch in thickness ranges from about 6 sq. ft. per hour for iron to about 60 sq. ft. per hour for lead.

The gun operates with oxygen and acetylene pressures ranging from 13 to 15 lb. per sq. in., and compressed air pressure ranging from 45 to 55 lb. per sq. in., depending on the metal being sprayed and the application. Approximately 23 to 26 cu. ft. of oxygen, 22 to 25 cu. ft. of acetylene and 2500 to 3500 cu. ft. of compressed air are consumed per hour per gun. The gun may be regulated within a sufficient range to enable the operator to obtain sprayed metal coatings of the greatest density and coherency under all conditions. However, where certain requirements indicate the desirability of a less dense or a porous coating, this may be accomplished also quite readily.

The gun is also adapted for the attachment of a reservoir for metal dust which may be fed into the spray nozzle in place of the usual standard gage wire. This device is seldom used, however.

Special Spray Nozzles.—For metal coating surfaces inaccessible with the standard nozzle, such as the inner walls of tubes, pipes and small cylindrical objects, special spray nozzles of rotary, fan and angle types have been developed. Any one of these nozzles may be attached directly to the gun, or used with 30-in., 60-in., 80-in. or longer extensions, up to 12 ft. in length. The rotary nozzle is for spraying the inner surfaces of tubes from 1 to 4 in. inside diameter. The fan spray nozzle produces a fan-shaped spray, about 1/4 in. by 1 1/2 in. in diameter, and is used for metal coating edges or narrow bands on surfaces. The angle spray nozzle changes the direction of the spray to about 45 deg. from the center axis. It is used for surfaces which cannot be reached with the standard straight nozzle.

Properties of Metal Coatings.—Photomicrographs of sprayed molten metal coatings show that they are made up of a multiplicity of plastic particles which, by high velocity impact on a surface, are flattened out and interlocked, first with the microscopic open grain of the surface on which they are deposited, and subsequently with each other.

Sprayed metal is described as coherent, by which is meant the joining of the individual atomized particles in the coating to each other. It is also spoken of as ad-
Diagram Showing Nature of Deposit Produced by Attempting to Coat a Smooth Surface with Sprayed Molten Metal

Diagram Showing Nature of Deposit Produced by Coating a Properly Roughened (Steel Grit Blasted) Surface with Sprayed Molten Metal

Diagram Illustrating How a Particle of Sprayed Molten Metal May Strike, Glide Along and Glance Off a Smooth Surface

herent, to indicate the ability of the sprayed particles, and eventually that of the entire coating, to stick to the base material on which they are applied.

For maximum adhesion, the surface of the base metal must be properly roughened.

No claim is made that sprayed molten metal coatings are either welded or brazed to the base metal. The firm adhesion obtained is due solely to the mechanical bond.

Adhesion and cohesion, together with the porosity, permeability and quality of the metal being sprayed, determine the density and hardness of the coating.

The fineness of grain of the sprayed metal coating influences both its cohesion and adhesion. Small particles are able to join better to each other and to penetrate more easily into the pores of the surface than coarse ones. The possibility of simply bridging over the pores is less when using a fine spray; hence, the importance of using correct wire feed speeds, oxygen, acetylene and compressed air pressures and technique, in operating the gun.

On properly prepared surfaces, correctly applied sprayed metal coatings become practically integral with the surface and show many properties of metals cast in the usual manner. Such coatings may be made practically as dense as castings of the same metal and will serve many purposes for which a sheet metal covering is adapted.

Metal Coatings vs. Other Types.—It is not claimed, nor can it be expected, that sprayed molten metal coatings may be applied as cheaply as many of the less dependable and less permanent surface coverings in common use. It can be stated without reservation, however, that, within their proper purpose and scope, sprayed metal coatings develop a more satisfactory appearance, show better wearing qualities and have a wider field of application than coatings developed by any other method. The extra effort and expense involved in applying sprayed metal coatings are more than compensated for by the greatly improved service which they render, especially where permanence is an essential factor.

Finishing Metal Coatings.—Sprayed molten metal coatings may be polished, ground, turned, filed or otherwise finished, just as cast metal would be. Polishing or grinding require care to avoid cutting through to the base or overheating the surface.

The matte or "sanded" appearance of the surface of metal coatings as applied is especially adapted for securing attractive wire-brushed or scratch-brushed finishes at much lower cost than highly polished finishes. On decorative work, emery cloth or steel wool is used to "highlight" and polish the high points. Decorative coatings should be protected by lacquering, to retain the original color. Bronzes are often oxidized with liver of sulphur to desired shade.

An allowance of approximately 12 thousandths of an inch in coating thickness should be made for machine finishing of a part, such as a shaft. In turning, fine cuts are taken, using a round-nosed tool for the softer metals and a pointed tool for the harder metals.

Sand or Grit Blasting.—For maximum adhesion of sprayed molten metal coatings to the base metal, a properly roughened surface is essential. Considerable research has been devoted to determine the most suitable and least expensive means of securing such a surface. Knurling, scratch brushing, scaling, pickling, etching, anodic electrical treatment, sand blasting and steel grit blasting were each thoroughly investigated. It was finally established that the best method of preparing a roughened surface with the maximum number of microscopic keys or dovetails required to give sprayed metal coatings the greatest adhesion was by sand or grit blasting. An additional outstanding advantage of sand or grit blasting is that it produces a chemically clean surface on which to spray the molten metal. This is, of course, essential for permanent adhesion and protection. Fortunately, sand or grit blasting is likewise the most economical method of properly preparing surfaces for metal coating.

It was recognized from the start that the necessity of sand- or grit-blasting surfaces, preparatory to metal coating, would be considered as handicapping the use of the process. Blasting equipment then available did present many objectionable features. However, this has now been perfected to the point where the defects have been eliminated.

Sprayed molten metal coatings should be applied as soon as possible after sand or grit blasting, while the surface is still clean and bright. In no case should more than 24 hrs. be allowed to intervene between sand or grit blasting and metal coating a surface. If handling of sand- or grit-blasted surfaces is necessary, it should be done with clean cotton gloves. Such surfaces should be kept free from grease, oil or moisture.

Surfaces of open-grain structure, such as unglazed pottery, terra cotta brick and plaster do not require sand or grit blasting before metal coating. The process may be applied to them in their natural state, without preparation.

Cost of Metal Coatings.—Metal coating costs are dependent upon a number of variables. Assuming average prices for oxygen, acetylene and compressed air, the cost of these items will total about $0.80 to $1.30 per
Metalayer per hour, depending on the speed of operation. Wire costs may, of course, be determined from the price per pound and the number of pounds used per hour. The price of the wire per pound depends upon the material which is being sprayed.

The cost of metal coating per square foot may be computed by dividing the total hourly cost by the number of square feet coated per hour. The latter is indirectly proportional to the thickness of the coating applied. Assuming a coating of six thousandths of an inch in thickness, which is developed by 4 to 6 passes and is a thickness frequently applied in actual work, the output per gun ranges from about 6 sq. ft. per hr. for iron to about 60 sq. ft. per hr. for lead. On this basis, wire, gas and compressed air cost per square foot for 0.006-in. coating is about as follows: iron, $0.18; lead or zinc, $0.11; aluminum, $0.09.

These figures do not take into account the "edge loss." Edge losses occur when metal coating near the edge of a surface, as a portion of the molten metal particles is sprayed past the edge and lost. On large surfaces the edge loss is a negligible percentage, but on small surfaces it is appreciable. Sand- or grit-blasting costs must be added to metal coating costs to obtain the total cost for applications where such preparation of the surface is required. These are also very variable, but as a rule do not exceed about $0.03 to $0.05 per sq. ft.

Applications of Sprayed Molten Metal Coatings

Corrosion-Resistant Metal Coatings.—When dissimilar metals are brought in contact with each other, as in metals coating, and immersed in electrolyte, an electric current will flow from the anodic to the cathodic metal, as determined by their relative position in a list known as the electromotive series of the metals. This list shows that aluminum and zinc are anodic to iron and will accelerate its corrosion. These figures do not take into account the "edge loss." Edge losses occur when metal coating near the edge of a surface, as a portion of the molten metal particles is sprayed past the edge and lost. On large surfaces the edge loss is a negligible percentage, but on small surfaces it is appreciable. Sand-or grit-blasting costs must be added to metal coating costs to obtain the total cost for applications where such preparation of the surface is required. These are also very variable, but as a rule do not exceed about $0.03 to $0.05 per sq. ft.

Decorative Metal Coatings.—Metal spraying is widely used in the decorative field and virtually has unlimited possibilities for this type of work. Besides metal trimmings and the coating of decorative objects, attractive patterns may be produced by means of stencils. Metals of different colors may be used and, by building up coatings, patterns in relief may be produced.
Due to the remarkable control of the operation obtained with metal spraying, the temperature of the surface being metal coated rises but slightly. Wood, fabrics or the thinnest paper receive the impacting particles of molten metal without charring. Delicate faces may be used as stencils for producing a pattern.

Plaster-of-Paris figures are well adapted to metal coating. Brick or stone may be coated in the same way. A variety of effects is obtained by polishing or not polishing the surfaces so treated. Applications for metal spraying in the decorative field are limited only by the imagination and artistic ability of the user.

Current-Conducting Metal Coatings.—Electric equipment manufacturers use metal coatings on both conducting and insulating materials, to conduct electricity and for various other purposes. For example, lead sprayed on glass furnishes a cheap and effective condenser plate. The coating may be applied to all or any part of the surface of any piece. Terminals may be soft soldered to metal coatings where desired. Other applications include sprayed zinc on radio tubes and coatings for electric, magnetic and thermic shielding effects.

In one instance, carbon resistors were metal coated with copper at the rate of 32,400 per 9-hour day with one spray gun and one operator. A simple jig and automatic machine control made this possible. The previous method required 10 boys to electroplate 25,000 resistors in 9 hours. Carbon brushes also are sprayed with copper.

Mass Coating Small Parts.—Pieces weighing anywhere from a fraction of an ounce up to approximately one pound may be mass coated in bulk. Such parts are placed in a special rumbling barrel, in lots of about one hundred pounds at a time. Sprayed molten metal is directed on the pieces as the rumbling barrel is rotated mechanically.

The coatings are evenly deposited on the surfaces of the entire lot of parts, in one operation. Threaded parts do not require chasing or re-threading. Hardened pieces do not have their temper affected in any way. Objects are entirely covered by the coating. If desired, they may be half-polished or rumbled in leather scrap before removal from the barrel. The quality of product, rate of output and cost of mass coating compare favorably with any other process for the metal coating of small parts.
Welded Rail Joints
Main Track
Steam Railroads

By H. S. CLARKE

IN THE final report of the Committee on welded rail joints, American Bureau of Welding, American Electrical Railway Engineering Association, with the cooperation of the National Bureau of Standards, issue of September 1932, we find the following:

"In the Way of Structural Division of the American Railway Association, the question of welded rail joints has been one for perennial discussion. It has been estimated that a complete solution of the problem, if it would add five years to the average life of track, would be worth $15,000,000.00 or more per year to the industry in less depreciation aside from decreased maintenance."

This was based on 25,000 miles of track. Such a saving applied to Class One steam railroads with their 300,000 miles of main track would possibly amount to twelve times this saving aside from decreased maintenance.

Electrical railway track is greatly different from steam railway track, as, generally, the electric railway track is buried solidly in a pavement and held rigidly in place, preventing the rail from expanding, contracting or buckling.

On steam railways, it has been considered that there was a limiting factor to the length of rails; namely, the necessity to allow enough space between the rail ends to permit free expansion of the steel under the influence of temperature rise.

A number of practical observations lead to the supposition that this factor is not so serious as it has seemed in the past.

The Germans have found that the theoretical expansion in their long rails does not actually take place.

Victorian railways in Australia, with rail lengths up to 225 ft., find with their standard track construction—spikes and ordinary joints—that their actual expansion and contraction is about one-half of the theoretical expansion.

It would seem, therefore, that forces sufficient to resist a tendency for the rails to expand must come into action; such as, the lateral friction between ties, rail and ballast.

That rail can be prevented from expanding in heat cannot be disputed.

Where rail is so fixed that it cannot expand into an extended position when heated and cannot move in any other way, as, for instance, by buckling, it must remain unaltered in size since the external stresses are greater than the inherent compressive stress set up by the temperature rise.

Alternatively, if the rail cools below the temperature at which it is fixed, an inherent tensile stress will arise to be resisted by the influence which fixes the rail.

It is felt by European roads that the tendency of track to buckle under rises in temperature with long rails is overcome in well-ballasted and maintained track by the frictional resistance of the ties and ballast. This difficulty can be entirely eliminated by either allowing the track to take its set in its extended position in the extreme hot periods or by welding the track in hot weather. Thereafter the only inherent stress will be tensile stress which will be greater in the cold months, but not sufficient to affect the service strength of the rails, and at periods when it is desirable to work the track in spring, summer or fall, there will be only a small tensile stress and no stress in hot weather.

With our standard construction, consisting of a double shoulder tie plate and spring clip fastening which resists the tendency for the rail to expand or contract under changes in temperature, only 1/16 of the theoretical expansion at the rail ends is found to be sufficient if rail is laid during cold periods.

European experience indicates that with long rails the tendency to expand or contract is greatly decreased; therefore, with the greater holding power of our construction, it was thought that rails could be welded in indefinitely long stretches without difficulty.

Rail exposed to temperature changes of 100 degrees from that at which it was laid will be subject to a stress of about 19,000 lb. per sq. in. if the rail is fixed. This will amount to 247,000 lb. in a rail of 13 sq. in. section, but it is well within the elastic limit of the steel, so that the rail will return to its original length when the initial temperature again prevails.

Our spring clip fastening set up at each tie plate a spring pressure resistance to end movement of from 4000 lb. to 5000 lb. per tie. It would take approximately 200 ties or 360 ft. of track on each side of the point of stress to prevent the movement of a rail of 13 sq. in. of section subjected to 100 deg. temperature. However, in addition to resistance of the clip, we have binding resistance of the double shoulder tie plate and a frictional resistance between the tie plate and the rail, due to its own weight. Our experience with long stretches of rail indicates that at the ends we have little more, if any, expansion or contraction than would be expected with a 33-ft. rail in ordinary track construction.

On electric railways many kinds of welds have been developed and used; however, the condition on steam railroads is different and here, to my mind, we must have a weld that duplicates the condition of the rest of the rail, or, in other words, a butt weld with all the properties of the rest of the rail with no bars or plates to interfere with the wave motion of the rail or to change its stresses.

In Europe, three methods of welding rails together have been used:

1. Electric Arc Weld.
2. Thermit Pressure Weld.
3. Electric Flash Weld.

The first of these welds has not proved successful, arc welding having a relatively short life under these conditions. It is probable, however, that with the present knowledge of electrodes and fluxes an arc-welded joint could be produced, which with proper heat treatment would be satisfactory. Obviously, it would be very difficult to get this proper heat treatment of a track joint.

Thermit welding, on the other hand, has been used successfully for a number of years in Europe under all conditions.

From a straight collar weld, came the Improved Thermit Pressure Weld, using the Thermit collar around the
base and web and a heat pressure weld on the head or ball of the rail.

The third method of welding, that is, the electric flash weld, is a development of the simple butt welding process when the heated ends are forced together—any oxide that may be present, being squeezed out of the joints, collects in beads which can subsequently be removed and a clean weld will result.

Welding machines for making the flash weld in Europe are semi-portable machines that can be erected at convenient depots taking rail to the machine to be welded in 90-ft. lengths or longer, their lengths being governed by the ability to transport them to the track.

We believe it is entirely practicable to build a portable equipment which will make electric flash welds in track in place of the ties.

In cooperation with the Metal & Thermit Corporation an experimental stretch of rail was welded in track during the hot weather of August 1933 on the Delaware and Hudson Railroad; rail laid varied from 500-ft. to 2800-ft. lengths, a total of 300 welds being made. At the ends of the welded stretches, the rails were connected with regular track joints and in one instance an expansion joint was installed; however, no trouble was experienced with this track, the ends or joint-connected rails showing no greater tendency to expand or contract than the 30-ft. rails in our other track.

Five (5) of the 300 joints welded failed:

First and second failures were due to defective welds; third, fourth and fifth failures occurred during extreme cold periods, all failures occurring in the southbound track and in one stretch of welded track. The three failures occurring in the cold weather have been identified as welds which were left for expansion and experience will quickly solve them. For instance, it was felt that it would not be practical to secure sufficient pressure to repair a break in the center of a long, say, 2000-ft. rail. After studying this problem, the railroad maintenance men cannot rest in an eternal alertness of all who would move with it, no business can escape change, time or season, nor depression serve to halt the rushing flow of new developments in which the "Art of Welding" is among the leaders.

The railroad maintenance men cannot rest in an established practice. Progress is incessant, demanding eternal alertness of all who would move with it, no business can escape change, time or season, nor depression serve to halt the rushing flow of new developments in which the "Art of Welding" is among the leaders.

Table 1

<table>
<thead>
<tr>
<th>131-Lb. Rail:</th>
<th>Composition</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>% C</td>
<td>% Mn</td>
<td>% P</td>
<td>% S</td>
<td>% Si</td>
</tr>
<tr>
<td>0.67</td>
<td>1.32</td>
<td>0.021</td>
<td>0.051</td>
<td>0.09</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Physical Properties</th>
<th>T. S. (Lb. per Sq. In.)</th>
<th>E. L. (Lb. per Sq. In.)</th>
<th>% Red</th>
<th>Area</th>
<th>Brinell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unwelded Rail</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rail head base</td>
<td>133,200</td>
<td>44,000</td>
<td>14.0</td>
<td>19.2</td>
<td>260</td>
</tr>
<tr>
<td></td>
<td>133,800</td>
<td>59,000</td>
<td>14.0</td>
<td>23.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.4</td>
<td>3.4</td>
</tr>
<tr>
<td>Through Weld</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rail head base</td>
<td>132,800</td>
<td>59,000</td>
<td>8.5</td>
<td>19.8</td>
<td>292</td>
</tr>
<tr>
<td></td>
<td>135,000</td>
<td>62,000</td>
<td>8.5</td>
<td>21.3</td>
<td>286</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.8</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.1</td>
<td>1.8</td>
</tr>
</tbody>
</table>

The General Electric Company has made for us a number of experimental electric flash welds in short lengths of 80, 130 and 131-lb. rails and tested these welds thoroughly in their laboratories. Typical laboratory tests of the electric flash welds are shown in Table 1.

Three of the electric flash welds were tested under the standard drop test for 130-lb. rail. Of these two broke and one did not break under one drop of the hammer. These tests have convinced me that we are very close to a 100% weld.

I am often asked what will we do about rail heats developing excessive transverse fissures, necessitating the removal of the entire heat. Until lately, no great attention was paid to keeping heat numbers together; however, it is practical for the steel companies to ship at least 90% of each heat together, so they can be laid in one stretch and it then becomes a simple matter to take out an entire heat, if necessary, whether it is welded into one rail or not.

The question of removal of broken rail is another problem; there are a number of ways to make temporary repairs to broken rail, depending on the characteristics of the break, and, in many cases in welded track, there will be a saving in the amount of rail wasted where it is not necessary to remove the entire rail, due to other defects in addition to the actual break; short pieces can be sawed out with small portable saws, now on the market, temporarily clamped in place and later welded.

These and many minor problems are all subject to solution and experience will quickly solve them. For instance, it was felt that it would not be practical to secure sufficient pressure to repair a break in the center of a long, say, 2000-ft. rail. After studying this problem, we found it was not a big problem and the Metal & Thermit Corporation made such a weld in track without difficulty.

There are many advantages in favor of indefinitely long rail lengths—lengths only to be governed by necessary breaks for signal circuits and switches:

1. Saving in maintenance costs and maintaining joints.
2. Longer life of rail, due to elimination of joint batt­
er.
3. Labor saving in laying rails, due to increased life.
5. Elimination of necessity to bond joints.
6. Saving in maintenance of rolling stock and motive power.
7. Smoother riding track with the continual pound from joints eliminated.

In fact, the advantages of welded track are so many and far reaching that it cannot afford to be overlooked when, at this time, economies in maintenance are so necessary and, at the same time, improved track conditions so essential.
The use of alternating current for arc welding is by no means new, since it has been used in England and European countries extensively for many years. This process has also been used in the United States for many years, but much less extensively. There are a number of reasons why this apparent discrepancy existed. First, there was no satisfactory covered electrodes available in the U. S. at a price to compete with bare electrodes. Second, arc-welding transformers had not been developed which would make bare electrode welding comparable with direct-current power. Third, the general advantages of heavily covered electrodes with alternating current for producing high-class welds had not been developed.

This general situation, however, is gradually changing since a number of the large manufacturers of pressure vessels and large pipe have appreciated some of the advantages of alternating current for arc welding. It is not the intention, however, to discuss in this paper the comparison of A.C. and D.C. from the standpoint of the welding results obtained. It is rather the intention to discuss the various transformer characteristics and welding circuit characteristics to show what effects they have on the welding arc from an arc-striking and maintenance standpoint and also the effects upon the volume of current delivered through the arc and general operation.

Transformer Characteristics

To be satisfactory for arc-welding service the transformer must fulfill a number of requirements, among which are:

1. Sufficiently high open-circuit voltage (or auxiliary circuits) to make arc striking easy for the operator.
2. Open-circuit voltage should be the same or nearly the same for all current values over the adjustment range.
3. Method of current adjustment should be as simple as possible and give as many steps of arc current as possible.
4. Mechanical design must provide for long life of any moving parts.
5. If normal open-circuit voltage is above 75 volts, some means to reduce or eliminate this voltage should be provided to protect the operator when changing electrodes.

The current delivered by the transformer to the arc depends partly upon the resistance but largely upon the reactance of the welding circuit leads from the transformer to the electrode holder and the work.
To enable an operator to strike and maintain an arc easily with either bare or "shielded" electrodes the open-circuit voltage of the transformer secondary should preferably be on the order of 110 volts unless some auxiliary means, such as a high-frequency oscillator, is connected to the welding circuit. With a suitably designed oscillator the normal open-circuit voltage may be reduced to as low as 70 to 75 volts. Such an equipment is illustrated by Fig. 1.

The open-circuit voltage has another effect which is often overlooked; namely, that the variations in arc current due to changes in arc length are inversely proportional to the open-circuit voltage. For example, from Fig. 2 let us assume 110 volts open circuit and a 40-volt arc with 750 amperes; then the IX component of the voltage is 102.2 volts. Now, if the operator momentarily increases his arc length to 50 volts, the arc current will decrease to about 717 amperes. Now let us assume 75 volts open circuit and a 40-volt arc, with 750 amperes; then the IX component of the voltage is 63.5 volts at 750 amperes. Now, if the arc volts are momentarily increased to 50 volts, the arc current will decrease to 661 amperes. In other words, with 110 volts open circuit a change in arc volts from 40 to 50 decreases the arc current about 4%, whereas with 75 volts open circuit the arc current will decrease about 12%. Similarly, it can be shown that if the open-circuit volts is 100 then a change in arc volts from 40 to 50 will decrease the arc current about 6%. The relations between open-circuit volts, arc volts and arc current are shown graphically by Fig. 3 which is based upon arc current as 100% with arc volts at 40.

These figures and curves clearly illustrate the fact that if the transformer is equipped with a tap-changing device for current adjustment which produces various open-circuit voltages, then the current will not remain equally constant on various settings with certain changes in arc length. To produce a constant open-circuit voltage with a tap-changing device it must be designed so that taps on both the primary and secondary are changed to keep the same turn ratio which will hold the open-circuit voltage constant.

The power factor of the reactance-controlled transformer is inversely proportional to the open-circuit volts. For example, if the open volts is 110 and the efficiency is 91% then, based on a 40-volt arc, the power factor is 40%, whereas if the open volts is 90 the power factor would be 49%.

The kv-a. input to the transformer, however, is equal to the product of open-circuit volts and arc amperes. Therefore, if open volts is held at 100 instead of 110 then the kv-a. will be reduced about 10% and the size of the transformer will likewise be reduced.

**Method of Current Adjustment**

The reactance-controlled transformer shown by Fig. 4 is provided with a movable iron core which can be shifted into various positions by turning the handwheel. A pointer in front indicates the approximate current values obtainable, there being an infinite sliding adjustment from minimum to maximum. The ammeter shows the exact current obtained while welding and the voltmeter indicates the secondary terminal voltage which is approximately equal to arc voltage when short welding leads are used.

By a unique method of floating, cushioned support for the moving core and by amply proportioned guides of micarta the equipment is unusually quiet in operations and long life of the mechanical parts is assured.

**Resistance-Controlled Arc-Welding Transformers**

An example of this type of transformer is illustrated by Fig. 1. This type of equipment employs a transformer of the conventional step-down type developing a constant voltage at the secondary terminals. This voltage is reduced to arc voltage by means of resistance in series with the arc. This resistance is switched into and out of the welding circuit by means of the switches shown.

With this type of equipment a much lower terminal voltage is satisfactory because the terminal voltage remains constant and does not drop down to arc volts when welding. Furthermore, a high-frequency arc-stabilizing oscillator is used which makes the arc characteristics entirely satisfactory even for bare-wire electrodes even though the terminal voltage is only 73 volts.

This scheme of control, however, is only satisfactory for welders of low capacity because the over-all efficiency is not nearly as high as that of the reactance-controlled
type. The power factor, however, is high, better than 90% at rated capacity. The reverse is true of the reactance-controlled transformer, namely, the efficiency will be high, usually above 90%, whereas the power factor will be low.

The power factor of the welding circuit can be readily raised to any reasonable figure, however, by the installation of capacitors (stator condensers) with each welding transformer. The capacitor should be connected to the circuit so that it will be switched on and off the line with the welding transformer.

Another and less expensive way to correct power factor where a number of welding transformers are to be used, say, ten or more, is to install a synchronous condenser.

Protection for Operator

There are two types of protective equipment available. The first and most simple is that of a contactor connected in the primary circuit of the welding transformer. The contactor is manually controlled by a switch in the handle of the electrode holder. Such an equipment is illustrated by Fig. 5. This scheme has only one disadvantage, namely, when the operator breaks his arc he must release his grip over the lever which operates the switch. In other words, it is not fully automatic.

The scheme, however, has several advantages. First, power is entirely cut off of the transformer, thereby eliminating the excitation or no load losses when no welding is being performed. Second, when the switch is opened, there is no voltage between the electrode holder and the work so the operator cannot get any shock. Third, the scheme is very simple and is, therefore, less expensive and subject to less maintenance.

The second scheme is fully automatic and involves two relays and a contactor as shown by Fig. 6. This circuit includes a current relay and a time-delay relay which can be adjusted for a delay of from one to five or more seconds. The scheme is such that when the operator breaks his arc, the voltage between the electrode and work is reduced to a low value, say, 30 volts, after an elapse of time determined by the time-delay relay. When ready to strike the arc the operator touches his electrode to the work momentarily which picks up the current relay and establishes the normal open-circuit voltage (say, 110 volts) between his electrode and work which makes it very easy to strike his arc. The adjustable time-delay relay when set for about two seconds provides sufficient time for this operation. It also provides time for an operator to restrike his arc in case it should be accidentally interrupted during welding. The objection to a long time-delay setting (say, five seconds) is, of course, that this gives a longer time interval during which the operator is liable to shock from the normal open-circuit volts.

This scheme has the advantage that the protection to the operator is automatically obtained. One disadvantage is that it is not practical to eliminate the time-delay feature which would, therefore, give the operator immediate protection. The disadvantages relative to the automatic type of protection are: first, the equipment is more expensive; second, it is more complicated and, therefore, subject to more maintenance; third, it does not open the transformer primary and, therefore, does not eliminate the no load losses.

Effects of Welding Circuit Resistance and Reactance on Arc Current

The operators of welding shops in the past who have used direct current for welding have realized the effect of resistance in the welding circuit upon the amount of current delivered through the welding circuit. If the length of the welding circuit was increased using the same size cable the current through the arc would decrease a certain amount. When alternating current is used, however, it will be found that the same change in the welding circuit will decrease the amount of current a great deal more. This is due to the fact that the total opposition (impedance) to the flow of alternating current through a circuit is due not only to the resistance of the circuit but also the reactance of the circuit. The reactance drop depends upon a number of factors and where circular conductors are used which are a reasonable distance from magnetic material such as iron or steel it can be calculated from the following:

\[
\% X = \frac{X}{E} \times \log \left( \frac{1.28 \times d}{r} \right)
\]

where:
- \( X \) is the reactance drop
- \( f \) is frequency
- \( I \) is amperes
- \( E \) is volts applied to circuit
- \( t \) is single length of one side of circuit in inches
- \( d \) is inches center to center of conductors
- \( r \) is inches radius of copper conductor.

Then:

\[
\% X = 1.47 \times f \times I \times t \times \log \left( \frac{1.28 \times d}{r} \right)
\]

Since the voltage of the circuit is known the actual reactance volts drop can be readily found by multiplying it by the \( \% X \) just determined.

The total voltage drop can then be determined from the following:
Qualification of Welding Equipment Operators

By HARRY W. PIERCE

The lack of a generally applicable, non-destructive means of inspecting finished welds for soundness has led to an accepted axiom that in welding we trust to the human element. Without arguing the point, the need of some knowledge of the operator's mechanical and technical ability is most essential, even if perfect inspection means were available. An arc-welded structure of some size and complication is not one which is thrown together and welded without some thought and planning. Aside from the waste of man-hours and metal when welds must be chipped out and re-welded, is the more important factor of re-welds which involve warping and residual strains.

Inspection and determination of poor work after the deed is done is not to be slighted; the point is, that it is to the manufacturer's and customer's best interests to eliminate, in so far as our knowledge goes, the possibility of poor workmanship.

Considerable contact with welding, and welding machine operators, has convinced the writer that given the proper material and tools and decent working and wage conditions, nine out of ten men make the best welds they can. The tenth man can be found, and quickly found, by competent supervision. His reclamation, or elimination, if it is not merely a question of training, is one of the duties of supervision. The point of the present discussion is the determination of the "man's best possible work"—is he sufficiently trained and skilled to do the work, granted that other conditions and circumstances permit or encourage him to do so?

To this end, whether required by the customer's inspection rules or not, some check of welder's qualification is an economic necessity. Under conditions not greatly dissimilar from those under which production is done, but with full understanding that this is a measure of the man's ability, welds are made which can be bent, broken and fully examined. Frequently there is no need to cut out a specimen, but if the job looks well to the eye, there is no need to take it on faith. There should be no quarrel with the necessity or basic idea of "qualification"; in its application, however, a multitude of codes, rules and what-nots have burdened the industry quite needlessly and without accomplishing any further gain of security.

In practically every code for welded construction, or the rules of a regulatory body, there is a more or less detailed set of welding operator tests for qualification. There is usually an attempt to approximate the type of work covered by that code or rule, that is, one covering work done only downhand in a shop requires nothing but flat or downhand test plates and so on. Pipe welds may be specified, or test plates of varying thickness. Again, no quarrel with principle, but after all, what is it that needs be known? Whether a certain type of joint in 1/4-in. or 1/2-in. plate is 80 or 90, or 100% efficient? That a pipe butt will stand 100 lb. or 1000 lb./sq. in. pressure? No. We do want to know whether John Doe, who says he is a welding operator and has been for blank years, can adjust a machine, grip his electrode and put satisfactory weld metal drop by drop in a joint as the designer expected it to go. To make the point clearer, let us consider the factors that determine this, irrespective of the exact use to which the joint is put.

For example, let us assume that we have a welding transformer capable of delivering 110 volts open circuit and 750 amps, to a 40-volt arc using short leads, say, 10 ft. long of 250,000 circular mill cable with leads 3 ft. apart, then

\[
\begin{align*}
\% X &= \frac{1.47 \times 60 \times 750 \times 120}{11,000,000} \log \frac{1.28 \times 36}{0.407} \\
&= 0.722 \times \log 113.2 = 0.722 \times 2.0538 = 1.48 \\
X &= 110 \times 0.0148 = 1.63 \text{ volts reactance drop} \\
\end{align*}
\]

Now \( R = \frac{750 \times 0.000432}{1.63} = 0.324 \text{ volts resistance drop} \)

\[
Z = \sqrt{1.63^2 + 0.324^2} = 1.66 \text{ volts impedance drop}
\]

Now suppose the welding circuit is extended to 100-ft. length, then

\[
\begin{align*}
X &= 110 \times 0.148 = 16.3 \text{ volts reactance drop} \\
R &= 750 \times 0.00432 = 3.24 \text{ volts resistance drop} \\
\end{align*}
\]

\[
Z = \sqrt{16.3^2 + 3.24^2} = 16.6 \text{ v. impedance drop}
\]

Now the arc current is approximately proportional to the IX component of Fig. 2; therefore, if the voltage drop of the welding circuit is increased from 1.66 volts to 16.6 volts we can determine that the welding current will be reduced to approximately 650 amperes.

Now, of all of these figures are based upon no magnetic material near the cable-carrying current. If these cables are carried across steel tanks or steel floors the reactance of the circuit will be materially increased and the current still further reduced.

It is interesting to observe that if the spacing between the cables is reduced from 36 in. to, say, 3 in. then in case of the 100-ft. circuit, \( \% X = 7.22 \times \log \frac{1.28 \times 3}{0.407} = 7.22 \times \log 9.42 \).

\[
= 7.22 \times 0.974 = 7.02
\]

\[
X = 110 \times 0.0702 = 7.72
\]

\[
Z = \sqrt{7.72^2 + 3.24^2} = 8.37 \text{ volts impedance drop}
\]

Therefore, the placing of the cable on 3-in. centers instead of 30-in. centers will reduce the voltage drop in the circuit from 16.6 volts to 8.37 volts, or about 50%.

---

*Paper to be presented at Fall Meeting, A. W. S., October 1-5, 1934, New York.
† Supervisor, Welding Section, New York Shipbuilding Corporation.
put. And it is well to remember that we are not looking for the obvious—the surface, contour, finish, etc., that any observer may see at a glance.

1. Does the man adjust his machine properly for the joint? Not that two or three or any number will choose X amperes and Y volts for the same job. Depending on individual skill and aptitude, there is quite a wide range of satisfactory "heats." The point to be noted is whether it is within the recognized range and suited to the man's skill. Or, in fact, whether he senses or knows what heat he can use.

2. Electrode Size. This is set by most tests, dependent on the joint, material, thickness, etc. For comparative results, this is probably best, yet this is a short-coming of most tests. A man's ability to handle $\frac{1}{16}$-in. wire, in all positions, is only a partial check as to whether he can use $\frac{1}{8}$ in. vertical or $\frac{1}{4}$ in. downhand.

3. Type of Joint. Except in highly specialized industries, an operator makes all kinds of joints, frequently in all positions, in the course of the average day's work. Why not pick the joint which is most difficult, for is it not logical to conclude that the same man can do equally well on less difficult work? Bear in mind that we say "can," not that he will. There are two welds used generally in all types of work, the butt and fillet. For test purposes the latter is undesirable, due to the difficulty of getting quantitative values, whereas the butt joint may be ground flush and tested for tensile strength, or bend, without approximation. Viewed in one sense, however, a fillet weld is not dissimilar from a 90° bevel butt, except that there is no opening at the root. Ability to make the butt weld with a 60° bevel, is practical assurance of the skill to fuse a fillet properly. The factors of contour, adherence to size, under-cut, etc., are susceptible to visual inspection, either on test, or production work. It is to an employer's advantage to check a new employee for these last items, but scarcely an inspector's for, from his standpoint, the test is to determine the factors he cannot fully inspect on the job. For these reasons, the writer believes a butt weld is the only test needed for "qualification." This applies to all types of work, even pipe work, the only additional factor in the latter being tightness, which is, or should be, tested in the complete job.

4. Thickness of test plate, assuming it is not sheet metal, has very little bearing on the test. Bearing in mind the items which must be determined, it makes little difference whether the man makes three passes or thirty. If they are made correctly, it is only a waste of time and money to make a man repeat the process time and again. This does not imply that butt welds in a $\frac{3}{8}$-in. plate require no difference in handling than in 3-in. plate. If both are manually welded, there is a considerable difference in procedure, but that is an item of procedure control and not one of the welder's skill. The latter is required to do the same operation in both, and so far as he is concerned, the only difference is in electrode size. Indirectly, and only through its bearing on electrode size, is plate thickness any factor of qualification.

As to number and type of specimens, there is very little the welder can do to change the normal tensile and elongation values. That is essentially a question of electrode, parent metal and process, of which none depend on the operator. Specimens do differ, due to flaws, which are due to lack of skill of the operator. It remains to detect those flaws and to observe their cause and effect. Due to the necessity for perfect surfaces for bend tests, requiring machined surfaces and placing too great a premium on specimens with flawless exterior, we do not favor the bend test. For quantitative results, the tensile test is excellent for comparison with any known standard. Examination of the fracture is quite illuminating and, if it is desired to go further, a simple nick-break test can be made. The only objection to the latter is its lack of exactness; in other words, it is a visual examination, and flaws per square inch or size of flaws is largely a matter of inspector's judgment.

Little more need be welded than is required for specimens.

Another vexing problem is the repetition of tests. Some rules require but one test, others every six months, some re-tests after a period of non-employment has elapsed. The writer has never understood, or seen any beneficial result in re-tests at stated periods. When a man has shown that he knows how, and is welding more or less steadily, the repetition of tests can only show that he still knows how. It is like asking a bookkeeper to add a column of figures once a month to qualify in arithmetic. If a man has been out of welding for more than, say three months, we believe it wise to check him before he goes on production work of any importance, to see that he has his hand in again. And it is well to hold the possibility of re-test over a man if his work shows lack of care, or other fault.

The remaining problem to the average fabricating plant, is the number of codes and inspection rules governing weldments and, not infrequently, the same weldment or structure. Take shipbuilding for example, in a yard doing both naval and commercial work; two Bureaus of the Navy having cognizance over a great deal of welding, having welding qualification tests, differ considerably. In addition, commercial work in such a yard comes under the rules of the Steamboat Inspectors and, as a rule, under the American Bureau of Shipping and Lloyds' Register, or both. The latter two do not have definite qualification tests, reserving the right to test the "qualification" of any operator at any time. These facts, I need to say, have been administered with common sense and reasonableness.
Every production operator, excluding only helpers and apprentices, is qualified by the test prescribed by the Bureau of Construction and Repair, U. S. Navy. The other bodies have accepted this qualification and certification for their work, in all but a few instances. Our grievance is, therefore, not with conditions as they are, but the possibility of the rules as they now stand. A yard employing, say, 100 welders, might have to qualify to five rules, either doing this to all employed or keeping an elaborate check, to be able to show that John Doe could weld tanks on the U. S. S. Blank, but not similar tanks on the S. S. Whoosis, if the American Bureau were classifying the job, but could if it were Lloyds, or vice versa or any number of combinations. The need of a uniform and enforceable rule is obvious.

Qualification costs money and, in the last analysis, is paid by the customer. The simplest type of butt-weld test, one tension specimen only, burned from plate and ground on an ordinary wheel, involves the following:

Preparation (beveling, etc., of plates)
Set-up and tacking
Welder’s time to take test
Burn out
Grind off reinforcement and backing strip
Test in machine
Make up and certify records

If a testing machine is not available, or if more elaborate and machined specimens are required, the total cost may rise to $20.00 or $25.00. Multiply this by a force of 100 men, by a number of codes and repeat it every six months and the amount of money expended becomes a real factor. No one objects to expenditure on which there is a return, but, as we have endeavored to point out, little additional security has been added.

The simplicity, yet excellent results, we have secured from the Bureau of Construction and Repair test recommends it as one adaptable to all ship work. There is no reason why it should not suffice for all welding on mild steel in which, so far as the welder is concerned, he puts in metal by a metallic electrode, according to directions. The electrode, the joint and the procedure are not under test. That must be done by other tests or demonstrations.

It is quite reasonable to expect added qualification tests on any material in which the technique is much different from mild steel, or if both bare and coated electrodes are in use. The latter condition is rapidly disappearing, however, and as a rule only a few operators need be specially tested on out-of-ordinary work.

Reference has been made to the use of the Bureau of Construction and Repair rules at this yard, for which the accepted best method for the highest type of arc welding, namely, that of pressure vessels. In this country, at least, practically all the companies who are complying with the Boiler Code requirements for Class I Vessels use alternating current for the reason that it is better, makes a better weld deposit, finer grain structure and less slag and gas inclusions.

The writer has labored for years and has become very tired in his struggle to tell the world of the advantages of A.C. and the shielded arc. In living with this problem for a long period, he has evolved the theory which he thinks explains the difference in action between A.C. and D.C. in arc welding.

Arc welding is a combination of metallurgical and electrical engineering and I believe from observation that alternating current so agitates the molten puddle that during solidification the crystal growth is aided. This action comes in two ways. First, by the mechanical agitation through the alternating current magnetic influence, and, second, but not secondarily, the reversal action of 50 or 60 cycle current keeps the puddle molten so as to allow more time for the desired finer grain structure to grow, and this extra time is the explanation of the less gas and dross inclusion.

It is a well-known fact that mechanical agitation of castings improves their quality. Why? I believe the answer is steel holds together and fusion welding is possible because of the intertwining of the crystal structure during solidification. In simpler words, the crystals grow like plant, vine and tree growth in a tropical forest and they so intertwine as to give the metal its strength and physical qualities. When the time of growth is short, as in the North temperate zone, the growth is not as lush as in the tropical zone where time and conditions of the growth are more favorable. In the Arctic zone, which would be equivalent to welding under water, the crystal growth is further arrested and chilled metal results. Chilling copper gives the opposite effect and here, again, A.C. is not as good for welding copper and its alloys as reversed D.C.

Alternating current lends itself admirably to automatic arc-welding conditions. The apparatus is all too

Acceptance of A.C. Welding

By C. J. HOLSLAG

ALTERNATING current arc welding has become the accepted best method for the highest type of arc welding, namely, that of pressure vessels. In this country, at least, practically all the companies who are complying with the Boiler Code requirements for Class I Vessels use alternating current for the reason that it is better, makes a better weld deposit, finer grain structure and less slag and gas inclusions.

The writer has labored for years and has become very tired in his struggle to tell the world of the advantages of A.C. and the shielded arc. In living with this problem for a long period, he has evolved the theory which he thinks explains the difference in action between A.C. and D.C. in arc welding.

Arc welding is a combination of metallurgical and electrical engineering and I believe from observation that alternating current so agitates the molten puddle that during solidification the crystal growth is aided. This action comes in two ways. First, by the mechanical agitation through the alternating current magnetic influence, and, second, but not secondarily, the reversal action of 50 or 60 cycle current keeps the puddle molten so as to allow more time for the desired finer grain structure to grow, and this extra time is the explanation of the less gas and dross inclusion.

It is a well-known fact that mechanical agitation of castings improves their quality. Why? I believe the answer is steel holds together and fusion welding is possible because of the intertwining of the crystal structure during solidification. In simpler words, the crystals grow like plant, vine and tree growth in a tropical forest and they so intertwine as to give the metal its strength and physical qualities. When the time of growth is short, as in the North temperate zone, the growth is not as lush as in the tropical zone where time and conditions of the growth are more favorable. In the Arctic zone, which would be equivalent to welding under water, the crystal growth is further arrested and chilled metal results. Chilling copper gives the opposite effect and here, again, A.C. is not as good for welding copper and its alloys as reversed D.C.

Alternating current lends itself admirably to automatic arc-welding conditions. The apparatus is all too

*Paper to be presented at Fall Meeting, A. W. S., October 1-5, 1934, New York.

7 Engineer, Electric Arc Cutting & Welding Company.
simple. A drive motor with two circuits and a fixed field will feed downward on the arc voltage balanced against a fixed or reactance voltage and upward on short-circuit or overbalance of the fixed or reactance voltage. There are no relays, switches or timed action. The control is inherent. The response is immediate and not subject to sequence.

CURRENT WELDING LITERATURE


Barges. Welded Barge "Texaco 325." Shipbldr. & Mar. Engine Blrdr. (May, 1934), vol. 41, no. 291, pp. 266-267. Non-ported oil-carrying barge built by John H. Mathis Co., Camden, N. J. for full coastwise service from Maine to Norfolk and from New York to Great Lakes; length 670 ft.; beam molded 33 ft.; depth molded at center 12 ft. 6 in.; equipped with two hand bilge pumps of Delug type, with 3 in. diam. galvanized pipe suction, installed on deck, one to force peak and one to pump room aft; table giving summary of main welding details.


Control, Procedure Control in Welding, R. E. Kinkeldey. Metal Progress (June 1934), vol. 25, no. 6, pp. 31-33.


Electric Welding, Resistance. Seam Welding Controlled by Electronic-Discharge, AEG Progress, no. 2, 1934, pp. 30-31. Welding with interrupted current; grid-controlled rectifiers regulate frequency and strength of current impulses; solves most difficult seam-welding problems.


Gas Holder Repair While in Operation, B. Heasle. Gas J. (June 6, 1934), vol. 128, no. 2707, pp. 655-656.


Mach. World (Feb. 2, 1934), vol. 95, no. 2457, pp. 93-94; (Feb. 9), vol. 95, no. 2458, pp. 121-122.


Steel Pipes. Fabrication of Welded Piping for Bur­　zard Point Plant, A. W. Moulder. Heating, Piping & Air Conditioning (June 1934), vol. 6, no. 6, pp. 241-244.


BOOKS

The Seventh Edition of "Arc Welding Handbook," by C. J. Hol­　 slag, is now available for distribution. Copies may be purchased through the AMERICAN WELDING SOCIETY at $2.00. The book has been brought up-to-date with chapters on Shielded Arc, Hammer Annealing, Flux-Covered Electrodes, Normalizing Electrode and some interesting explanations on fusion welding.
WELDING SOCIETY ACTIVITIES
AND RELATED EVENTS

Fall Dinner
No efforts have been spared by the 1934 Dinner Committee of the AMERICAN WELDING SOCIETY to make this dinner a huge success.

It will be a stag affair. Andy F. Keogh is Chairman. The other members of the Committee are: R. W. Boggs, T. C. Fetherston, C. J. Holdag, C. Kandel, M. Male, G. B. Rose, P. W. Swain, G. Van Alstyne and E. Vom Steeg.

Plenty to eat and unusual entertainment are promised.

The Dinner Committee guarantees a good time.

SECTION ACTIVITIES

BOSTON
On Saturday, July 28th, the Boston Section held a mid-summer meeting on board the U. S. S. Medusa off Newport, Rhode Island. The meeting consisted of visiting the many shops on the U. S. S. Medusa, and visiting the U. S. S. California which was along side. As repair ship for the ships of the Battle Force, the Medusa is equipped to handle most any repair work encountered. A few of the shops on the Medusa are:

Sheet Metal Shop  Welding Shop  Plating  "Blacksmith"
Copper  "Carpenter"  Boiler  "Pattern"
Shipfitter  "Foundry"  Pipe  "Electrical"
Range Finder  "Gage"  Radio Shop  "Machine"
Optical Instrument Shop  Gyro Compass  "Fire Control"
Aviation Machine Shop

It was a most interesting meeting, and was arranged through the courtesy of Mr. V. M. Goode, C. M. M., of the U. S. S. Medusa. Mr. Goode is a former member of the Boston Section and is now with the Los Angeles Section.

PITTSBURGH
The following members of the Pittsburgh Section were elected as Officers for the 1934-1935 season.

Chairman—E. J. W. Eggers
Vice-Chairman—Marshall Williams Sec.-Treas.—J. F. Minnotte
Representative on National Board—W. W. Reddie

SAN FRANCISCO
An important meeting of this Section will be held on Friday, September 21st, at the Wm. Taylor Hotel. This is the first meeting of the new season and promises to be a good one. Dr. D. S. Jacobs, President of the Society, will present an address which will be illustrated with fifty slides.

LOS ANGELES—PORTLAND
A joint meeting of the local sections of the A. S. M. E. and A. W. S. will be held on September 18th at Los Angeles and on September 24th at Portland at which Dr. D. S. Jacobs, President of the AMERICAN WELDING SOCIETY will present an address which will be supplemented by a series of fifty slides showing the development of welding in the pressure-vehicle field.

William Hastings Bassett
William Hastings Bassett, newly elected President of the American Society for Testing Materials, and prominent member of the AMERICAN WELDING SOCIETY, died at his home in Cheshire, Conn., on Saturday, July 21st. Mr. Bassett, a pioneer metallurgist in the non-ferrous metal industry, and directly concerned with many of its technologic advances, was Metallurgical Manager, The American Brass Co., Waterbury.

While he had not been well for several months, his condition was improving and death came to him with unexpected suddenness. The immediate cause of death was embolism. He was sixty-six years of age.

Mr. Bassett's early and sustained work in the copper and brass industry probably did more than that of any others to place the industry on a scientific and technical basis. He introduced in this country the use of microscopy in the metallurgy of non-ferrous metals and was among the first to apply the spectroscope to routine work in the non-ferrous industry.

In 1925 he received the James Douglas Medal "for constructive research in copper and brass and other non-ferrous metals and their alloys and for his contributions to the establishment of the high standards of quality."

In June, after serving a two-year term as vice-president, he was elected president of the American Society for Testing Materials with which he had been affiliated since 1903. As a personal member and the official representative of his company, he participated actively in the work of the AMERICAN WELDING SOCIETY. He always took a keen interest in advancing the knowledge of the properties of non-ferrous metals and actively supported research and standardization.

Mr. Bassett received the B.S. degree from Massachusetts Institute of Technology, Class of 1891. He was chemist and superintendent of the Popes Island Manufacturing Co., New Bedford, for five years; then chief chemist, Newark Works, New Jersey Zinc Co. After serving as chemist of the Cce Brass Mfg. Co. in 1902, he became chief chemist and metallurgist of The American Brass Co. In 1903, technical superintendent and metallurgist in 1912, and in 1930 was appointed to his present office. During the World War, he was active on the Committee on Materials for Airplane Construction, in Washington.

He was a past-president of the American Institute of Mining and Metallurgical Engineers (1930) and a former director of the American Institute of Chemical Engineers. Other societies in which he held membership included American Chemical Society, American Society of Mechanical Engineers, Society of Automotive Engineers, American Electrochemical Society, Mining and Metallurgical Society of America, American Geographical Society, Member of Franklin Institute, Institute of Metals of London, England, and of Society of Chemical Industry of London, England. His clubs included the Engineers' Club and Chemists' Club of New York and the Waterbury Club of Waterbury.

The Institution of Welding Engineers

Indicative of the growth of the Institution of Welding Engineers is the appointment of a full-time Secretary and the acquisition of new offices at 7/8 Holborn Hall, Grays Inn Road, London. This step was necessitated by (a) the rapid growth in membership during the last few years, and (b) the work entailed in consequence of the fact that the Institution is widely recognized as the body pre-eminently fitted, both by its achievements and its declared objects, to represent every welding interest in Great Britain.

Achievement Medal

The Trustees of the American Society for Metals at a recent meeting voted to establish a "Achievement Medal" for the recognition of metallurgical achievement which has stimulated work along similar lines and contributed to advances in metallurgical knowledge.

In recognition of Dr. Albert Sauveur's eminent contributions to the science of metallurgy, it was voted that the A. S. M. Achievement Medal be named in his honor and it will be known henceforth as the Albert Sauveur Achievement Medal. As a fitting tribute to Dr. Sauveur, who is Gordon McKay Professor of Mining and Metallurgy at Harvard University, he will receive the first Achievement Medal at the annual banquet of the American Society for Metals at Hotel Pennsylvania in New York City on Thursday evening, October 4th.

Dr. Sauveur is a member of the AMERICAN WELDING SOCIETY.

New Movie Shows Construction of Oil and Gas Pipe-Lines

A new educational motion picture portraying the construction of arc-welded oil and gas pipe-lines is offered gratis for showing upon application to The Lincoln Electric Company, Cleveland, Ohio. The new film, entitled "Shielded Arc Welding of Oil and Gas Lines," tells a graphic story of how pipe-lines are built from the time the pipe arrives from the manufacturers through each successive step until completion. Procedure of firing line and bell hole welding is shown in detail. Operations on recent pipe-line projects were photographed in order to illustrate the most up-to-date methods of construction.

Of 16mm film, the picture is suitable for showing to large or small audiences, in either offices or auditoriums. It is a purely technical film and has been received with great interest wherever shown.

Time required for showing is approximately 12 minutes.

Acetylene Association Meeting

Preparations are fast assuming final form for the annual meeting of the International Acetylene Association, which will be held at the William Penn Hotel in Pittsburgh on November 14th, 15th and 16th.

Each technical sessions of the convention will stress such important subjects as Oxy-Acetylene Cutting as Applied to Steel Mill Applications; the Metallurgical Aspects of the Oxy-Acetylene Welding Process; and Testing, Inspection and Safety in Welding.

This is a complete course of lectures. The series constitutes a course of connected lectures, each one tying-in to the following lecture. At the conclusion of each lecture Prof. McKibben or Dr. Nelson will answer questions on welding problems.

The following is an outline of the lectures.

Lecture No. 1, October 5, 1934.—Fundamentals and Processes of Welding and Gas Cutting, and Their Range of Applicability. Prof. McKibben

Lecture No. 2, October 19, 1934.—Metalurgy of Welds. Dr. Nelson


Lecture No. 4, November 10, 1934.—Welding of Bridges and Buildings. New Structures. Strengthening Existing Structures. Prof. McKibben

Lecture No. 5, December 7, 1934.—Pipe and Pressure Vessel Welding, Inspection Testing by Destructive and Non-Destructive Methods. Training and Qualifying Welding Operators. Welding Wire. Prof. McKibben

Lecture No. 6, December 17, 1934.—Recent Applications of Welding to the Boulder Dam Penstocks, to the Century of Progress Exhibition and to Ships. Prof. McKibben

Prof. McKibben is well known to the AMERICAN WELDING SOCIETY having served as President for two years and as a member of many important committees of the Society, notably, that on Building Codes.

In 1922, Prof. McKibben made the first shearing tests on welded joints; from 1927 to 1932 was consulting engineer on welding of steel structures for the General Electric Company, and of various other companies in connection with welding of structures, such as the office buildings for the Boston Edison Electric Illuminating Company, the Dallas Power and Light Company, the Du Pont Company, the Boston City Hospital, the Providence County Court House, etc.

Dr. T. Holland Nelson is a metallurgist of international standing, having served such companies as the United Alloy Steel Corporation, the Ludlum Steel Company, the Chrome Alloy Products, Inc., and the Midvale Company.

How to Enroll for the Course

This course is offered to all interested at a nominal fee of ten dollars ($10.00) for the six lectures. In addition the Philadelphia Section of the AMERICAN WELDING SOCIETY, sponsors of this feature course, have made special arrangements for those interested.
taking the course to become associate members, at no extra cost. An associate membership entitles you to attend the regular meetings of the Society throughout the year, and receive the Journal of the AMERICAN WELDING SOCIETY.

The Journal of the AMERICAN WELDING SOCIETY is the official technical monthly publication of the AMERICAN WELDING SOCIETY.

The regular meetings of the Philadelphia Section of the AMERICAN WELDING SOCIETY are most interesting and instructive. Foremost speakers covering every field of welding operation are engaged and most talks are illustrated with motion pictures and slides. In addition, you are invited to join the round-table discussions held after each meeting.

The information you will secure from attendance at these lectures, talks and round-table discussions should repay you the cost of this course and membership—many times over.

---

PROGRAM

FOURTEENTH FALL MEETING
AMERICAN WELDING SOCIETY
OCTOBER 1-5, 1934
Hotel New Yorker, New York

Important Notice

Members and guests are requested to register immediately upon arrival, Hotel New Yorker so as to get copy Fall Meeting papers and badge admitting you to Exposition, inspection trips and social events.

Upon registering you will be furnished with copy of the Journal containing papers to be presented at the technical sessions. The supply of Journals is limited, one to each registrant, and on this account you are urged to retain your copy throughout the meeting.

Technical sessions and committee meetings will be held at the Hotel New Yorker.

All sessions will start promptly as scheduled. There will be no stenotype reporter. Members of the Society desiring to discuss papers are urgently requested to prepare discussion in writing in advance of the meeting and to send copies to headquarters as those preparing written discussion will be given preference at the meetings. Members and guests giving extemporaneous discussion at meetings should forward a written transcript of discussion as soon after the meeting as possible.

The National Metal Congress Exposition will be held at the Port of Authority Building, 15th Street at Eighth Avenue, New York. This is readily reached from the Hotel New Yorker by the Eighth Avenue Subway.

---

Monday, October 1st

Morning

Registration

Facilities will be provided throughout the week from 9:30 A.M. to 5:00 P.M., commencing Monday, October 1st.

Afternoon

Opening Session

1:45 P.M. Introduction of President of the American Welding Society—S. S. Scott, Chairman, New York Section.

Address of welcome by Dr. D. S. Jacobus.

2:00 P.M. Presentation of Miller Memorial Medal Award.

Technical Session

2:30 P.M. Presiding Officer—D. S. Jacobus, President.


"Impact Resistance of Welded Joints," by W. Spraragen, Secretary, American Bureau of Welding.

Evening

6:30 P.M. Dinner Meeting, Board of Directors, Hotel New Yorker.

---

Tuesday, October 2nd

Morning

Technical Session

9:45 A.M. Presiding Officer—Leon S. Moiseiff, Chairman, Structural Steel Welding Committee.


"Investigation of Welded Seat Angle Connections," by Inge Lyse and N. G. Schreiner, Fritz Engineering Laboratory, Lehigh University.


Afternoon

Technical Session

2:00 P.M. Presiding Officer—C. A. Adams, Director, American Bureau of Welding.

Fundamental Research in Welding

"Effect of Peening on Physical Properties of Welds and Stress Relief," by O. M. Harrelson, Georgia School of Technology.

"Note on the Fatigue Testing of Welds," by J. H. Zimmerman, Massachusetts Institute of Technology.


"Residual Welding Stresses," by R. E. Jamieson, McGill University.


Evening

7:30 P.M. Hotel New Yorker. Conference and Meeting of the Fundamental Research Committee, American Bureau of Welding—H. M. Hobart, Chairman, presiding.

This conference is scheduled for the benefit of university research workers in the fundamentals of welding.

Wednesday, October 3rd

Morning

Technical Session

9:45 A.M. Presiding Officer—J. J. Crowe, Senior Vice-President.

"Brazing with Silver Solders," by R. H. Leach, Handy & Harman Company.

"Sprayed Molten Metal Coatings," by E. V. David, Air Reduction Sales Company.


Afternoon

2:00 P.M. Presiding Officer—J. B. Tinnon, Chairman, Meetings and Papers Committee.

Railroad Session


Thursday, October 4th

Morning

TECHNICAL SESSION

9:45 A.M. Presiding Officer—E. A. Doyle, Past-President American Welding Society.


Afternoon

2:00 P.M. Presiding Officer—F. T. Llewellyn, Past-President American Welding Society.

SYMPOSIUM ON QUALIFYING OPERATORS OF WELDING EQUIPMENT AND EXPENSES INCURRED THEREIN


“Qualifying Operators of Welding Equipment,” by E. D. Debes, Bethlehem Shipbuilding Company, Fore River Plant, and “Qualification of Welding Equipment Operators,” by H. W. Pierce, New York Shipbuilding Co.


“Pipe Welding,” by Dr. S. Lewis Land and John H. Zink, Heating, Piping and Air Conditioning Contractors National Association.


Evening

7:00 P.M. Annual Banquet—Stag Affair, Hotel New Yorker.

Friday, October 5th and Saturday, October 6th

INSPECTION TRIPS

Include Midtown Tunnel and a Brewery. Details furnished at Registration Quarters. Make early reservation.

LADIES ENTERTAINMENT

Includes luncheon, boat trip around New York Harbor and visit to Broadcasting Station. Details furnished at Registration Quarters. Make early reservation.

The Regulator with the Two Year Performance Guarantee

RECO

RED STAR TWO STAGE DUPLEX REGULATOR

Visit Our Booth No. 325 at THE NATIONAL METAL CONGRESS

Learn Why the Complete RECO Line Will Increase Your PROFITS

PRODUCT OF BASTIAN-BLESSING—242 E. Ontario St., Chicago

Pioneers in Equipment for Using and Controlling High Pressure Gases—Distributors in all Principal Cities. Write for Latest Catalog.

ACETYLENE IN PORTABLE CYLINDERS FOR OXY-ACETYLENE WELDING AND CUTTING

Do you understand our free loan cylinder plan? If not, we are glad to explain.

Supplied in the following size cylinders:

10” x 30”—capacity 125 cu. ft.
12” x 36”—“ 225 “ “
12” x 44”—“ 275 “ “

Prompt and efficient service on any quantity through plants and warehouses and truck deliveries.

Commercial Acetylene Supply Co., Inc.

(Main Office) 40 Rector Street

New York City, N. Y.

BRANCHES:

Atlanta Office: 680 HAMILTON AVE., S. E.
ATLANTA, GA.

Chicago Office: 600 W. JACKSON BLVD.
CHICAGO, ILL.
Fifty-eight years ago a telephone was demonstrated at the Philadelphia Centennial. Today, there are more than thirteen million Bell telephones in the United States. Three-quarters of a million people own the Bell System. They and their families would make a city larger than Philadelphia.

It took long years of pioneering, forward-looking planning and honest management to build the Bell System as it is today, a national institution fulfilling a national need.

It is a big system, for it serves a big country. It has grown in size and usefulness because it has been built upon the solid foundation of service to the public. Its constant purpose has been to give you the best possible telephone service, and the most, at the lowest cost consistent with financial safety.

The test of trying times has shown the soundness of its structure and the rightness of its one policy, one system and universal service.
"Too much time is wasted, Lad, in going back and forth between welder and work to change current."

"You can spend that time profitably, Pop, in actual welding—with a 'Shield-Arc'."

"SHIELD-ARC'S"
Lincontrol
BOOSTS WELD PRODUCTION

Now you can get more welding per day. Time formerly consumed in trips to and from the welder for current adjustment can now be devoted to actual welding. Lincontrol, "Shield-Arc's" amazing remote control device, puts regulation of welding current right in the operator's hands, regardless of distance from the welder. Requires no extra cables, rheostat or portable accessories. Merely tapping the electrode on the work raises or lowers the welding current as desired. Users report increase in weld production as much as 50 to 100 per cent.

Lincontrol is just one of the eleven features of the "Shield-Arc" welder which help to speed up welding, improve quality and cut production costs. No other welder has all these features. That's why more Lincoln welders are in use today than any other make—and why many have found it more economical to scrap their old type machines for "Shield-Arcs." The savings made by the "Shield-Arc" generally pay for it in only a few months of operation. Find out now how much Lincoln can save you. Ask for a free study of your welding costs.

TO BE MODERN . . .
A WELDER MUST
HAVE THESE FEATURES

1. Uniform Current
2. High K. W. Capacity
3. Sparkless Commutation
4. High Efficiency
5. Remote Control (without portable accessories)
6. Polarity Switch
7. Center Reading Meter
8. Dual Control
9. Laminated Magnetic Circuit
10. "Handy Height" Controls
11. Drip Proof, Welded Steel Construction

"SHIELD-ARC" has them all

THE LINCOLN ELECTRIC COMPANY, Largest Manufacturers of Arc Welding Equipment in the World, CLEVELAND, OHIO

"SHIELD-ARC" WELDERS AND ELECTRODES

Mention "The Welding Journal"
WELDERS who use Roebling Welding Wire will tell you that it is outstanding for uniformity and freedom from non-metallic impurities. It should be, The steel for this wire is custom-made specifically for welding. To begin with, only special, pure melting stock is used to make Roebling Welding Steel. Then, small open-hearth furnaces, permitting very close control of the melt, are employed in the exacting refining process. This is far different than making steel on the usual tonnage basis. And, there is a difference in the result.

You will find it worthwhile to send for samples and data on Roebling Custom-Made Welding Wire. It is made in both gas and electric types.

ROEBLING WELDING CABLES: These cables are made in a complete line for arc welding purposes. Many leading welders consider them to be the finest welding cables on the market. Samples, data and prices gladly furnished.

JOHN A. ROEBLING'S SONS CO.
Trenton, N.J. Branches in principal cities.

ROEBLING WELDING WIRE
Custom Made

Our Advertisers Are Supporting the Society
All failed in the parent metal

* NOT ONE FAILED IN THE WELD *

Laboratory inspected cast-iron bars were cut in two, the edges beveled, then welded together with Tobin Bronze...and subjected to straight pull strength tests. All failed in the cast iron...there were no failures in the Bronze! Tobin Bronze is uniformly dependable—welders like the way it flows, and the tough, strong, durable bonds it produces.

The uniformity of Tobin Bronze is the result of close inspection and the manufacturing skill developed during a century of experience in the production of copper, brass and bronze products.

There are 14 Anaconda Welding Rods...a suitable one for every purpose. Their characteristics and welding procedures are outlined in detail in Anaconda Publication B-13. A copy will be mailed to you—without cost—for the asking.

THE AMERICAN BRASS COMPANY
General Offices: Waterbury, Connecticut

ANAconda WELDING RODS

* Mention "The Welding Journal"
Tentative Program For Meeting At Hotel New Yorker:

**Monday, Oct. 1**

**Morning**
- Registration

**Afternoon**
- Address of welcome by President D. S. Jacobus, Babcock & Wilcox Co., New York.
- Presentation of Miller memorial medal.

**Evening**
- Dinner meeting, board of directors, Hotel New Yorker.

**Tuesday, Oct. 2**

**Morning**

**Afternoon**
- "Fundamental Research in Welding Effect of Peening on Physical Properties of Welds and Stress Relief," by O. M. Harrelson, Georgia School of Technology, Atlanta, Ga.
- "Residual Welding Stresses," by R. E. Jamieson, McGill University, Montreal, Quebec.

**Wednesday, Oct. 3**

**Morning**
- "Hard Faceing," by Bradley Stoughton, Lehigh University, Bethlehem, Pa.

**Afternoon**
- "Symposium on Qualifying Operators of Welding Equipment and Expenses Incurred Therein"

**Thursday, Oct. 4**

**Morning**
- "Flame Cutting," by Bradley Stoughton, Lehigh University, Bethlehem, Pa.

**Afternoon**
- "Welded Joints in Main Line Track," by H. S. Clark, engineer, maintenance of way, Delaware & Hudson railroad, New York.
- "Technical Phases of Application of Welding in Hi-Tensile Division of Edward G. Budd Mfg. Co."
  - "Welding of Chromium Steel," by H. M. Boykston, Ohio Northern university, Ada, O.

You Owe It To Your Future Progress and Prosperity to Attend This Great Annual Event!
Meet your fellow metalists at the 16th Annual Metal Congress & Exposition, New York City, October 1, 2, 3, 4 and 5th. This will be the greatest Show in years. 150 Exhibitors have already contracted for space and six leading technical Societies are participating.

Key men from these Societies will present the developments of a year of amazing progress. Discussion will enable you to check your methods against those from every section of the country. Inspection of the Exhibits will enable you to SEE what engineering ingenuity has devised for your benefit.

At the National Metal Congress & Exposition—the Mecca for Metal Men—specialists in every phase of the metal-working industry will keep you in touch with the latest trends. Members and non-members are cordially invited to reap the benefits of attendance at this year’s Congress & Exposition.

Bring your individual problems and let the other fellow’s experience work out the kinks for you. Take away new ideas that you can put to work at once. Be there for the Roll Call on October 1! Port of Authority Bldg., 8th Ave. at 15th St., New York City.

The following technical Societies are cooperating in this great event:

**In Attendance**

- American Society for Metals
- American Welding Society
- The Wire Association
- Iron & Steel Division, A.I.M.E.
- Institute of Metals Div., A.I.M.E.
- Iron & Steel Division, A.S.M.E.

**Announcement**

In addition to a thoroughly practical Welding Program which can readily be adapted to your daily work, there will be a Short Course on TOOL STEELS conducted by James P. Gill, B.S., M.S., Met. Eng., Chief Metallurgist of Vanadium Alloy Steel Co. Mr. Gill, one of America’s foremost experts on carbon, low alloy and high speed tool steels, is eminently qualified to present this general survey of commercial tool steels. Write today for Enrollment Card!

*Address:* W. H. Eisenman, Managing Director, National Metal Congress & Exposition, 7016 Euclid Avenue, Cleveland, Ohio, for General Program. Hotel Headquarters: Hotel New Yorker.

**National Metal Congress**

**October 1 • 2 • 3 • 4 • 5 • 1934**

Mention “The Welding Journal”
Fabrication of machine bases and frames, such as those made by Whitehead & Kales of Detroit, is no ordinary welding job. It demands careful design and the best of workmanship. It means working to close limits and calls for consistently flawless welding. The weld metal must be of high tensile strength and great ductility. Where appearance also is a factor, deposits must be clean and smooth. Much depends, of course, on the electrode employed.

Seeking an electrode which would meet not just a few, but all of their exacting requirements, Whitehead & Kales, after thorough tests, have adopted Murex.

There is no doubt about it, Murex has set a new standard of electrode performance. In addition to assuring economical welding and weld metal of highest quality, these electrodes save the welder's time by being easier to use, by burning with a short, quiet arc, and by depositing smooth, quickly cleaned welds. A comprehensive booklet explains in more detail what Murex can do for you. May we send you a copy?
Quality Coke
Plus
Quality Lime Stone
Plus
Engineering Ability
Equal
National Carbide

Let RESULTS prove SUPERIOR QUALITY

CLAIMS and statements are necessary to point out the merits of a product— but final judgment is based on results alone. Proved results— better work at less cost— is the reason that thousands of users are standardizing on American Steel & Wire Company Premier Tested Welding Wire. Highest quality, constant uniformity, freedom from impurities and the marking of each piece for grade—are factors that make superior performance possible.

1831 × 1934

AMERICAN STEEL & WIRE COMPANY
208 South La Salle Street, Chicago
94 Grove Street, Worcester
SUBSIDIARY OF UNITED STATES STEEL CORPORATION
AND ALL PRINCIPAL CITIES
First National Bank Bldg., Baltimore
Pacific Coast Distributors: Columbia Steel Company, Russ Building, San Francisco
Export Distributors: United States Steel Products Company, New York
Introducing

a new member of

the AIRCO-DB

Oxyacetylene

Cutting Machine family

The

AIRCO-DB No. 1

TRACTOGRAPH

This small, compact machine opens up new fields for the use of MACHINE GAS CUTTING. It makes possible the cutting of steel plates and slabs into shapes having straight, circular or irregular outlines and extending over practically unlimited areas. It cuts beveled as well as perpendicular edges.

It is motor-propelled and can be quickly adjusted to travel at any speed from $2\frac{1}{2}$ to 36 inches per minute. As it travels it is guided by hand along the desired contour laid out and scribed directly on the plate or slab.

An entirely new principle in cutting machine drive, combined with other features which enable the operator to change the direction of the machine with exceptional ease, makes it possible to turn sharp corners and to follow both simple and intricate contours with unusual accuracy.

Measuring only $7\frac{1}{2} \times 8\frac{1}{4} \times 16$ inches and weighing but 18 pounds, the TRACTOGRAPH can be easily carried about and used wherever 110 volts A.C. or D.C. are available.

WRITE for the TRACTOGRAPH Bulletin

It gives full details of the machine and the work it will do. Write for your copy—today.

AIR REDUCTION SALES COMPANY

General Offices: 60 East 42nd St., New York, N. Y.

District Offices and Distributing Stations in Principal Cities

PIONEERS IN DEVELOPING OXYACETYLENE CUTTING PRACTICE AND MACHINES