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THE WELDING OF FERRITIC STEELS TO AUSTENITIC STAINLESS STEELS

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ABSTRACT

As part of the Oak Ridge National Laboratory program in support of the Experimental Gas-Cooled Reactor, satisfactory procedures were developed for making the ferritic steel-to-austenitic stainless steel welds in the primary coolant pipes of the reactor. In addition, suitable procedures were developed for welding stainless steel-nozzle-stub extensions to the carbon steel pressure vessel.

A new nickel-base alloy welding electrode, given the developmental designation BP-85 and now known as Inconel-182, was selected as the most promising weld metal for the applications. Nickel-base alloy weld metal appears to be particularly suitable for joining these combinations of materials for cyclic temperature service. The coefficient of expansion approximates that of ferritic steels; and during thermal cycling, the differential expansion stresses are located primarily at the stainless steel-weld metal interface. The use of nickel-base weld metal also reduces the degree of carbon migration from the ferritic steels to the weld metal.

Welding procedures were developed for joining ASTM A-212, grade B, carbon-silicon steel to type 304 stainless steel, and ASTM A-387, grades C and D, low-alloy steels to type 304 stainless steel. The deposition characteristics of the Inconel-182 electrode were excellent in all positions and weld-metal cracking and porosity were not encountered. Transverse tensile tests on welds at both room and elevated temperatures were conducted and all specimens fractured in the base metal. Thermal-cycling test specimens containing welds made with Inconel-182 electrode have not revealed any evidence of cracking, whereas specimens containing welds made with stainless steel electrodes have revealed serious cracking.

THE WELDING OF FERRITIC STEELS TO AUSTENITIC STAINLESS STEELS

INTRODUCTION

The Experimental Gas-Cooled Reactor (EGCR), which is under construction at the Oak Ridge National Laboratory (ORNL), is a combined experimental and power demonstration reactor.[1] It is fueled with slightly enriched uranium dioxide clad in stainless steel, moderated with graphite, and cooled with helium. The plant is designed to produce 85 Mw of thermal power at a gas-outlet temperature of 1050°F and 25 Mw of net electrical power.

The reactor portion of the plant consists of an ASTM A-212, grade B, carbon steel pressure vessel, a graphite core, fuel assemblies, and control rods. The 2-3/4-in.-thick pressure vessel is cylindrical with hemispherical top and bottom heads, has an inner diameter of 20 ft, and has an inside height of 46 ft. A 1-in.-thick, stainless steel, cylindrical temperature barrier is located between the pressure vessel shell and the graphite core. Helium gas from the vessel cooling system flows in the annulus between the temperature barrier and the pressure vessel and limits the reactor vessel temperature to 650°F maximum.

The helium coolant gas is circulated in a closed circuit consisting of two piping loops, each of which contains one steam generator and one blower. The design flow of coolant through the reactor is 428,000 lb/hr and is equally distributed in the two loops. The 300-psia gas leaves the reactor at 1050°F, is cooled to 490°F in the steam generators, and is returned to the reactor at 510°F. Type 304 stainless steel piping is used between the reactor pressure vessel outlets and the chromium-molybdenum (ASTM A-387, grade C) steam generator inlets, while the piping from the steam generators to the reactor vessel inlets is carbon steel.

As a part of the ORNL program in support of the EGCR, the Metallurgy Division was assigned the responsibility for developing satisfactory procedures for making the dissimilar-metal welds in the primary coolant piping

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[1] Experimental Gas-Cooled Reactor Preliminary Hazards Summary Report, prepared for the U. S. Atomic Energy Commission by Kaiser Engineers and Allis-Chalmers Manufacturing Company with technical advice and assistance of the Oak Ridge National Laboratory, ORO-196 (May, 1959).

system of this reactor. Figure 1 is a simplified cross-sectional view of the EGCR showing the primary coolant pipes. These pipes are massive in size with the dimensions at the location of the carbon steel-to-stainless steel weld being 36-in. o.d. x 1-in. wall. Figure 2 is a drawing of a typical nozzle-stub extension where the penetration of the burst-slug-detection tubes and thermocouples through the pressure vessel wall occurs.[2] The metal thickness at the location of the dissimilar-metal weld is 1-1/4 in.

This report presents a detailed description of the program conducted at ORNL concerning the welding of carbon and chromium-molybdenum ferritic steels to austenitic stainless steels. A discussion of the important factors to be considered in making welds of these types is included, as is a summary of the procedures commonly used by the steam power, petroleum, and other industries who use piping and associated components for high-temperature, high-pressure service.

GENERAL CONSIDERATIONS

The problem of cracking in ferritic steel-to-austenitic stainless steel welds during cyclic temperature service has been the subject of reports in recent years by several investigators, both in the United States and in Europe.[3-7] Cracks have been observed in the heat-affected zones of the

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[2]G. M. Slaughter and T. R. Housley, Fabrication and Inspection Procedures for EGCR Burst-Slug-Detection Tube and Thermocouple Penetrations, ORNL-CF-61-8-29.

[3]G. E. Lien, F. Eberle, and R. D. Wylie, "Results of Service Test Program on Transition Welds Between Austenitic and Ferritic Steels at the Philip Sporn and Twin Branch Plants," Trans. Am. Soc. Mech. Engrs. 76, 1075–83 (1954).

[4]H. Weisberg, "Cyclic Heating Test of Main Steam Piping Joints Between Ferritic and Austenitic Steels – Sewaren Generating Station," Trans. Am. Soc. Mech. Engrs. 71, 643–64 (1949).

[5]D. B. Kittle, Evaluation of Weld Transition Joints of Type 304 Stainless Steel to Croloy 2-1/4, KAPL-M-DBK-1 (Nov. 20, 1956).

[6]R. V. Blaser, F. Eberle, and J. T. Tucker, "Welds Between Dissimilar Alloys in Full-Size Steam Piping," Am. Soc. Testing Materials, Proc. 50, 789–807 (1950).

[7]F. Zimmer, "Welded Joints Between Ferritic Steels and Austenitic Steels," Tube Investments Limited – Translation No. 1439, translation of publication issued by the Bureau d'Etudes Industrielles Fernand Courtoy S. A., 3rd and 4th ternes, 1957.

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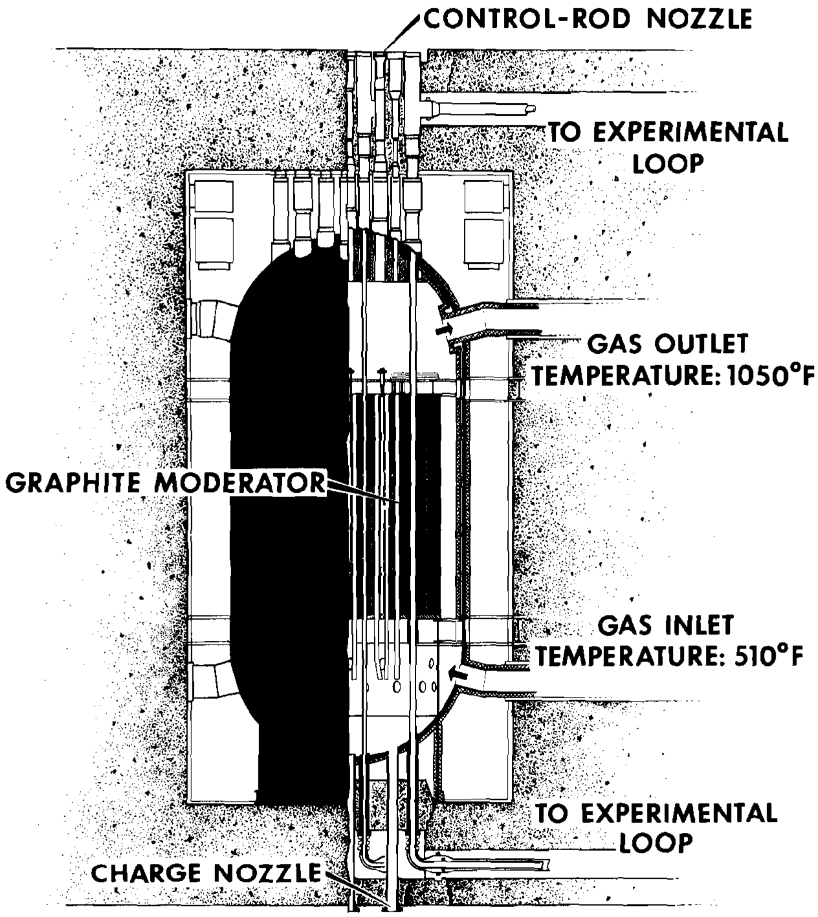

SECTION OF REACTOR VESSEL
(20-ft. inside diameter by 46 ft. 4 in. high)

Fig. 1. Cross Section of the EGCR Showing the Primary Coolant Pipes.

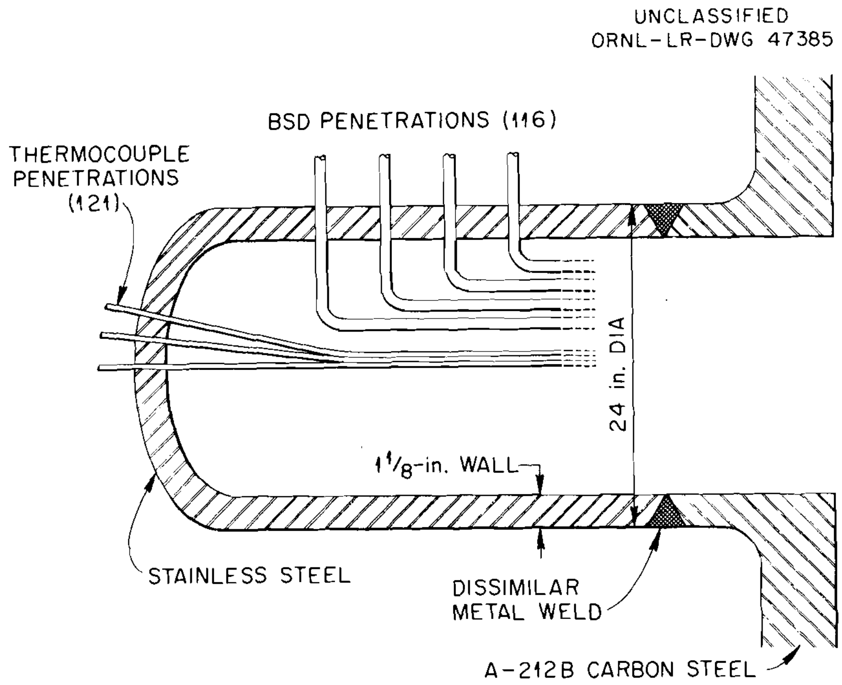

Fig. 2. Nozzle-Stub Extension for Penetration of the Burst-Slug-Detection Tubes and Thermocouples Through the Pressure Vessel Wall.

ferritic steel portions of dissimilar-metal welds which had been repeatedly thermally cycled to elevated temperatures in the range of 1050°F. The possibility of such a cracking problem is of vital importance to those in the steam power industry, since repair maintenance is costly in itself and the increased down-time of the power plant adds considerable expense. In the nuclear industry, however, the problem is even more serious. The radioactivity of the system makes the maintenance very difficult, and the leakage of radioactive contaminants through the failure area could endanger operating personnel.

The principal factors responsible for the cracking problem in ferritic steel-to-austenitic stainless steel welds have been discussed in the literature[8] and the most important are listed below.

1. Differences in coefficients of thermal expansion between ferritic steels and austenitic stainless steels. – The mean coefficients of expansion between room temperature and 1200°F for the materials of interest are compared below.

Type 304 stainless steel	– 10.4×10^{-6} in./in./°F
Low carbon steel	– 8.2×10^{-6} in./in./°F
2-1/4 Cr-1 Mo steel	– 8.9×10^{-6} in./in./°F

As a result of these expansion differences, thermal cycling may cause high stresses to be built up in the joint.

2. Differences in thermal conductivity between ferritic steels and austenitic stainless steels. – The thermal conductivities of these materials at 212°F are as follows:

Type 304 stainless steel	– 113 Btu/hr-ft^2-in.-°F
Low carbon steel	– 350 Btu/hr-ft^2-in.-°F
Chromium-molybdenum steel	– 195 Btu/hr-ft^2-in.-°F

3. Carbon depletion in the ferritic material. – Austenitic weld metals are commonly used for joining these dissimilar metals, and such a weld metal permits migration of carbon from the ferritic material to the austenitic,

[8] O. R. Carpenter, N. C. Jessen, J. L. Oberg, and R. D. Wylie, "Some Considerations in the Joining of Dissimilar Metals for High-Temperature, High-Pressure Service," Am. Soc. Testing Materials, Proc. 50, 809–57 (1950).

producing a decarburized band. This migration can occur during high temperature service or during high-temperature stress relief and may noticeably reduce the strength of the dissimilar-metal joint.

4. Oxide notches occurring in the ferritic material. – Preferential oxidation at the highly stressed weld interface may promote premature failure of the joint.

Such factors as microfissuring of weld metal and martensite formation in the weld metal were of definite importance in the past, but improved weld-metal compositions, closer quality control, and improved welding and inspection techniques have reduced these factors to minor importance today.

COMMON PROCEDURES IN USE FOR WELDING FERRITIC STEELS TO AUSTENITIC STAINLESS STEELS

The successful joining of dissimilar ferrous metals has been accomplished since 1940. The Krupp Steel Works in Germany investigated the use of austenitic welding electrodes for this application as early as 1935 but did not recommend its use for the I. G. Farben power plant until approx 1940. Around 1940, the petroleum industry in the United States also initiated the use of austenitic stainless steel electrodes for welding chromium-molybdenum hot-oil transfer lines. However, it was not until 1948 in this country that serious consideration was given to the joining of austenitic materials to ferritic materials for the main piping of steam power plants.[9]

The Sewaren Generating Station of the Public Service and Gas Company, New Jersey, was the first steam power plant to operate at an initial steam temperature of 1050°F, the steam pressure being 1500 psi.[4] The turbines were furnished with austenitic stainless steel valves and piping, while the boilers were equipped with chromium-molybdenum piping. For the first three units at Sewaren, it was decided to use Kelcaloy transition pieces between the ferritic piping and austenitic components. The joint was developed by the M. W. Kellogg Company and was fabricated by integrally "casting" stainless steel on a chromium-molybdenum steel forging. Bonding was axial to the pipe rather than radial as in a butt weld.

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[9] R. W. Emerson and W. R. Hutchinson, "Welded Joints Between Dissimilar Metals in High-Temperature Service," Welding J. 32, 126s–41s (March, 1952).

Another welding procedure in common usage in industry involves "buttering" or overlaying the welding edge of the ferritic steel with stainless steel weld metal before welding to the mating stainless steel component. A typical application which has been reported[10] requires the joining of a type 316 stainless steel superheater to a large (54-in. o.d. x 5-in. thick) chromium-molybdenum steam drum through a chromium-molybdenum transition member. A 5/8-in.-thick overlay of type 309 stainless steel weld metal was deposited on the chromium-molybdenum transition member so that a stainless steel-to-stainless steel weld could be subsequently made in the field.

The Babcock and Wilcox Company has been investigating the welding of austenitic steels to ferritic alloys for some time and has obtained considerable experience along these lines.[11] The use of 25 Cr–20 Ni (wt %) and 19 Cr–9 Ni–Cb (wt %) electrodes is indicated in the literature up until approx 1955–56. However, they established that joints of type 347 stainless steel welded to 2-1/4 Cr–1 Mo (wt %) ferritic steel with 19 Cr–9 Ni–Cb (wt %) electrodes failed after thermal cycling between 1100°F and room temperature.[12] The cracks occurred in the ferritic material, adjacent to and following the weld deposit contour, and appeared to be associated with accelerated oxidation at the highly stressed weld interface.

Tucker and Eberle[12] also reported a technique for welding ferritic steels to austenitic stainless steels using a 50 Ni–10 Cr electrode. Joints welded with this material were completely resistant to cracking under their cyclic test conditions. In addition to good oxidation resistance and good creep strength, this electrode composition possessed a thermal expansion coefficient similar to that of the ferritic steel. The use of Inconel (Ni–15 Cr–10 Fe–2.5 Cb, wt %) electrodes for joining these materials has also

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[10] Alco Products, Inc., Welded Transition Joint Between 2-1/4% Cr–1% Mo Steel and Type 316 Stainless Steel, APAE No. 73 (Aug. 15, 1960).

[11] John J. B. Rutherford, "Welding Stainless Steel to Carbon or Low-Alloy Steel," Welding J. 38, 19s–26s (Jan., 1959).

[12] J. T. Tucker and F. Eberle, "Development of a Ferritic-Austenitic Weld Joint for Steam Plant Application," Welding J. 35, 529s (Nov., 1956).

been investigated for a few commercial applications, and the results were encouraging.[13] A modified Inconel electrode, known as INCO-Weld A Electrode,[14] was subsequently developed for the welding of dissimilar metals. This electrode, however, did not serve adequately for all-position welding and has been used only to a limited extent.

ORNL DEVELOPMENT PROGRAM

Electrode Selection

The most important criterion for the dissimilar-metal welds for the EGCR application was that they possess the utmost in integrity. This reactor, being experimental in nature, will undoubtedly be subject to numerous complete shutdowns plus a very large number of moderate power fluctuations. The prevention of cracking in these welds during cyclic temperature service is therefore paramount.

After technical discussions with personnel from Babcock and Wilcox Company, General Electric Company, International Nickel Company, and others, it was the considered opinion that the use of nickel-base metal-arc electrodes would provide the most reliable welded joints for the EGCR applications. This decision was based on the following factors:

1. The coefficients of thermal expansion of Inconel-type materials (8.5×10^{-6} in./in./°F) approximates those of the ferritic steels. During cyclic temperature service, the major differential expansion stresses are located primarily at the stainless steel-weld metal interface. When stainless steel weld metal is used, these stresses are located primarily at the ferritic steel-weld metal interface.

2. The use of a nickel-base weld metal markedly reduces the amount of carbon migration from the ferritic steels to the weld metal. Extensive carbon migration into stainless steel weld metal has been reported in the literature with resultant weakening of the heat-affected zone of the ferritic steel.[8]

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[13]Personal communication with R. D. Wylie, Babcock and Wilcox Company, Barberton, Ohio.

[14]International Nickel Company, New York, N. Y.

3. An improved nickel-base electrode has been recently developed by the International Nickel Company. This electrode, formerly designated as BP-85 and now known as Inconel-182, was developed primarily for welding Inconel to carbon or stainless steel and for overlaying steel and was reported to possess excellent overall properties.[15]

4. The slightly higher cost of nickel-base electrodes was not an important factor in the selection of the optimum weld metal since the integrity requirements for the EGCR applications were overriding.

In view of these considerations, the International Nickel Company Inconel-182 electrode was selected as the most promising weld metal for further study.

Electrode Evaluation and Welding Procedure Development

A quantity of 1-in.-thick plate of ASTM A-212, grade B material, ASTM A-387, grade D material, and ASTM A-167, grade 3 (type 304 stainless steel) material were obtained for evaluation tests on the Inconel-182 electrode and for welding procedure development. After this work was completed, a welding procedure was also developed for joining ASTM A-387, grade C material to type 304 stainless steel.

Chemical analyses of the base metals and welding electrodes are shown in Table 1.

Weld-test plates of the various dissimilar-metal combinations were made under a high degree of restraint. This high restraint was imposed in order to simulate the conditions of stress that might be encountered in the field and was obtained by first welding the 1-in. base-metal plates to a 2-in.-thick backing plate. A photograph of a completed test plate welded to the backing plate is shown in Fig. 3.

Preliminary welding studies indicated that this Inconel-182 electrode possessed excellent deposition characteristics in all positions and that weld-metal cracking and porosity were not problems. Radiographs of the welds showed no evidence of these defects.

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[15]C. E. Witherell, "Welding of Nickel-Chromium-Iron Alloy for Nuclear-Power Stations," Welding J. **39**, 473s–78s (Nov., 1960).

Table 1. Chemical Analyses of Base Metals and Welding Electrodes

Material	Element (wt %)										
	C	Mn	Si	P	S	Cr	Mo	Ni	Ti	Fe	Cb
ASTM A-212, grade B, steel	0.23	0.74	0.20	0.015	0.026					bal	
ASTM A-387, grade D, low alloy steel	0.12	0.55	0.25	0.015	0.035	2.20	0.99			bal	
ASTM A-387, grade C, low alloy steel	0.11	0.57	0.78	0.011	0.020	1.33	0.50			bal	
ASTM A-167, grade 3, stainless steel	0.07	0.169	0.63	0.023	0.011	18.2		9.6		bal	
Inconel-182 electrode	0.10 max	7.5	1.00 max		0.015 max	15		bal	1.0 max	8	2

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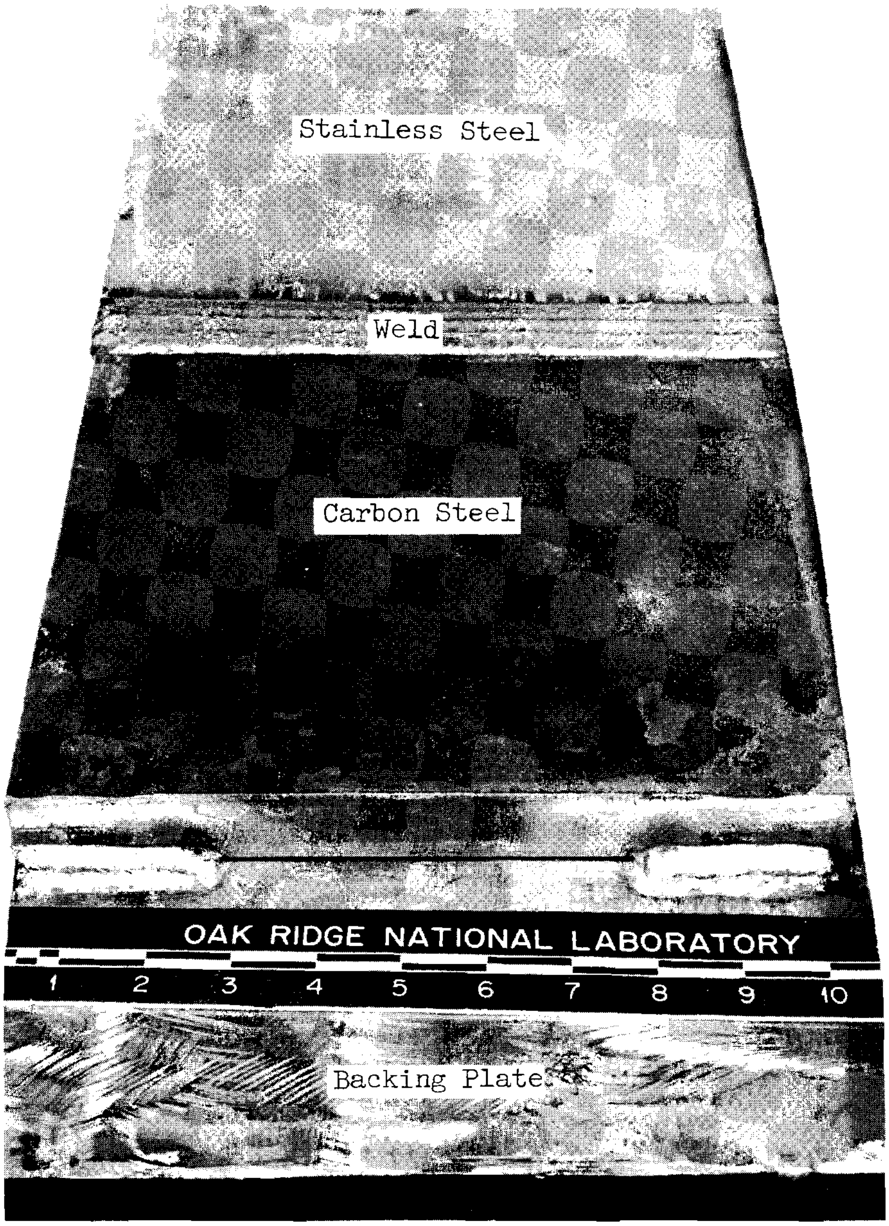

Fig. 3. Completed Test Plate Welded to a Thick Backing Plate.

In view of the excellent behavior of the electrode in these initial studies, further weld-test plates were made in all positions in order to qualify welding procedures in accordance with the ASME Boiler and Pressure Vessel Code, Section IX. Visual, radiographic, dye-penetrant, and metallographic inspection of all welds was conducted and conventional bend and tensile tests were performed. No difficulties were encountered, and the welding procedures were considered to be satisfactory.

Typical side-bend test specimens taken from the carbon steel-to-stainless steel welds are shown in Fig. 4a, while similar specimens taken from the low alloy steel-to-stainless steel welds are shown in Fig. 4b. No evidence of cracking can be seen. Inspection reports for these two dissimilar-metal combinations made in the 4-G (overhead) position are shown in Fig. 5a and Fig. 5b, respectively. Metallographic inspection reports for the two material combinations welded in the 1-G (downhand) and 4-G (overhead) positions are shown in Fig. 6a and Fig. 6b, respectively.

Welding procedures were prepared and are attached to this report as Appendices I, II, and III. Appendix I contains <u>ORNL Procedure Specification P.S.-32 for Metal Arc Welding of Carbon Steel Plate ASME P-Number-1 to Type 304, 308, 316, and 347 Stainless Steel Plate</u> and the corresponding <u>ORNL Operator's Qualification Test Specification QTS-32 for Metal Arc Welding of Carbon Steel Plate P-Number-1 to Type 304, 316, and 347 Stainless Steel Plate</u>. Appendix II contains <u>ORNL Procedure Specification P.S.-31 for Metal Arc Welding of ASTM-A-387 Chromium-Molybdenum Grade-D Steel Plate to Type 304, 304L, 308, 316, 316L, and 347 Stainless Steel Plate</u> and the corresponding <u>ORNL Operator's Qualification Test QTS-31 for Metal Arc Welding of ASTM A-387 Chromium-Molybdenum Grade-D Steel Plate to Type 304, 304L, 308, 316, 316L, and 347 Stainless Steel Plate</u>. Appendix III contains <u>ORNL Procedure Specification P.S.-38 for Metal Arc Welding of ASTM-A-387 Chromium-Molybdenum Grade-C Steel Plate, Pipe and Fittings to Type 304, 304L, 308, 316, 316L, and 347 Stainless Steel Plate, Pipe and Fittings</u> and the corresponding <u>ORNL Operator's Qualification Test Specification QTS-38 for Metal Arc Welding of ASTM A-387 Chromium-Molybdenum Steel Grade-C Plate, Pipe and Fittings to Types 304, 304L, 308, 316, 316L, and 347 Stainless Steel Plate, Pipe and Fittings</u>.

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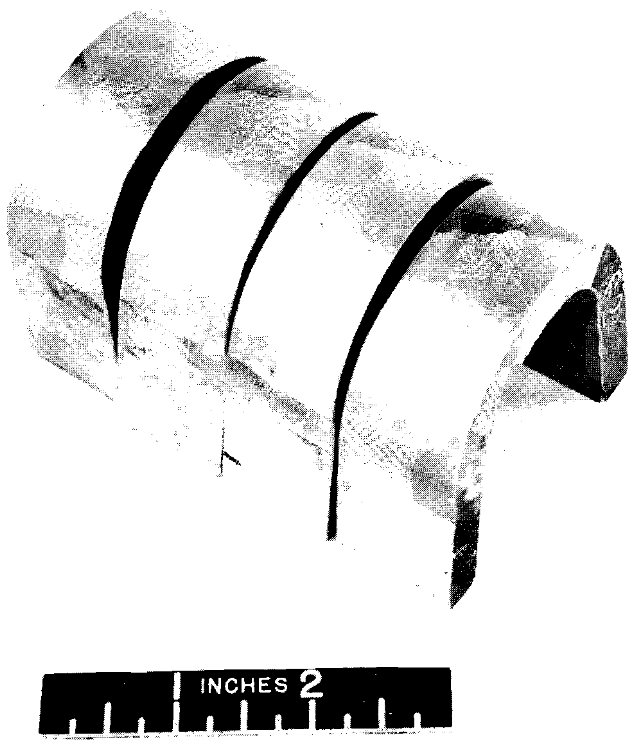

Fig. 4a. Side Bend Test Specimens from Carbon Steel-to-Stainless Steel Weld.

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Fig. 4b. Side Bend Test Specimens from 2-1/4 Cr–1 Mo Steel-to-Stainless Steel Weld.

X-548 (3-53)

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RECORD OF QUALIFICATION TEST OF WELDING OPERATORS

RECORD OF P.S.-32

~~XXXXXXXXXXX~~

EMPLOYER UCNC   DATE TEST STARTED 5-11-60

WELDING OPERATOR D. R. Frizzell   DESIGNATING NO. ____ BADGE NO. 5295

MATERIAL: Kind A-212, grade B-to-304 SS (Plate or Pipe)   SPECIFICATION A-212 A-167   T. S. ____

THICKNESS 1 in. inches   WELDING POSITION 4-G

METHOD OF WELDING Metal arc   ROD, ELECTRODE 1/8-in. EP-85 (Ht. No. 36)

~~FACE BEND TEST~~

SPECIMEN NO.	NATURE, SIZE, AND LOCATION OF DEFECTS
	Visual, x-ray, and dye penetrant O K

~~ROOT BEND TEST~~

SIDE BEND TEST

1	No defects
2	No defects
3	No defects
4	No defects

RESULTS: Satisfactory

The undersigned certifies that the statements made in this report are correct and that the test welds were prepared, welded, and tested in accordance with requirements of Union Carbide Nuclear Company Engineering Standard Specification

INSPECTOR H. T. Hovchin   DATE 5-16-60

APPROVED T. R. Housley   DATE 5-16-60

OAK RIDGE NATIONAL LABORATORY
UNION CARBIDE NUCLEAR COMPANY
A Division of Union Carbide and Carbon Corporation
Oak Ridge, Tennessee

SIGNED: ____

Fig. 5a. Inspection Report of Carbon Steel Weld Made in Overhead Position.

X-548 (3-53)

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RECORD OF QUALIFICATION TEST OF WELDING OPERATORS

RECORD OF P.S.-31

~~XXXXXXXXXXX~~

EMPLOYER UCNC   DATE TEST STARTED 5-15-60

WELDING OPERATOR D. R. Frizzell   DESIGNATING NO. ____ BADGE NO. 5295

MATERIAL: Kind A-387, grade D-to-304 SS (Plate or Pipe)   SPECIFICATION A-387 A-167   T. S. ____

THICKNESS 1 in. inches   WELDING POSITION 4-G

METHOD OF WELDING Metal arc   ROD, ELECTRODE 1/8-in. EP-85 (Ht. No. 36)

~~FACE BEND TEST~~

SPECIMEN NO.	NATURE, SIZE, AND LOCATION OF DEFECTS
	Visual, x-ray, and dye penetrant O K

~~ROOT BEND TEST~~

SIDE BEND TEST

1	No defects
2	No defects
3	No defects
4	No defects

RESULTS: Satisfactory

The undersigned certifies that the statements made in this report are correct and that the test welds were prepared, welded, and tested in accordance with requirements of Union Carbide Nuclear Company Engineering Standard Specification

INSPECTOR H. T. Hovchin   DATE 5-24-60

APPROVED T. R. Housley   DATE 5-2-60

OAK RIDGE NATIONAL LABORATORY
UNION CARBIDE NUCLEAR COMPANY
A Division of Union Carbide and Carbon Corporation
Oak Ridge, Tennessee

SIGNED: ____

Fig. 5b. Inspection Report of 2-1/4 Cr–1 Mo Steel-to-Stainless Steel Weld Made in Overhead Position.

Y-36846

RECORD OF QUALIFICATION TEST OF WELDING OPERATORS METALLOGRAPHIC EXAMINATION

SPECIFICATION NO. P.S.-32 OPERATORS STENCIL

Welding Operator Frizzell Employer

Position	Type Metal	Met. Specimen Number	Wall Thickness	Project Number	Nature, Size, Location of Defects
1-G	A212-to-304 SS	A-5153	1 in.	A70194-11	1 Void - 0.002 in.
1-G	A212-to-304 SS	A5154	1 in.	A70194-11	O.K.
4-G	A212-to-304 SS	A-5170	1 in.	A70194-11	Oxide inclusion 0.030 in.
4-G	A212-to-304 SS	A-5171	1 in.	A70194-11	1 Void - 0.002 in; 1 void - 0.003 in.

Remarks

Inspected by Billy J. Reese Date June 15, 1960

Approved by C. R. Housley Date 6-16-60

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Fig. 6a. Metallographic Inspection Report of Carbon Steel-to-Stainless Steel Welds Made in Downhand and Overhead Positions.

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RECORD OF QUALIFICATION TEST OF WELDING OPERATORS METALLOGRAPHIC EXAMINATION

SPECIFICATION NO. P.S.-31 OPERATORS STENCIL

Welding Operator Frizzell Employer

Position	Type Metal	Met. Specimen Number	Wall Thickness	Project Number	Nature, Size, Location of Defects
1-G	Cr-Mo-to-304 SS	A-5151	1 in.	A70194-11	O. K.
1-G	Cr-Mo-to-304 SS	A-5152	1 in.	A70194-11	1 Void - 0.043 in.
4-G	Cr-Mo-to-304 SS	A-5161	1 in.	A70194-11	1 Void - 0.005 in.; 1 void 0.010 in.
4-G	Cr-Mo-to-304 SS	A-5162	1 in.	A70194-11	1 Void - 0.008 in.; 2 voids 0.002 in.

Remarks

Inspected by Billy J. Reese Date June 15, 1960

Approved by C. R. Housley Date 6-16-60

TX-2297

Fig. 6b. Metallographic Inspection Report of 2-1/4 Cr-1 Mo Steel-to-Stainless Steel Welds Made in Downhand and Overhead Positions.

Additional Mechanical Test and Metallographic Studies

In addition to the mechanical properties determinations required by the ASME Code, additional tests were performed to determine the properties at elevated temperatures. Tensile specimens, 0.505 in. in diameter, were machined transverse to the welds in ASTM A-212, grade B, carbon steel-to-type 304 stainless steel welds and from 2-1/4 Cr-1 Mo steel-to-type 304 stainless steel welds. These were tested at room and at elevated temperatures. A temperature of 650°F was used for the samples containing carbon steel since this was the maximum temperature which the reactor vessel would attain. A temperature of 1050°F was used for the samples containing 2-1/4 Cr-1 Mo steel since this is the operating temperature of the steam generators. Tabulations of the as-welded mechanical properties are shown in Tables 2 and 3. Photographs of typical specimens containing both types of dissimilar-metal welds are shown in Fig. 7a and Fig. 7b.

Table 2. Mechanical Properties of ASTM A-212, Grade B, Carbon Steel-to-Type 304 Stainless Steel Welds Made with Inconel-182 Electrode

(Values are average of two tests)
(All welds stress relieved 4 hr at 1150°F)

Temperature of Test (°F)	Tensile Strength (psi)	Yield Strength (psi)	Elongation (% in 2 in.)	Location of Failure
Room	73,600	44,600	21	A-212, grade B, base metal
650	65,700	35,000	19	Type 304 stainless steel base metal

Table 3. Mechanical Properties of ASTM A-387, Grade D, Cr-Mo Steel-to-Type 304 Stainless Steel Welds Made with Inconel-182 Electrode

(Values are average of two tests)
(All welds stress relieved 1 hr at 1350°F)

Temperature of Test (°F)	Tensile Strength (psi)	Yield Strength (psi)	Elongation (% in 2 in.)	Location of Failure
Room	72,900	43,200	21	A-387, grade D, base metal
1050	54,100	30,500	23	A-387, grade D, base metal

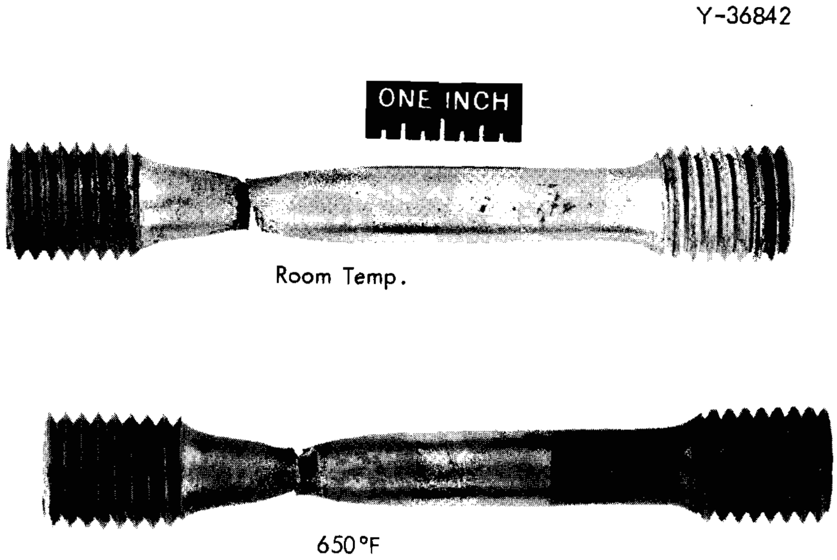

Fig. 7a. ASTM A-212 B-to-Type 304 Stainless Steel Transverse Tensile Specimens Welded with Inconel-182 Electrode.

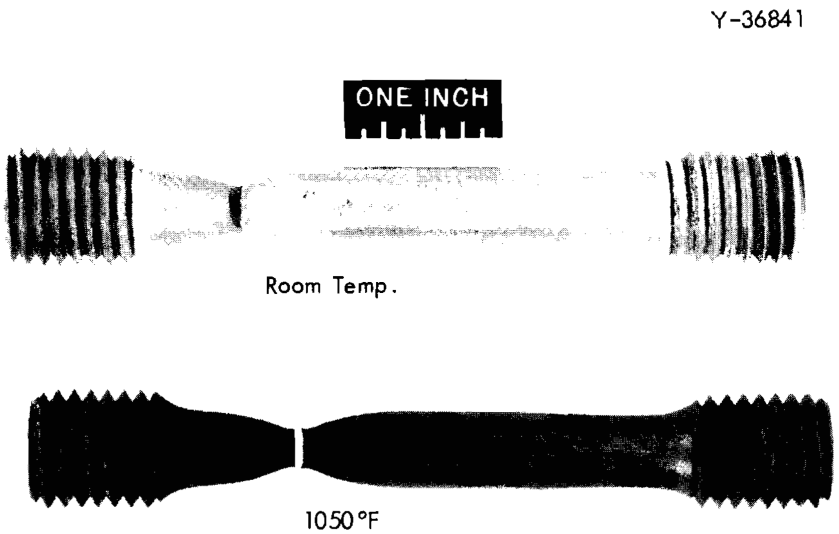

Fig. 7b. ASTM A-387 D-to-Type 304 Stainless Steel Transverse Tensile Specimens Welded with Inconel-182 Electrode.

Additional ASTM A-212, grade B-to-type 304 stainless steel welds were aged at 650°F for 1000 hr and the data are presented in Table 4. It can be

Table 4. Mechanical Properties of ASTM A-212, Grade B-to-Type 304 Stainless Steel Welds Made with Inconel-182 Electrode

(Values are average of two tests)
(Stress relieved 4 hr at 1150°F, aged 1000 hr at 650°F)

Temperature of Test (°F)	Tensile Strength (psi)	Yield Strength (psi)	Elongation (% in 2 in.)	Location of Failure
Room	73,500	43,700	21	A-212 base metal
650	64,300	38,200	19	Type 304 Stainless Steel base metal

seen that the behavior closely approximates that observed in the as-welded condition. Another series of samples is currently being aged for 10,000 hr.

Metallographic sectioning of numerous weld samples of both types of dissimilar-metal welds was made and high-integrity joints were always evident. A composite photograph showing the soundness in the weld metal and at the fusion line in an ASTM A-212, grade B, carbon steel-to-type 304 stainless steel weld is shown in Fig. 8. Figure 9 shows representative microstructures for welds containing ASTM A-387, grade D, steel.

Thermal Cycling of Dissimilar-Metal Welds

Thermal-cycling studies on ASTM A-212, grade B-to-type 304 stainless steel joints and ASTM A-387, grade D-to-type 304 stainless steel joints were also conducted. Two types of specimens were investigated: miniature specimens (1-in. o.d. x 0.040-in. wall and 3-in. o.d. x 1/8-in. wall) and massive specimens (15-in. o.d. x 1-in. wall). Welds in each size specimen were made with type 347 stainless steel electrodes as well as with Inconel-182 electrodes in order to detect any effects resulting from differences in weld-metal properties. The miniature specimens were welded from the outside using a single V-joint design. The greater accessibility available with the 15-in.-o.d. specimens permitted the deposition of a few passes from the inside, although the major portion of the welding was from the outside. Photographs of typical 1- and 15-in.-diam specimens are shown in Fig. 10a and 10b, respectively.

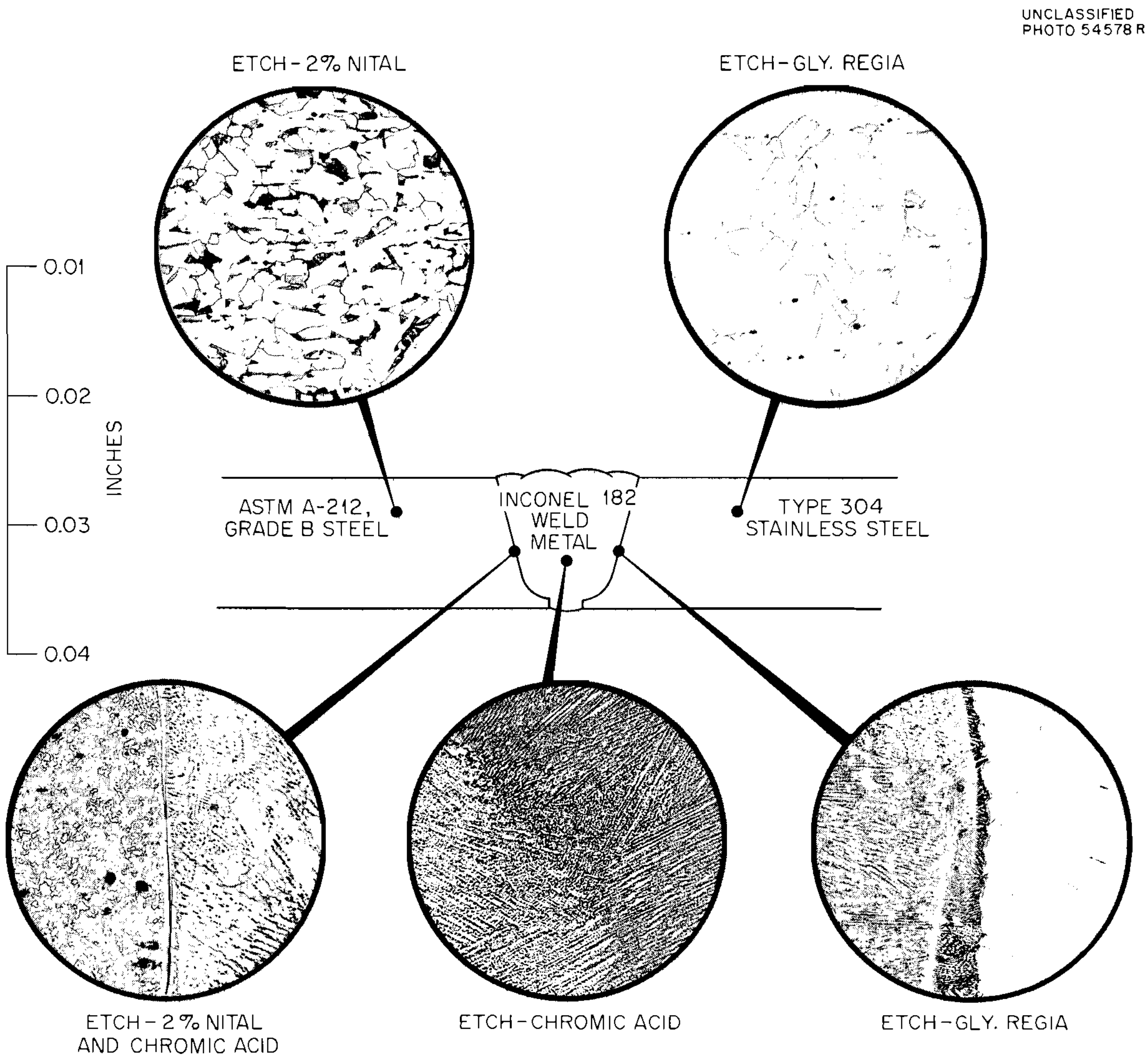

Fig. 8. Microstructures Obtained at Different Points Within an ASTM SA-212, Grade B, Carbon Steel-to-Type 304 Stainless Steel Weld.

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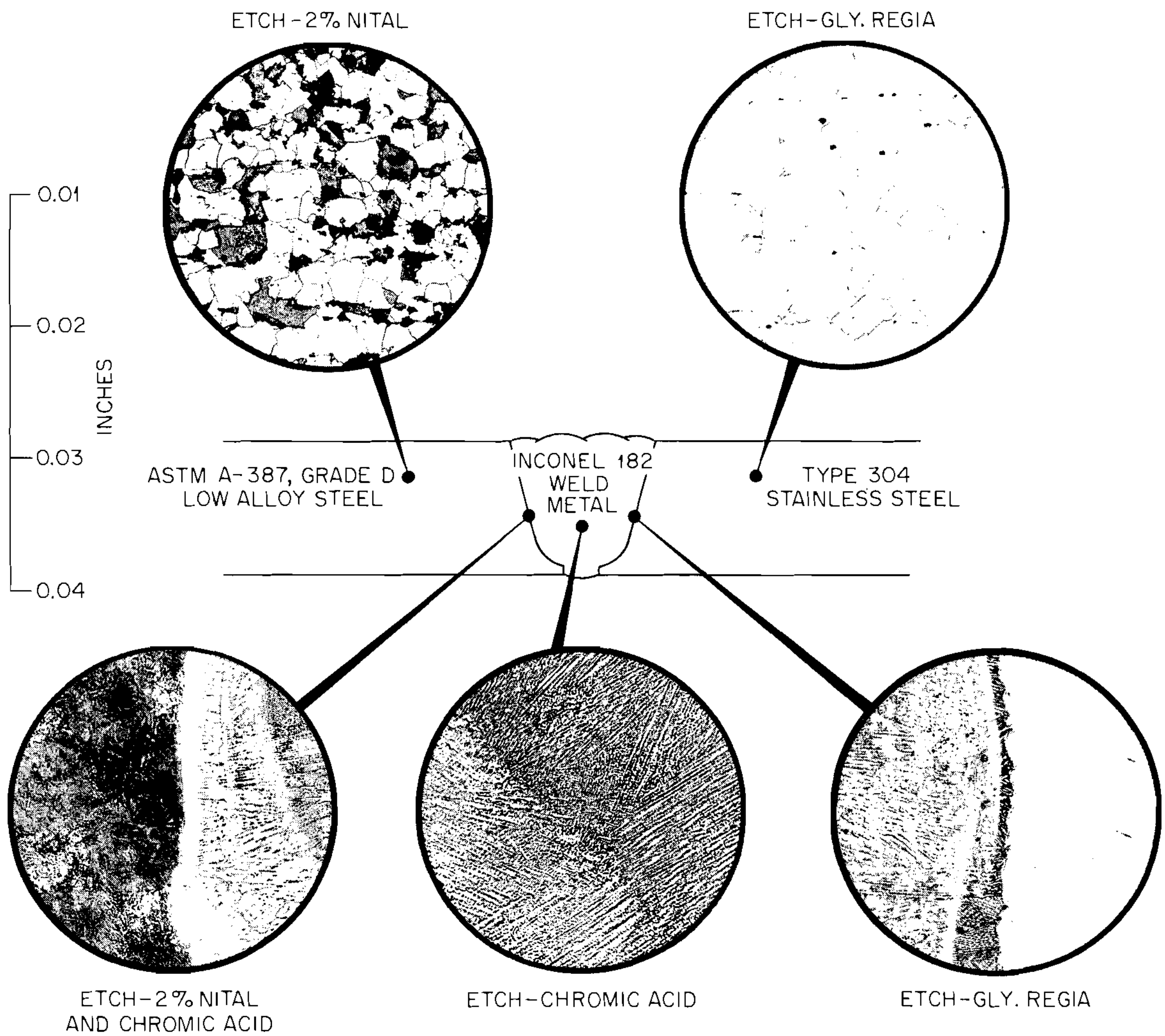

Fig. 9. Representative Microstructures Obtained at Different Points Within an ASTM A-387, Grade D, Steel-to-Type 304 Stainless Steel Weld.

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Fig. 10a. 1 in.-o.d. x 0.040-in.-Wall Test Specimen for Thermal-Cycling Tests.

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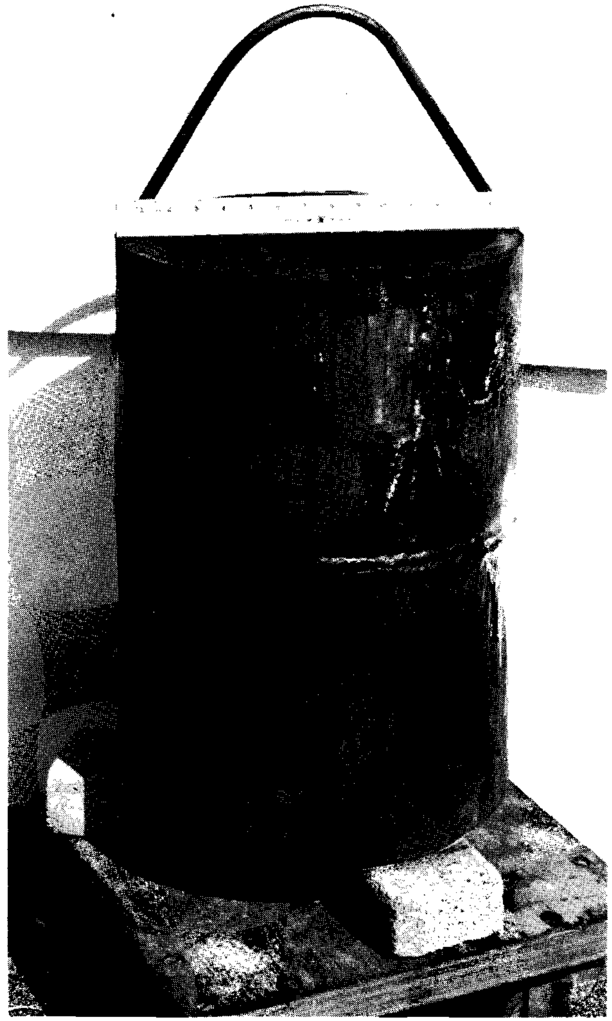

Fig. 10b. 15-in.-o.d. x 1-in.-Wall Test Specimen for Thermal-Cycling Tests.

During thermal cycling, specimens of the two smaller sizes were pressurized with an inert gas to 300 psia, while the 15-in.-o.d. specimens were tested unpressurized. The temperature range through which all specimens were cycled was room temperature to 1050°F. This was selected as the maximum temperature of test, since it corresponds with the operating temperature of the chromium-molybdenum-to-stainless steel welds in the EGCR and since it was probable that it would take a very large number of cycles to obtain cracking of carbon steel-to-stainless steel welds upon cycling from the maximum service temperature of 650°F.

Several 1- and 3-in.-diam specimens made with all of the various base-metal and weld-metal combinations described above were cycled in the range of 1000–8000 total cycles with no indication of damage. However, in the case of the 15-in.-diam specimens, dye-penetrant inspection revealed an incipient crack in the carbon steel heat-affected zone of the ASTM A-212, grade B-to-stainless steel joint welded with type 347 stainless steel after 60 thermal cycles (each cycle consisted of loading the specimen in a hot furnace, holding for 2 hr, and air cooling). The weld was cycled an additional 17 times after which an additional dye-penetrant inspection revealed a definite crack. The 3-1/2-in.-diam plug shown in Fig. 11 was machined from the specimen and metallographically examined. Extensive cracking in the heat-affected zone of the carbon steel was evident and a photomicrograph of the area is shown in Fig. 12. The presence of oxide in the cracks indicates that preferential oxidation at the highly stressed weld interface may also have helped promote premature failure of the joint in the manner suggested by Carpenter.[16] Evidence of carbon migration from the ferritic steel to the weld metal along the weld interface was also observed, and the resultant weakening effect undoubtedly contributed somewhat to failure.

Dye-penetrant inspection also revealed an incipient crack in the 2-1/4 Cr–1 Mo steel-to-stainless steel joint welded with type 347 stainless steel after 60 cycles from 1050°F. A plug was also machined from this sample

[16] O. R. Carpenter, N. C. Jessen, J. L. Oberg, and R. D. Wylie, "Some Considerations in the Joining of Dissimilar Metals for High-Temperature, High-Pressure Service," Am. Soc. Testing Materials, Proc. 50, 809–57 (1950).

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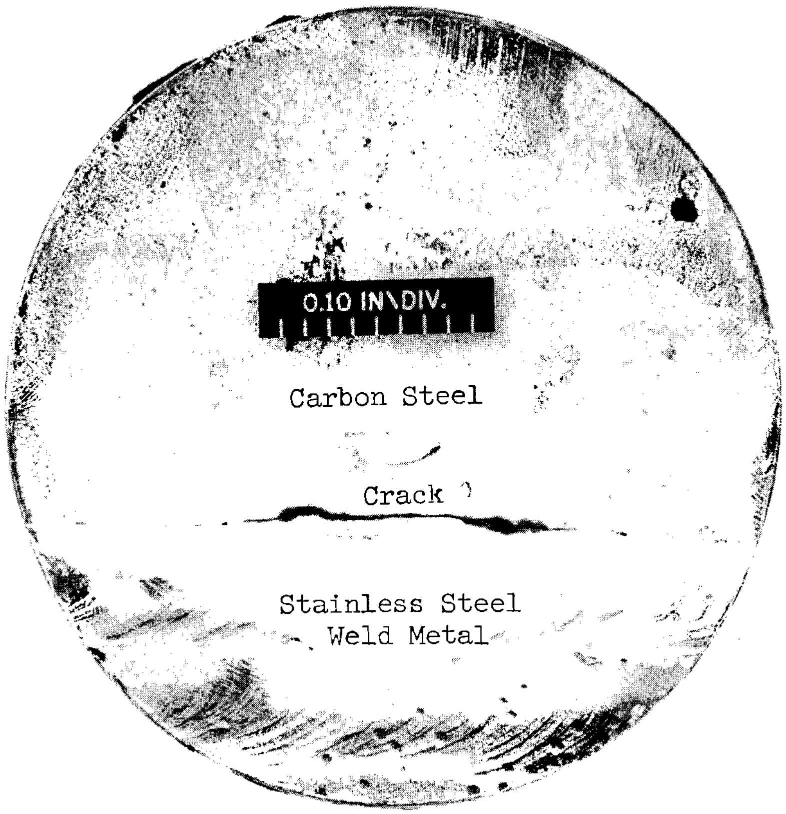


Fig. 11. Plug, Containing a Crack in a Dissimilar-Metal Weld, Which was Machined from a Thermal-Cycling Test Specimen. The dye-penetrant indication on the plug shows the location and length of the crack in the heat-affected zone of the carbon steel.

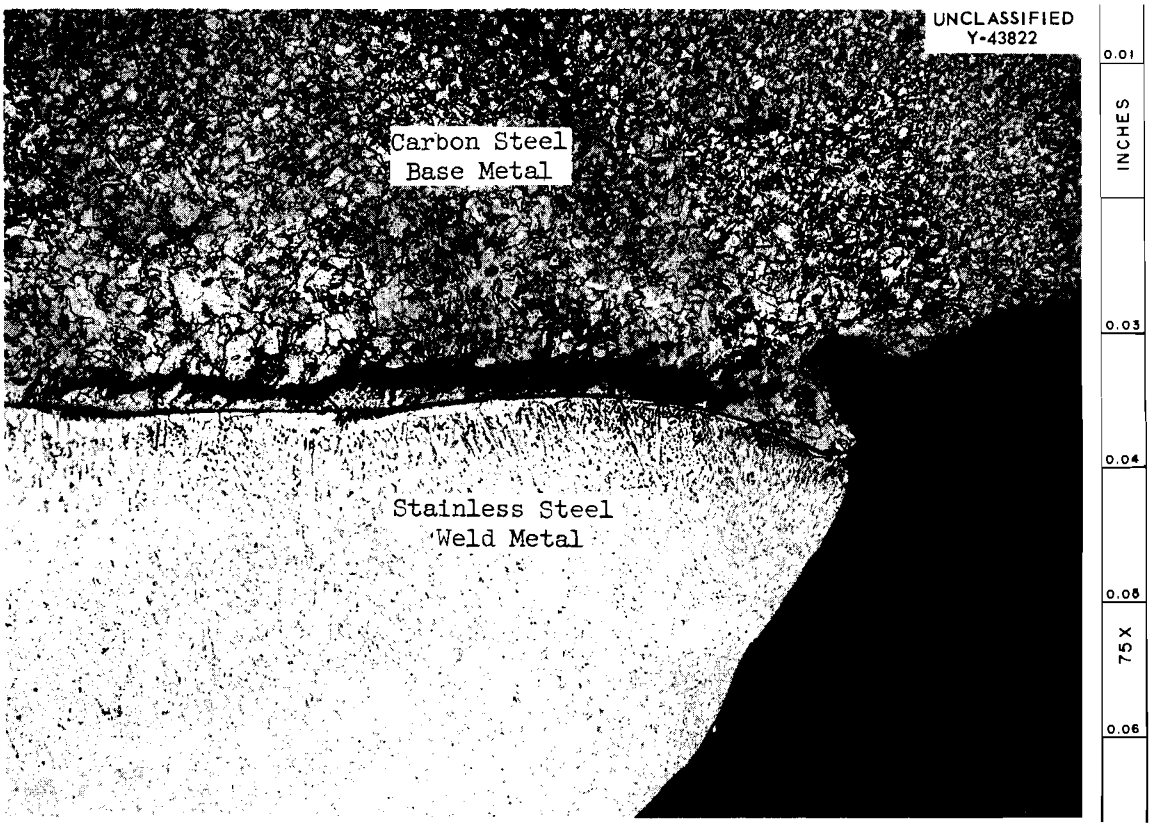


Fig. 12. Crack in Heat-Affected Zone of Carbon Steel after Thermal-Cycling Test.

and the crack at the boundary between the weld metal and ferritic steel is shown in Fig. 13. Extensive oxidation in this crack is also evident, and some decarburization in the ferritic steel heat-affected zone was noted.

Evidence of cracking, as determined by dye-penetrant inspection, has not been observed after 130 cycles in either of the dissimilar-metal specimens welded with Inconel-182 electrode, and cycling is continuing.

RECOMMENDATIONS TO KAISER ENGINEERS PERTAINING TO DISSIMILAR-METAL WELDS IN EGCR

At the request of Kaiser Engineers, recommended procedures for making the dissimilar-metal welds in the EGCR have been considered. These specific recommendations are presented in Appendix IV.

CONCLUSIONS

As a result of this study, the following general conclusions can be drawn.

1. The nickel-base welding electrode, Inconel-182, appears to be very attractive as a filler metal for joining ASTM A-212, grade B, carbon steel to type 304 stainless steel and ASTM A-387, grades C and D, low alloy steels to type 304 stainless steel. The deposition characteristics of this electrode are excellent in all positions and weld-metal cracking and porosity were not encountered.

2. Welding procedures for these various dissimilar-metal combinations were developed and qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX. In addition to meeting conventional bend- and tension-test requirements of the Code, the welds met supplementary visual, dye-penetrant, radiographic, and metallographic requirements.

3. Additional transverse tensile tests on both types of dissimilar-metal welds were made at room and elevated temperatures and all fractures were located in the base material. Aging of similar specimens containing carbon steel-to-stainless steel welds was conducted at 650°F and no influence on the mechanical properties was noted.

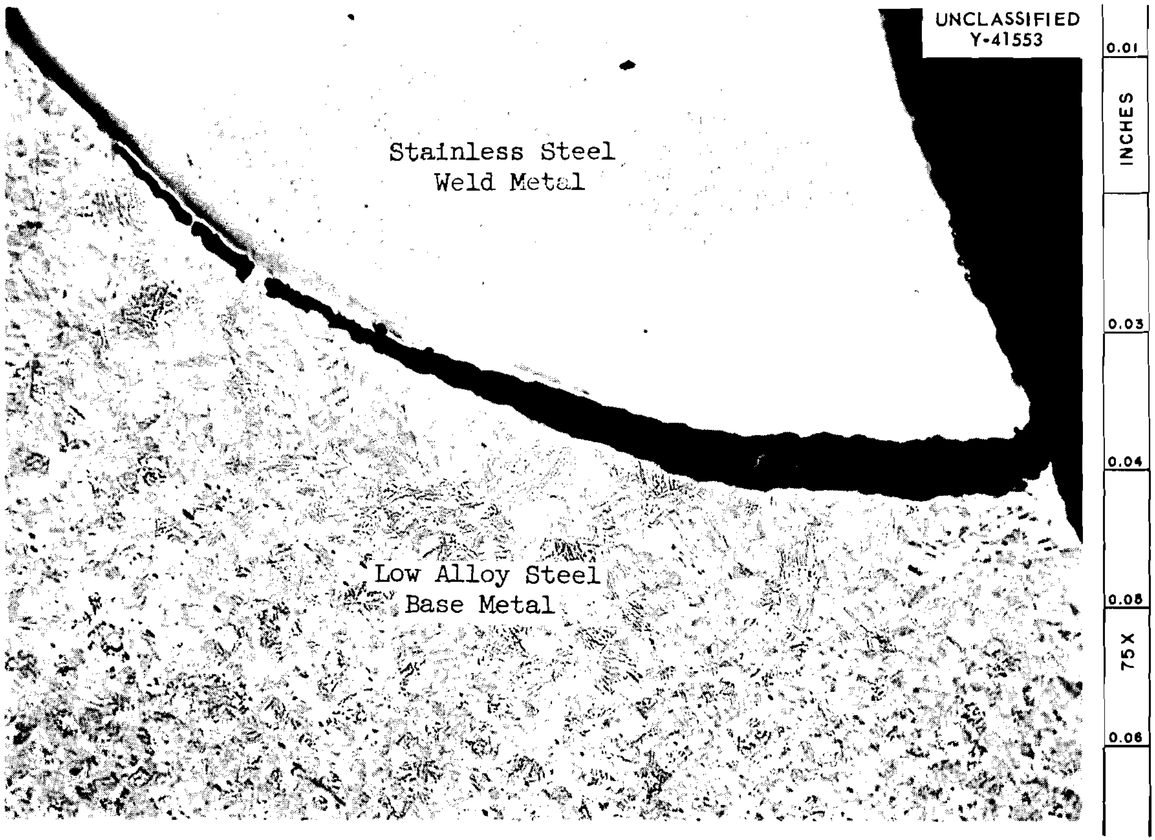


Fig. 13. Crack at Boundary Between Stainless Steel Weld Metal and 2-1/4 Cr—1 Mo Ferritic Steel after Thermal-Cycling Test.

4. Ferritic steel-to-stainless steel joints welded with Inconel-182 electrodes exhibited a markedly better resistance to cracking during thermal cycling than did similar joints welded with type 347 stainless steel electrodes. This appears to be associated with the fact that the differential expansion stresses are located primarily at the stainless steel-base metal—nickel-base weld-metal interface. When stainless steel weld metal is used, these stresses are located primarily at the ferritic steel-weld metal interface. Obviously, other factors, such as the reduction in the amount of carbon migration from the ferritic steel into the weld metal, are also of importance.

5. ORNL Welding Procedure Specifications P.S.-31 and -32, as well as the inspection procedures previously discussed, are recommended for making the various dissimilar-metal welds in the EGCR.

ACKNOWLEDGMENT

The invaluable assistance of R. G. Shooster and L. G. Bryson of the Welding and Brazing Laboratory and D. R. Frizzell and V. T. Houchin of the Fabrication Department in the preparation of weld test plates and test specimens is gratefully acknowledged. The assistance of personnel of the Metallography Group of the Metallurgy Division is also acknowledged, with particular appreciation extended to E. R. Boyd. The assistance of R. V. Tindula and A. G. Lyon of the Welding and Brazing Laboratory and R. W. Swindeman, J. T. Venard, and C. W. Dollins of the Mechanical Properties Group for the testing of weld specimens is also acknowledged.

APPENDIX I

ORNL PROCEDURE SPECIFICATION P.S.-32 FOR METAL ARC WELDING OF CARBON STEEL PLATE ASME P-NUMBER-1 TO TYPE 304, 308, 316 AND 347 STAINLESS STEEL PLATE

ORNL PROCEDURE SPECIFICATION P.S.-32 FOR METAL ARC WELDING OF CARBON STEEL PLATE ASME P-NUMBER-1 TO TYPE 304, 308, 316 and 347 STAINLESS STEEL PLATE

SCOPE:

1. This specification covers the procedure for metal arc welding of carbon steel plate (ASME P-number-1) to type 304, 308, 316, and 347 stainless steel plate in the range of thickness 3/16" through 2".

2. All welding performed by this procedure shall be done by welders qualified in accordance with Operators Qualification Test Specification QTS-32. If the operator has not welded in accordance with this procedure specification during the preceding 90 day period, he shall be required to pass tests in the 2G and 5G positions on plate in thickness similar to that being used in the construction before he will be eligible to perform work in accordance with this procedure.

REFERENCES:

Procedure Specification P.S.-32.
Qualification Test Specification QTS-32.
Qualification Test Specification QTS-11.
Qualification Test Specification QTS-32.
ASME Boiler & Pressure Vessel Code Section IX.

BASE METAL:

The base metal shall conform to the A.S.T.M. Specification A-167 or A-240 (latest revision) for corrosion-resisting chromium nickel steel plate and any one of the A.S.T.M. Specifications for carbon steel plate listed in P-number-1 table Q-11.1, Sec. IX, ASME Boiler and Pressure Vessel Code.

FILLER METAL:

The filler metal shall be BP-85 International Nickel Company developmental alloy.

PROCESS:

The welding shall be done by the (D.C.) metal arc process, (coated electrode).

POSITIONS:

The welding of the plate shall be done in the flat, horizontal, vertical or overhead positions.

PREPARATION OF BASE METAL:

1. The plate to be joined by welding shall be beveled and fitted in accordance with the joint design shown in Figure P.S.-32-A.

2. If machine preparation is impractical, grinding, filing or other means may be employed to obtain the same results as machining. Before making the welds, all filings, grease, etc., shall be removed and the plate cleaned.

CLEANING:

Before assembling any joints to be welded, the mating surfaces and adjacent areas shall be thoroughly cleaned by wiping with clean cloths saturated with trichloroethylene or other approved solvents.

Caution:

After cleaning with trichloroethylene, allow time for fluid to evaporate before welding is started.

NATURE OF WELDING CURRENT:

The welding current shall be direct current (D.C.). The base metal shall be on the negative side and the electrode on the positive side of the line (reverse polarity).

WELDING TECHNIQUE:

1. The electrode size, number of passes, pass sequence, and the mean amperage and voltage shall be substantially as shown in Fig. P.S.-32-A.

2. All welding electrodes shall be kept in the manufacturer's sealed containers until time to be used by the welder. All electrodes remaining in an opened container and not in immediate use shall be kept in a dry place and at a temperature of approximately 125°F. Where there is a question of the electrode coating having absorbed moisture, the electrodes shall be heated to 500°F in an oven and held at that temperature for two hours before using.

3. When breaking the arc it should be shortened and the rate of travel increased. The restrike shall be ahead of the previously deposited metal and then moved back to fill the crater.

4. It is mandatory that all flux or slag be removed before laying down each succeeding bead. This can be accomplished by chipping and brushing with a stainless steel wire brush.

5. All defects such as cracks, blowholes, crater cracks, cold laps etc. shall be removed by grinding, filing or chipping followed by brushing with a stainless steel wire brush before laying down each succeeding bead.

PREHEAT AND POSTHEAT:

The preheat and postheat requirements shall be in accordance with the recommendations presented in the Welding Research Council book "Weldability of Steels" by R. D. Stout and W. D. Doty, 1953 edition, pp. 318 - 361.

IDENTIFICATION OF WELDS:

Identification of each weld shall be maintained on the inspection report and on the record copies of the shop drawings. Permanent marking of the material with stencils or like methods shall not be used as a means of identification.

GENERAL:

1. At all times during welding of joints in accordance with this specification the authorized inspector shall evaluate the weld quality in terms of the soundness requirements of Qualification Test Specification QTS-32. This shall include the right to remove and test questionable welds. If the joint is substandard to the soundness requirements of QTS-32 the operator shall be disqualified until a satisfactory re-test is made.

2. It shall be the duty of the welding operator using this procedure to report to his foreman any irregularities which might impair the quality of workmanship desired by this procedure.

T. R. Housley

T. R. Housley, Chief Welding Inspector
Engineering & Mechanical Division

G. M. Slaughter

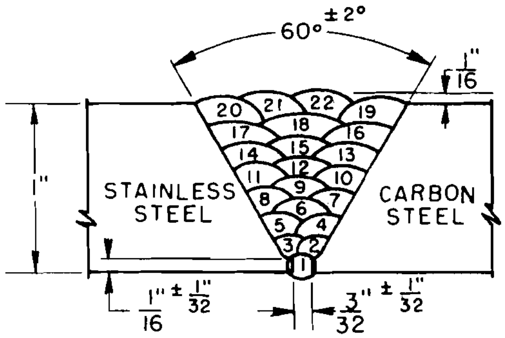
G. M. Slaughter, Metallurgist
Metallurgy Division

Date: 7-20-60

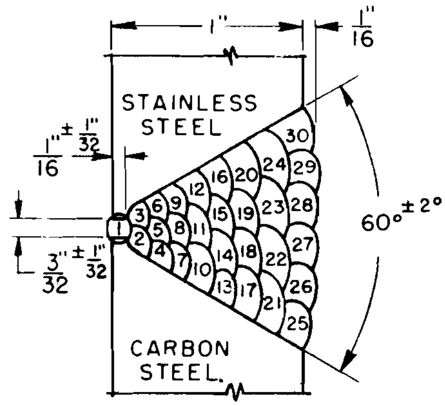
FIG. P.S. 32-A
JOINT DESIGN FOR GROOVE WELDS IN PLATE

JOINT DETAILS

POSITION 1G



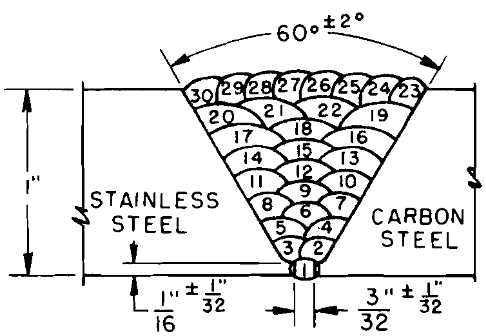
POSITION 2G



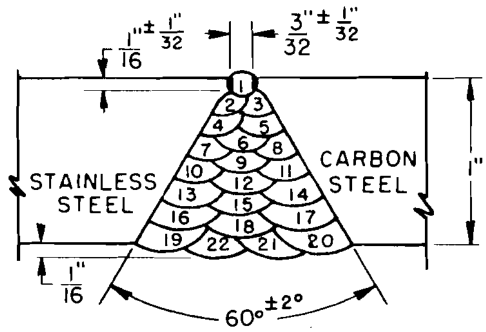
JOINT THICKNESS	POSITION 1G NO. OF PASSES	ROD SIZE	PASS NUMBER AND TYPE	AMPS	VOLTS	POSITION 2G NO. OF PASSES	ROD SIZE	PASS NUMBER AND TYPE	AMPS	VOLTS
3/8"	4	1/8	# 1 STRING	60	21	6	1/8"	# 1 STRING	60	21
		1/8"	# 2-4 "	90	23		1/8"	# 2-6 "	90	23
5/8"	12	1/8"	# 1 "	60	21	16	1/8"	# 1 "	60	21
		1/8"	# 2-3 "	90	23		1/8"	# 2-3 "	90	23
		5/32"	# 4-12 "	120	24		5/32"	# 4-16 "	115	24
1"	22	1/8"	# 1 "	60	21	30	1/8"	# 1 "	60	21
		1/8"	# 2-3 "	90	23		1/8"	# 2-3 "	90	23
		5/32"	# 4-22 "	120	24		5/32"	# 4-30 "	115	24

JOINT DETAILS

POSITION 3G



POSITION 4G



JOINT THICKNESS	POSITION 3G NO. OF PASSES	ROD SIZE	PASS NUMBER AND TYPE	AMPS	VOLTS	POSITION 4G NO. OF PASSES	ROD SIZE	PASS NUMBER AND TYPE	AMPS	VOLTS
3/8"	6	1/8"	# 1 STRING	60	21	4	1/8"	# 1 STRING	65	21
		1/8"	# 2-6 "	80	22		1/8"	# 2-4 "	80	22
5/8"	15	1/8	# 1 "	60	21	15	1/8"	# 1 "	65	21
		1/8"	# 2-30 "	80	22		1/8"	# 2-22 "	80	22
1"	30	1/8"	# 1 "	60	21	22	1/8"	# 1 "	65	21
		1/8"	# 2-30 "	80	22		1/8"	# 2-18 "	80	22
							1/8"	# 19-22 "	75	22

ORNL OPERATOR'S QUALIFICATION TEST SPECIFICATION QTS-32 FOR METAL ARC WELDING OF CARBON STEEL PLATE P-NUMBER-1 TO TYPE 304, 316, and 347 STAINLESS STEEL PLATE

SCOPE:

This specification covers the qualification of operators for approval to metal arc weld carbon steel plate listed under P-number-1, Table Q-11.1, Sec. IX, ASME Boiler and Pressure Vessel Code to type 304, 308, 316, and 347 stainless steel in accordance with ORNL Procedure Specification P.S.-32.

REFERENCES:

Procedure Specification P.S.-32.
Procedure Specification Figure P.S.-32-A.
Qualification Test Specification Figure QTS-32-A.
ASTM A-212 (latest revision)
ASTM A-167 (latest revision)
Operators Qualification Test Specification QTS-11.
ASME Boiler & Pressure Vessel Code Section IX.

PRIOR QUALIFICATION OF WELDER:

The operator shall meet the requirements of Operators Qualification Test Specification QTS-11 before taking the qualification test.

MATERIAL REQUIRED:

Test weldments shall be made using ASTM A-212 grade B plate and ASTM A-167 plate as noted below:

For groove weld tests.

5 pieces of ASTM A-212 grade B plate 1" X 4" X 6" and 5 pieces of ASTM A-167 type 304 stainless steel plate 1" X 4" X 6" are required, each piece shall be beveled as shown in Figure QTS-32-A.

FILLER METAL:

The filler metal shall be BP-85 International Nickel Co. developmental alloy.

TEST POSITIONS:

1. Test # 1 - Position 2G - A groove weld shall be made between one piece of ASTM A-212 grade B carbon steel plate and one piece of ASTM A-167 type 304 stainless steel plate placed with the axis in the vertical position and the welding groove in a horizontal plane as shown on Figure QTS-32-A. After welding the plate shall be stamped with the proper identification number of the operator and position.

2. Test # 2 - Position 3G - A groove weld shall be made between one piece of ASTM A-212 grade B plate and one piece of ASTM A-167 type 304 stainless steel plate placed with the axis in the vertical position and the welding groove in the vertical plane as shown on QTS-32-A. After welding the plate shall be stamped with the proper identification number of the operator and position.

3. Test # 3 - Position 4G - A groove weld shall be made between one piece of ASTM A-212 grade B plate and one piece of ASTM A-167 type 304 stainless steel plate placed with the axis in the horizontal position and the welding groove horizontal (overhead) as shown on QTS-32-A. After welding the plates shall be stamped with the proper identification number of the operator and position.

WELDING REQUIREMENTS:

1. The welding operator shall be requiredto follow procedure specification P.S.-32 in making the test welds and shall not be allowed to rotate or turn the weldment during welding.

2. An inspector shall be present at all times while the qualification test is in progress. The inspector may refuse acceptance of a test weldment if the operator does not comply with the standard procedure in all respects.

NON-DESTRUCTIVE INSPECTION OF WELDMENTS:

Visual Inspection:

The finished weldments shall be inspected for deviation from the procedure specification and for the points listed below:

1. The appearance of the completed welds shall indicate that the welds were made in a workmanlike manner. Undercutting and overlapping shall be kept to a minimum. The reinforcement shall be uniform in width and height and shall not be less than 1/16 or more than 1/8" above the surface of the base metal.

   There shall be complete penetration. Any weldment having weld metal protruding through the root more than 3/32 inch will not be accepted.

Radiographic Inspection:

The completed weldment shall be radiographed and meet the requirements as stated below:

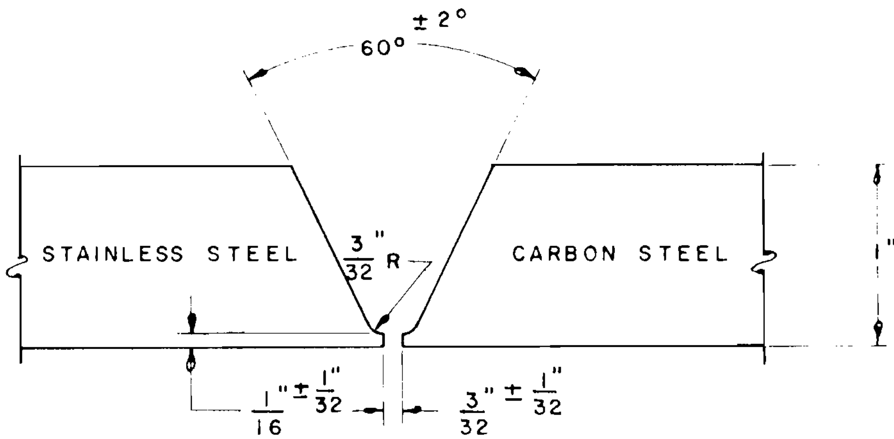
1. Techniques as specified in UW 51 of the 1956 ASME Code for Unfired Pressure Vessels shall be used.

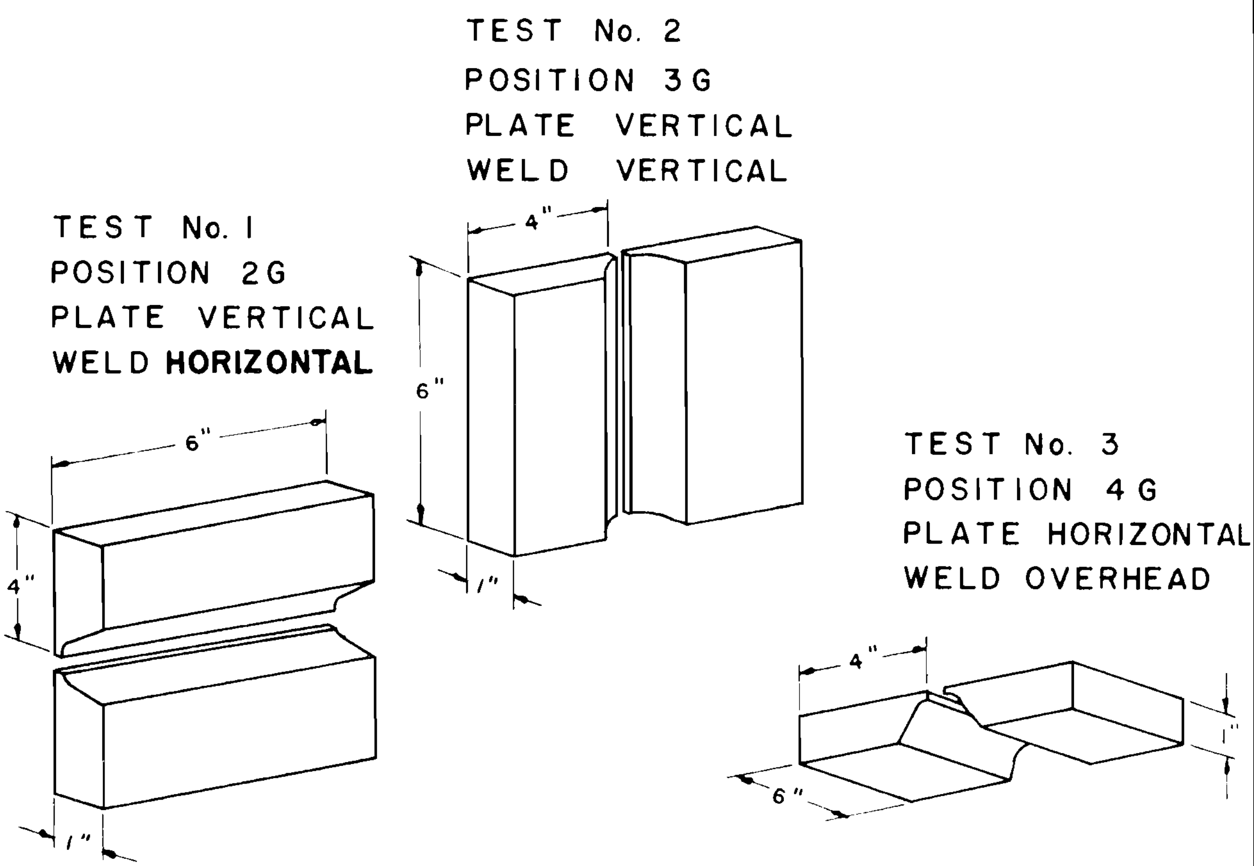
2. The welds shall show no cracks or lack of fusion. Porosity or slag inclusions shall not exceed the limitations as defined in Paragraph UW-51, Sec. VIII, ASME Boiler and Pressure Vessel Code, for plate 1/2" to 1-1/4" in thickness.

FIG. QTS - 32-A

DESIGN FOR GROOVE WELDS IN PLATE

ALL POSITION





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3. Defects found in the first and last one inch of weld shall not be cause for rejection.

DESTRUCTIVE INSPECTION OF WELDMENTS:

Test Specimens:

1. The plates shall be cut and specimens removed in accordance with paragraph Q-24, Fig. Q-13.1 (b), Sec. IX, ASME Boiler and Pressure Vessel Code. The specimens shall be stamped with the proper identification number of the operator, position and specimen number. Additional specimen cutting is required in paragraph three below.

2. Each specimen shall be machined in accordance with Fig. Q-7.1, "Side Bend Specimens for Ferrous Materials", Sec. IX, ASME Boiler and Pressure Vessel Code.

3. A sample piece approximately 1/2 inch wide shall be removed as welded from each of the five plates and these shall be stamped with the proper identification number of the position and operator. The welds shall then be prepared for metallographic evaluation of the transverse section and examined in the as polished and etched condition for evidence of flaws.

4. Weld reinforcement on the specimens shall be removed flush with the surface of the plate by machining, filing or grinding and it will not be permissible to remove undercutting or other defects below the surface of the base metal.

5. Neither will it be permissible to remove any base metal from the under side of the plate in order to conceal any evidence of lack of penetration or fusion at the root of the weld. The edges of all groove weld specimens shall be rounded by removal of the burr with a file.

6. A guided bend jig proportioned for 3/8" material shall be used to conduct bend test as follows. Each specimen shall be given a guided side bend test in accordance with paragraph Q-8 (b), Sec, IX, ASME Boiler and Pressure Vessel Code.

RESULTS REQUIRED:

1. The convex surface of the bend specimens shall be free of cracks or other open defects exceeding 3/32" in any direction. The total number of all other cracks or open defects shall not exceed 3 in any one specimen. Cracks occurring at corners of specimens during testing shall not be considered unless it is indicated that the origination was from a welding defect.

2. The metallographic examination shall show no evidence of cracking or incomplete fusion. Gas pockets or inclusions shall not exceed limitations as defined in paragraph UW-51, Sec. VIII, ASME Boiler and Pressure Vessel Code.

RETESTS:

In case a welding operator fails to meet the requirements as stated, a retest may be allowed under the following conditions:

1. An immediate retest may be made which shall consist of two test welds of each type and test position that has been failed, all of which shall meet the requirements specified for such welds, or;

2. A complete retest may be made at the end of a minimum period of one week providing there is evidence that the operator has had further training and/or practice.

ASSIGNMENT OF CODE UPON PASSING QUALIFICATION TEST:

Welding operators passing the above test will be qualified and his operator's card so marked for welding as specified under Procedure Specification P.S.-12.

RECORD OF TEST:

A record shall be kept of all pertinent test data with results thereof for each operator meeting these requirements. This record shall be originated by the inspector.

Tested specimens shall be identified and made available for examination by interested parties until all fabrication requiring the use of this specification has been completed and the system has been accepted.

T. R. Housley
T. R. Housley, Chief Welding Inspector

G. M. Slaughter
G. M. Slaughter, Metallurgist
Metallurgy Division

Page 4
QTS-32

Date: 7-20-60

APPENDIX II

ORNL PROCEDURE SPECIFICATION P.S.-31 FOR METAL ARC WELDING OF ASTM-A-387 CHROMIUM-MOLYBDENUM GRADE-D STEEL PLATE TO TYPE 304, 304-L, 308, 316 316L, and 347 STAINLESS STEEL PLATE

ORNL PROCEDURE SPECIFICATION P.S.-31 FOR METAL ARC WELDING OF ASTM-A-387 CHROMIUM-MOLYBDENUM GRADE-D STEEL PLATE TO TYPE 304, 304-L, 308, 316, 316L, and 347 STAINLESS STEEL PLATE

SCOPE:

1. This specification covers the procedure for metal arc welding of ASTM-387 chromium-molybdenum grade D plate to type 304, 304L, 308, 316, 316L and 347 stainless steel plate in the range of thickness 3/8" through 2", in all positions.

2. All welding performed by this procedure shall be done by welders qualified in accordance with Operators Qualification Test Specification QTS-31. If the operator has not welded in accordance with this procedure specification during the preceding 30 day period, he shall be required to pass tests in the 2G and 5G positions on plate in thickness similar to that being used in the construction before he will be eligible to perform work in accordance with this procedure.

REFERENCES:

Procedure Specification P.S.-31.
Qualification Test Specification QTS-31.
ASTM A-387 (latest revision)
ASTM A-167 (Latest revision)
ASME Boiler & Pressure Vessel Code Section IX.

PROCESS:

The welding shall be done by the (D.C.) metal arc process.

BASE METAL:

The base metal shall conform to the ASTM specifications A-378 (latest revision) for chromium-molybdenum steel plates and A-167 latest revision for chromium-nickel steel plates.

FILLER METAL:

The filler metal shall be BP-85 International Nickel Company developmental alloy.

POSITIONS:

The welding of the plate shall be done in the flat, horizontal, vertical or overhead positions.

PREPARATION OF BASE METAL:

1. The plate to be joined by welding shall be beveled and fitted in accordance with the joint design shown in Figure P.S.-31-A.

2. If machine preparation is impractical, grinding, filing or other means may be employed to obtain the same results as machining. Before making the welds, all filings, grease, etc., shall be removed and the plate cleaned.

CLEANING:

Before assembling any joints to be welded, the mating surfaces and adjacent areas shall be thoroughly cleaned by wiping with clean cloths saturated with trichloroethylene or other approved solvents.

Caution:

After cleaning with trichloroethylene, allow time for fluid to evaporate before welding is started.

NATURE OF WELDING CURRENT:

The welding current shall be direct current (D.C.). The base metal shall be on the negative side and the electrode on the positive side of the line (reverse polarity).

WELDING TECHNIQUE:

1. The electrode size, number of passes, pass sequence, and the mean amperage and voltage shall be substantially as shown in Fig. P.S.-31-A.

2. All welding electrodes should be kept in the manufacturers sealed containers until time to be used by the welder. All electrodes remaining in an open package and not in immediate use shall be kept in a dry place and a temperature of approximately 125°F. Where there is a question of the electrode coating having absorbed moisture, the electrodes shall be heated to 500°F in an oven and held at that temperature for 2 hours before using.

3. When breaking the arc it should be shortened and the rate of travel increased. The restrike shall be ahead of the previously deposited metal and then moved back to fill the crater.

4. It is mandatory that all flux or slag be removed before laying down each succeeding bead. This can be accomplished by chipping and brushing with a stainless steel wire brush.

5. All defects such as cracks, blowholes, crater cracks, cold laps etc. shall be removed by grinding, filing or chipping followed by brushing with a stainless steel wire brush before laying down each succeeding bead.

PREHEAT:

The material to be welded shall be preheated to 500°F and held at that temperature at all times during welding and prior to postheat treatment.

POSTHEAT:

1. Following completion of the weld the weld area shall be heated to 1325°F to 1375°F and held at this temperature for 1 hour per inch of thickness, but not less than 1/2 hour.

2. After postheating the weld area shall be allowed to cool to a minimum of 300°F in still air.

IDENTIFICATION OF WELDS:

Identification of each weld shall be maintained on shop drawings and weld inspection reports. No identification will be permitted on the material.

GENERAL:

1. At all times during welding of joints in accordance with this specification the authorized inspector shall evaluate the weld quality in terms of the soundness requirements of Qualification Test Specification QTS-31. This shall include the right to remove and test questionable welds. If the joint is substandard to the soundness requirements of QTS-31 the operator shall be disqualified until a satisfactory re-test is made.

2. It shall be the duty of the welding operator using this procedure to report to his foreman any irregularities which might impair the quality of workmanship desired by this procedure.

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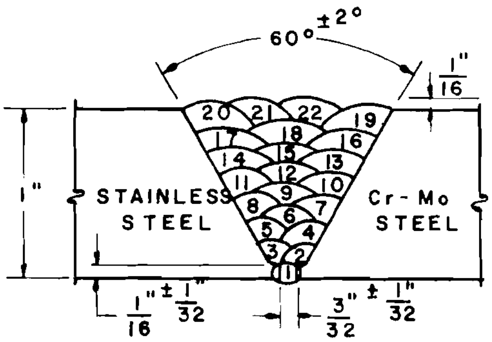
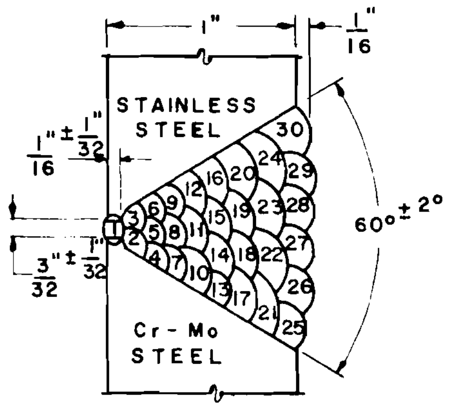
FIG. P.S. 31-A
JOINT DESIGN FOR GROOVE WELDS IN PLATE

JOINT DETAILS

POSITION 1G



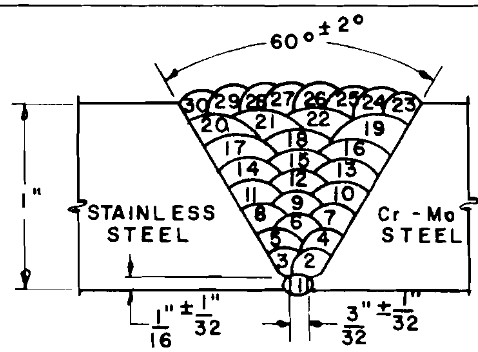
POSITION 2G



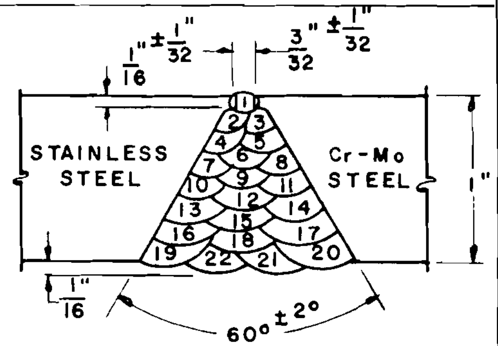
JOINT THICKNESS	1G: NO. OF PASSES	1G: ROD SIZE	1G: PASS NUMBER AND TYPE	1G: AMPS.	1G: VOLTS	2G: NO. OF PASSES	2G: ROD SIZE	2G: PASS NUMBER AND TYPE	2G: AMPS	2G: VOLTS
3/8"	4	1/8"	#1 STRING	60	21	6	1/8"	#1 STRING	60	21
		1/8"	#2-4 "	90	23		1/8"	#2-6 "	90	23
5/8"	12	1/8"	#1 "	60	21	16	1/8"	#1 "	60	21
		1/8"	#2-3 "	90	23		1/8"	#2-3 "	90	23
		5/32"	#4-12 "	120	24		5/32"	#4-16 "	115	24
1"	22	1/8"	#1 "	60	21	30	1/8"	#1 "	60	21
		1/8"	#2-3 "	90	23		1/8"	#2-3 "	90	23
		5/32"	#4-22 "	120	24		5/32"	#4-30 "	115	24

JOINT DETAILS

POSITION 3G



POSITION 4G



JOINT THICKNESS	3G: NO. OF PASSES	3G: ROD SIZE	3G: PASS NUMBER AND TYPE	3G: AMPS	3G: VOLTS	4G: NO. OF PASSES	4G: ROD SIZE	4G: PASS NUMBER AND TYPE	4G: AMPS	4G: VOLTS
3/8"	6	1/8"	#1 STRING	60	21	4	1/8"	#1 STRING	65	21
		1/8"	#2-6 "	80	22		1/8"	#2-4 "	80	22
5/8"	15	1/8"	#1 "	60	21	15	1/8"	#1 "	65	21
		1/8"	#2-30 "	80	22		1/8"	#2-22 "	80	22
1"	30	1/8"	#1 "	60	21	22	1/8"	#1 "	65	21
		1/8"	#2-30 "	80	22		1/8"	#2-18 "	80	22
							1/8"	#19-22 "	75	22

ORNL OPERATOR'S QUALIFICATION TEST SPECIFICATION QTS-31 FOR METAL ARC WELDING OF ASTM A-387 CHROMIUM-MOLYBDENUM STEEL GRADE-D PLATE TO TYPE 304, 304L, 308, 316, 316L and 347 STAINLESS STEEL PLATE

SCOPE:

This specification covers the qualification of operators for approval to metal arc weld ASTM A-387 chromium-molybdenum grade-D plate to type 304, 304L, 308, 316, 316L, and 347 stainless steel plate in accordance with ORNL Procedure Specification P.S.-31.

REFERENCES:

Procedure Specification P.S.-31.
Procedure Specification Figure P.S.-31-A.
Qualification Test Specification Figure QTS-31-A.
ASTM A-387 (latest revision)
ASTM A-167 (latest revision)
Operators Qualification Test Specification QTS-11.
ASME Boiler & Pressure Vessel Code Section IX.

PRIOR QUALIFICATION OF WELDER:

The operator shall meet the requirements of Operators Qualification Test Specification QTS-11 before taking the qualification test.

MATERIAL REQUIRED:

Test weldments shall be made using ASTM A-387 grade-D plate and ASTM A-167 type 304 plate.

For groove welds

5 pieces of plate 1" X 4" X 6" ASTM A-387 chromium-molybdenum grade-D, and 5 pieces of plate 1" X 4" X 6" ASTM-A-167 stainless steel type 304 are required, each piece shall be beveled as shown on Figure QTS-31-A.

FILLER METAL:

The filler metal shall be BP-85 International Nickel Company developmental alloy.

TEST POSITIONS:

Groove welds.

1. Test # 1 - Position 2G - A groove weld shall be made between one piece of chromium-molybdenum grade-D plate and one piece of stainless steel type 304 plate placed with the axis in the vertical position and the welding groove in a horizontal plane as shown on Figure QTS-31-A. After welding the plate shall be stamped with the proper identification number of the operator and position.

2. Test # 2 - Position 3G - A groove weld shall be made between one piece of chromium-molybdenum grade-D and one piece of stainless steel type 304 plate placed with the axis in the vertical position and the welding groove in a vertical plane as shown on Figure QTS-31-A After welding the plate shall be stamped with the proper identification number of the operator and position.

3. Test # 3 - 4G Position - A groove weld shall be made between one piece of chromium-molybdenum grade-D plate and one piece of stainless steel type 304 plate placed with the axis in the horizontal plane and the welding groove horizontal (overhead) as shown on QTS-31-A After welding the plates shall be stamped with the proper identification number of the operator and position.

WELDING REQUIREMENTS:

1. The welding operator shall be required to follow procedure specification P.S.-31 in making the test welds and shall not be allowed to rotate or turn the weldment during welding.

2. An inspector shall be present at all times while the qualification test is in progress. The inspector may refuse acceptance of a test weldment if the operator does not comply with the standard procedure in all respects.

NON-DESTRUCTIVE INSPECTION OF WELDMENTS:

Visual Inspection:

The finished weldments shall be inspected for deviation from the procedure specification and for the points listed below:

1. The appearance of the completed welds shall indicate that the welds were made in a workmanlike manner. Undercutting and overlapping shall be kept to a minimum. The reinforcement shall be uniform in width and height and shall not be less than 1/16" or more than 1/8" above the surface of the base metal.

2. There shall be complete penetration. Any weldment having weld metal protruding through the root more than 3/32" will not be accepted.

Radiographic Inspection:

The completed weldment shall be radiographed and meet the requirements as stated below:

1. Techniques as specified in UW 51 of the 1956 ASME Code for Unfired Pressure Vessels shall be used.

2. The welds shall show no cracks or lack of fusion. Porosity or slag inclusions shall not exceed limitations as defined in paragraph UW-51, Section VIII, ASME Boiler and Pressure Vessel Code, for plate 1/2" to 1-1/4" in thickness.

3. Defects found in the first and last one inch of weld shall not be cause for rejection.

DESTRUCTIVE INSPECTION OF WELDMENTS:

Test Specimens:

1. The plates shall be machine cut and specimens removed in accordance with paragraph QN-24, Fig. QN-13.1(b) Section IX, ASME Boiler and Pressure Vessel Code. The coupons shall be stamped with the proper identification number of the operator, position and specimen. Additional specimen cutting is required in paragraph (3) below.

2. Each specimen shall be machined in accordance with Fig. Q-7.1, Side Bend Specimens for Ferrous Materials Sec. IX ASME Boiler and Pressure Vessel Code.

3. A sample piece approximately 1/2" wide shall be removed as welded from each weldment and these shall be stamped with the proper identification number of the position and operator. The welds shall than be prepared for metallographic evaluation of the transverse section and examined in the as polished and etched condition for evidence of flaws.

4. Weld reinforcement on the specimens shall be removed flush with the surface of the plate by machining, filing or grinding and it will not be permissible to remove undercutting or other defects below the surface of the base metal.

5. Neither will it be permissible to remove any base metal from the under side of the plate in order to conceal any evidence of lack of penetration or fusion at the root of the weld. The edges of all groove weld specimens shall be rounded by removal of the burr with a file.

6. A guided bend jig proportioned for 3/8" material shall be used to conduct bend test as follows. Each specimen shall be given a guided side bend test.

RESULTS REQUIRED:

1. The convex surface of the bend specimens shall be free of cracks or other open defects exceeding 3/32" in any direction. The total number of all other cracks or open defects shall not exceed 3 in any one specimen. Cracks occurring at corners of specimens during testing shall not be considered unless it is indicated that the origination was from a welding defect.

2. The metallographic examination shall show no evidence of cracking or incomplete fusion. Gas pockets or inclusions shall not exceed limitations as defined in paragraph UW-51 Sec. VIII ASME Boiler and Pressure Vessel Code.

RETESTS:

In case a welding operator fails to meet the requirements as stated, a retest may be allowed under the following conditions:

1. An immediate retest may be made which shall consist of two test welds of each type and test position that has been failed, all of which shall meet the requirements specified for such welds, or;

2. A complete retest may be made at the end of a minimum period of one week providing there is evidence that the operator has had further training and/or practice.

ASSIGNMENT OF CODE UPON PASSING QUALIFICATION TEST:

Welding operators passing the above test will be qualified and his operator's card so marked for welding as specified under Procedure Specification P.S.-12.

RECORD OF TEST:

A record shall be kept of all pertinent test data with results thereof for each operator meeting these requirements. This record shall be originated by the inspector.

Tested specimens shall be identified and made available for examination by interested parties until all fabrication requiring the use of this specification has been completed and the system has been accepted.

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Engineering & Mechanical Division

G. M. Slaughter, Metallurgist
Metallurgy Division

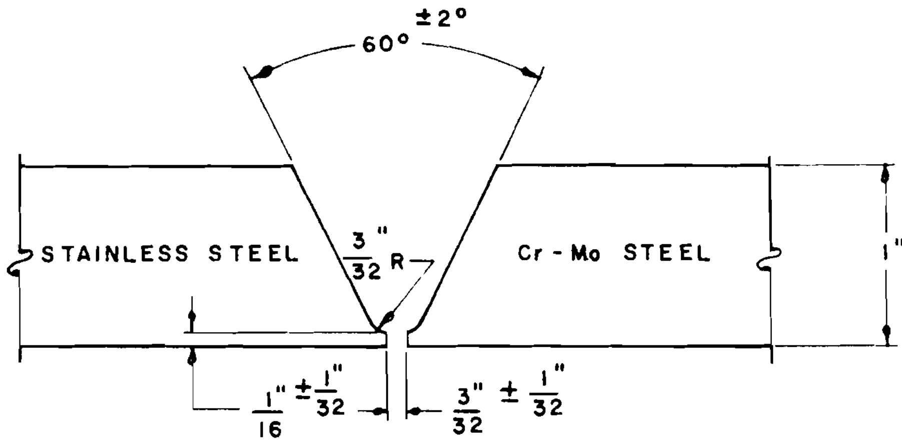
Page 5 QTS-31

Date: 6-16-60

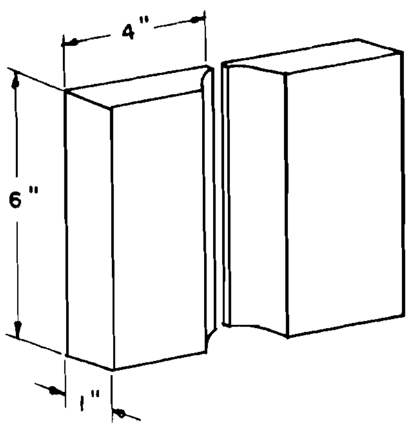
FIG. QTS - 31-A

DESIGN FOR GROOVE WELDS IN PLATE

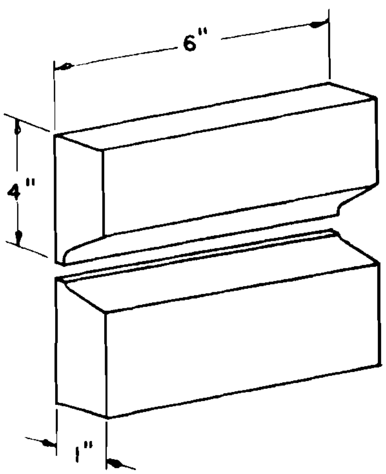
ALL POSITION



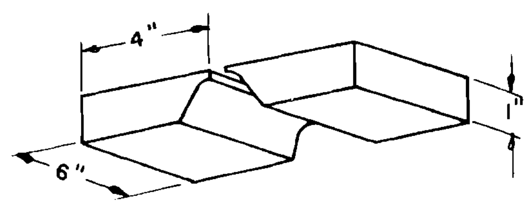
TEST No. 2
POSITION 3G
PLATE VERTICAL
WELD VERTICAL



TEST No. 1
POSITION 2G
PLATE VERTICAL
WELD HORIZONTAL



TEST No. 3
POSITION 4G
PLATE HORIZONTAL
WELD OVERHEAD



DATE: 6-60

ORNL PROCEDURE SPECIFICATION P.S.-31 FOR METAL ARC WELDING OF ASTM-A-387 CHROMIUM-MOLYBDENUM GRADE-D STEEL PLATE TO TYPE 304, 304-L, 308, 316, 316L, and 347 STAINLESS STEEL PLATE

SCOPE:

1. This specification covers the procedure for metal arc welding of ASTM-387 chromium-molybdenum grade D plate to type 304, 304L, 308, 316, 316L and 347 stainless steel plate in the range of thickness 3/8" through 2", in all positions.

2. All welding performed by this procedure shall be done by welders qualified in accordance with Operators Qualification Test Specification QTS-31. If the operator has not welded in accordance with this procedure specification during the preceding 30 day period, he shall be required to pass tests in the 2G and 5G positions on plate in thickness similar to that being used in the construction before he will be eligible to perform work in accordance with this procedure.

REFERENCES:

Procedure Specification P.S.-31.
Qualification Test Specification QTS-31.
ASTM A-387 (latest revision)
ASTM A-167 (Latest revision)
ASME Boiler & Pressure Vessel Code Section IX.

PROCESS:

The welding shall be done by the (D.C.) metal arc process.

BASE METAL:

The base metal shall conform to the ASTM specifications A-378 (latest revision) for chromium-molybdenum steel plates and A-167 latest revision for chromium-nickel steel plates.

FILLER METAL:

The filler metal shall be BP-85 International Nickel Company developmental alloy.

POSITIONS:

The welding of the plate shall be done in the flat, horizontal, vertical or overhead positions.

PREPARATION OF BASE METAL:

1. The plate to be joined by welding shall be beveled and fitted in accordance with the joint design shown in Figure P.S.-31-A.

2. If machine preparation is impractical, grinding, filing or other means may be employed to obtain the same results as machining. Before making the welds, all filings, grease, etc., shall be removed and the plate cleaned.

CLEANING:

Before assembling any joints to be welded, the mating surfaces and adjacent areas shall be thoroughly cleaned by wiping with clean cloths saturated with trichloroethylene or other approved solvents.

Caution:

After cleaning with trichloroethylene, allow time for fluid to evaporate before welding is started.

NATURE OF WELDING CURRENT:

The welding current shall be direct current (D.C.). The base metal shall be on the negative side and the electrode on the positive side of the line (reverse polarity).

WELDING TECHNIQUE:

1. The electrode size, number of passes, pass sequence, and the mean amperage and voltage shall be substantially as shown in Fig. P.S.-31-A.

2. All welding electrodes should be kept in the manufacturers sealed containers until time to be used by the welder. All electrodes remaining in an open package and not in immediate use shall be kept in a dry place and a temperature of approximately 125°F. Where there is a question of the electrode coating having absorbed moisture, the electrodes shall be heated to 500°F in an oven and held at that temperature for 2 hours before using.

3. When breaking the arc it should be shortened and the rate of travel increased. The restrike shall be ahead of the previously deposited metal and then moved back to fill the crater.

4. It is mandatory that all flux or slag be removed before laying down each succeeding bead. This can be accomplished by chipping and brushing with a stainless steel wire brush.

5. All defects such as cracks, blowholes, crater cracks, cold laps etc. shall be removed by grinding, filing or chipping followed by brushing with a stainless steel wire brush before laying down each succeeding bead.

PREHEAT:

The material to be welded shall be preheated to 500°F and held at that temperature at all times during welding and prior to postheat treatment.

POSTHEAT:

1. Following completion of the weld the weld area shall be heated to 1325°F to 1375°F and held at this temperature for 1 hour per inch of thickness, but not less than 1/2 hour.

2. After postheating the weld area shall be allowed to cool to a minimum of 300°F in still air.

IDENTIFICATION OF WELDS:

Identification of each weld shall be maintained on shop drawings and weld inspection reports. No identification will be permitted on the material.

GENERAL:

1. At all times during welding of joints in accordance with this specification the authorized inspector shall evaluate the weld quality in terms of the soundness requirements of Qualification Test Specification QTS-31. This shall include the right to remove and test questionable welds. If the joint is substandard to the soundness requirements of QTS-31 the operator shall be disqualified until a satisfactory re-test is made.

2. It shall be the duty of the welding operator using this procedure to report to his foreman any irregularities which might impair the quality of workmanship desired by this procedure.

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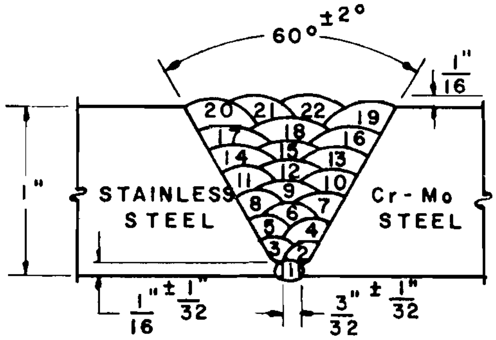
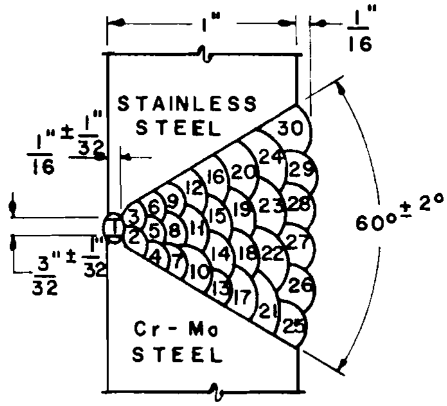
Metallurgy Division

FIG. P.S. 31-A
JOINT DESIGN FOR GROOVE WELDS IN PLATE

POSITION 1G / POSITION 2G

JOINT DETAILS

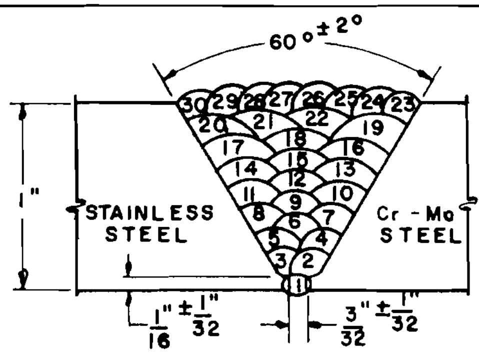


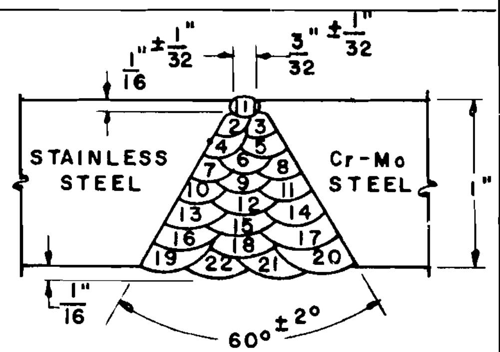


JOINT THICKNESS	1G NO. OF PASSES	1G ROD SIZE	1G PASS NUMBER AND TYPE	1G AMPS.	1G VOLTS	2G NO. OF PASSES	2G ROD SIZE	2G PASS NUMBER AND TYPE	2G AMPS	2G VOLTS
3/8"	4	1/8"	#1 STRING	60	21	6	1/8"	#1 STRING	60	21
		1/8"	#2-4 "	90	23		1/8"	#2-6 "	90	23
5/8"	12	1/8"	#1 "	60	21	16	1/8"	#1 "	60	21
		1/8"	#2-3 "	90	23		1/8"	#2-3 "	90	23
		5/32"	#4-12 "	120	24		5/32"	#4-16 "	115	24
1"	22	1/8"	#1 "	60	21	30	1/8"	#1 "	60	21
		1/8"	#2-3 "	90	23		1/8"	#2-3 "	90	23
		5/32"	#4-22 "	120	24		5/32"	#4-30"	115	24

POSITION 3G / POSITION 4G

JOINT DETAILS





JOINT THICKNESS	3G NO. OF PASSES	3G ROD SIZE	3G PASS NUMBER AND TYPE	3G AMPS	3G VOLTS	4G NO. OF PASSES	4G ROD SIZE	4G PASS NUMBER AND TYPE	4G AMPS	4G VOLTS
3/8"	6	1/8"	#1 STRING	60	21	4	1/8"	#1 STRING	65	21
		1/8"	#2-6 "	80	22		1/8"	#2-4 "	80	22
5/8"	15	1/8"	#1 "	60	21	15	1/8"	#1 "	65	21
		1/8"	#2-30 "	80	22		1/8"	#2-22 "	80	22
1"	30	1/8"	#1 "	60	21	22	1/8"	#1 "	65	21
		1/8"	#2-30 "	80	22		1/8"	#2-18 "	80	22
							1/8"	#19-22 "	75	22

ORNL OPERATOR'S QUALIFICATION TEST SPECIFICATION QTS-31 FOR METAL ARC WELDING OF ASTM A-387 CHROMIUM-MOLYBDENUM STEEL GRADE-D PLATE TO TYPE 304, 304L, 308, 316, 316L and 347 STAINLESS STEEL PLATE

SCOPE:

This specification covers the qualification of operators for approval to metal arc weld ASTM A-387 chromium-molybdenum grade-D plate to type 304, 304L, 308, 316, 316L, and 347 stainless steel plate in accordance with ORNL Procedure Specification P.S.-31.

REFERENCES:

Procedure Specification P.S.-31.
Procedure Specification Figure P.S.-31-A.
Qualification Test Specification Figure QTS-31-A.
ASTM A-387 (latest revision)
ASTM A-167 (latest revision)
Operators Qualification Test Specification QTS-11.
ASME Boiler & Pressure Vessel Code Section IX.

PRIOR QUALIFICATION OF WELDER:

The operator shall meet the requirements of Operators Qualification Test Specification QTS-11 before taking the qualification test.

MATERIAL REQUIRED:

Test weldments shall be made using ASTM A-387 grade-D plate and ASTM A-167 type 304 plate.

For groove welds

5 pieces of plate 1" X 4" X 6" ASTM A-387 chromium-molybdenum grade-D, and 5 pieces of plate 1" X 4" X 6" ASTM-A-167 stainless steel type 304 are required, each piece shall be beveled as shown on Figure QTS-31-A.

FILLER METAL:

The filler metal shall be BP-85 International Nickel Company developmental alloy.

TEST POSITIONS:

Groove welds.

1. Test # 1 - Position 2G - A groove weld shall be made between one piece of chromium-molybdenum grade-D plate and one piece of stainless steel type 304 plate placed with the axis in the vertical position and the welding groove in a horizontal plane as shown on Figure QTS-31-A. After welding the plate shall be stamped with the proper identification number of the operator and position.

2. Test # 2 - Position 3G - A groove weld shall be made between one piece of chromium-molybdenum grade-D and one piece of stainless steel type 304 plate placed with the axis in the vertical position and the welding groove in a vertical plane as shown on Figure QTS-31-A After welding the plate shall be stamped with the proper identification number of the operator and position.

3. Test # 3 - 4G Position - A groove weld shall be made between one piece of chromium-molybdenum grade-D plate and one piece of stainless steel type 304 plate placed with the axis in the horizontal plane and the welding groove horizontal (overhead) as shown on QTS-31-A After welding the plates shall be stamped with the proper identification number of the operator and position.

WELDING REQUIREMENTS:

1. The welding operator shall be required to follow procedure specification P.S.-31 in making the test welds and shall not be allowed to rotate or turn the weldment during welding.

2. An inspector shall be present at all times while the qualification test is in progress. The inspector may refuse acceptance of a test weldment if the operator does not comply with the standard procedure in all respects.

NON-DESTRUCTIVE INSPECTION OF WELDMENTS:

Visual Inspection:

The finished weldments shall be inspected for deviation from the procedure specification and for the points listed below:

1. The appearance of the completed welds shall indicate that the welds were made in a workmanlike manner. Undercutting and overlapping shall be kept to a minimum. The reinforcement shall be uniform in width and height and shall not be less than 1/16" or more than 1/8" above the surface of the base metal.

2. There shall be complete penetration. Any weldment having weld metal protruding through the root more than 3/32" will not be accepted.

Radiographic Inspection:

The completed weldment shall be radiographed and meet the requirements as stated below:

1. Techniques as specified in UW 51 of the 1956 ASME Code for Unfired Pressure Vessels shall be used.

2. The welds shall show no cracks or lack of fusion. Porosity or slag inclusions shall not exceed limitations as defined in paragraph UW-51, Section VIII, ASME Boiler and Pressure Vessel Code, for plate 1/2" to 1-1/4" in thickness.

3. Defects found in the first and last one inch of weld shall not be cause for rejection.

DESTRUCTIVE INSPECTION OF WELDMENTS:

Test Specimens:

1. The plates shall be machine cut and specimens removed in accordance with paragraph QN-24, Fig. QN-13.1(b) Section IX, ASME Boiler and Pressure Vessel Code. The coupons shall be stamped with the proper identification number of the operator, position and specimen. Additional specimen cutting is required in paragraph (3) below.

2. Each specimen shall be machined in accordance with Fig. Q-7.1, Side Bend Specimens for Ferrous Materials Sec. IX ASME Boiler and Pressure Vessel Code.

3. A sample piece approximately 1/2" wide shall be removed as welded from each weldment and these shall be stamped with the proper identification number of the position and operator. The welds shall than be prepared for metallographic evaluation of the transverse section and examined in the as polished and etched condition for evidence of flaws.

4. Weld reinforcement on the specimens shall be removed flush with the surface of the plate by machining, filing or grinding and it will not be permissible to remove undercutting or other defects below the surface of the base metal.

5. Neither will it be permissible to remove any base metal from the under side of the plate in order to conceal any evidence of lack of penetration or fusion at the root of the weld. The edges of all groove weld specimens shall be rounded by removal of the burr with a file.

6. A guided bend jig proportioned for 3/8" material shall be used to conduct bend test as follows. Each specimen shall be given a guided side bend test.

RESULTS REQUIRED:

1. The convex surface of the bend specimens shall be free of cracks or other open defects exceeding 3/32" in any direction. The total number of all other cracks or open defects shall not exceed 3 in any one specimen. Cracks occurring at corners of specimens during testing shall not be considered unless it is indicated that the origination was from a welding defect.

2. The metallographic examination shall show no evidence of cracking or incomplete fusion. Gas pockets or inclusions shall not exceed limitations as defined in paragraph UW-51 Sec. VIII ASME Boiler and Pressure Vessel Code.

RETESTS:

In case a welding operator fails to meet the requirements as stated, a retest may be allowed under the following conditions:

1. An immediate retest may be made which shall consist of two test welds of each type and test position that has been failed, all of which shall meet the requirements specified for such welds, or;

2. A complete retest may be made at the end of a minimum period of one week providing there is evidence that the operator has had further training and/or practice.

ASSIGNMENT OF CODE UPON PASSING QUALIFICATION TEST:

Welding operators passing the above test will be qualified and his operator's card so marked for welding as specified under Procedure Specification P.S.-12.

RECORD OF TEST:

A record shall be kept of all pertinent test data with results thereof for each operator meeting these requirements. This record shall be originated by the inspector.

Tested specimens shall be identified and made available for examination by interested parties until all fabrication requiring the use of this specification has been completed and the system has been accepted.

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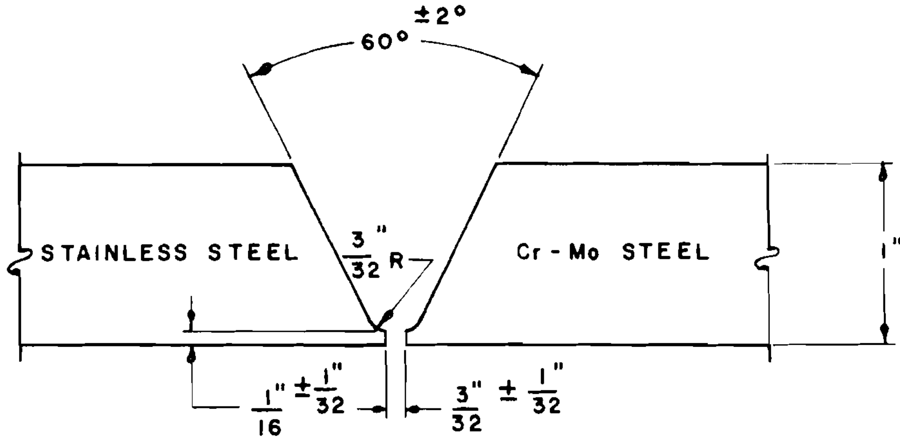
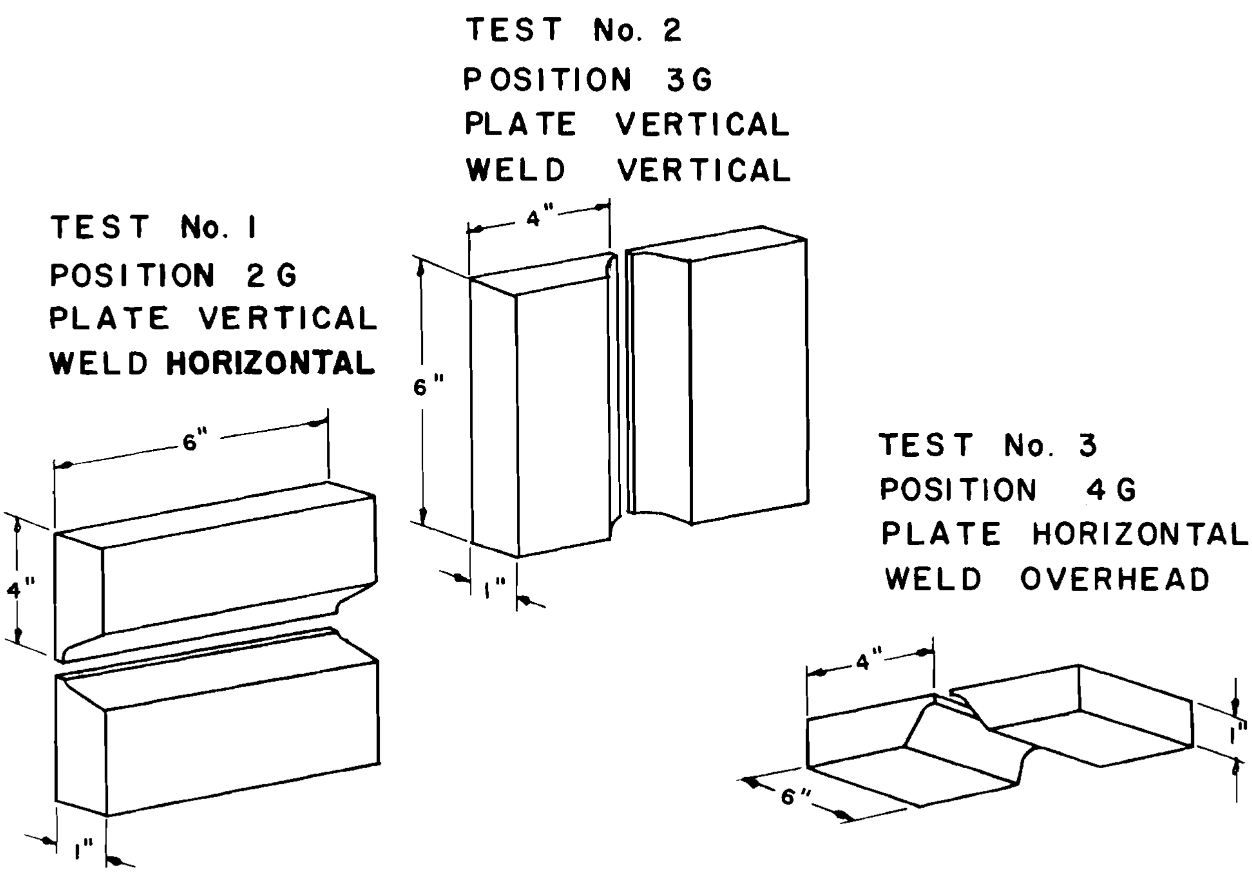
Date: 6-16-60

FIG. QTS - 31-A

DESIGN FOR GROOVE WELDS IN PLATE

ALL POSITION





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APPENDIX III

ORNL PROCEDURE SPECIFICATION P.S.-38 FOR METAL ARC WELDING OF ASTM-A-387 CHROMIUM-MOLYBDENUM GRADE-C STEEL PLATE, PIPE AND FITTINGS TO TYPE 304, 304L, 308, 316, 316L, AND 347 STAINLESS STEEL PLATE, PIPE, AND FITTINGS

ORNL PROCEDURE SPECIFICATION P.S.-38 FOR METAL ARC WELDING OF ASTM-A-387 CHROMIUM-MOLYBDENUM GRADE-C STEEL PLATE, PIPE AND FITTINGS TO TYPE 304, 304L, 308, 316, 316L, AND 347 STAINLESS STEEL PLATE, PIPE, AND FITTINGS

SCOPE:

1. This specification covers the procedure for metal arc welding of ASTM-387 chromium-molybdenum grade-C plate, pipe, and fittings to type 304, 304L, 308, 316, 316L, and 347 stainless steel plate, pipe, and fittings in the range of thickness 3/8" through 2", in all positions.

2. All welding performed by this procedure shall be done by welders qualified in accordance with Operators Qualification Test Specification QTS-38. If the operator has not welded in accordance with this procedure specification during the preceding 90-day period, he shall be required to pass tests in the 2G and 5G positions on plate in thickness similar to that being used in the construction before he will be eligible to perform work in accordance with this procedure.

REFERENCES:

Procedure Specification Figure P.S.-38-A.
Qualification Test Specification QTS-38.
ASTM A-387 (latest revision).
ASTM A-167 (latest revision).
ASME Boiler & Pressure Vessel Code Section IX.
ASTM-A-312 (latest revision)

PROCESS:

The welding shall be done by the (D.C.) metal arc process.

BASE METAL:

The base metal shall conform to the following ASTM specifications: A-387 grade-C for chromium-molybdenum steel plates, A-167 for chromium-nickel steel plates, and A-312 for chromium-nickel steel pipe.

FILLER METAL:

The filler metal shall be Inconel 182-T International Nickel Company alloy.

POSITIONS:

The welding shall be done with the axis of the pipe in the horizontal rolled, horizontal fixed and vertical fixed positions. The welding of the plate shall be done in the flat, horizontal, vertical, or overhead positions.

PREPARATION OF BASE METAL:

1. The pipe or plate to be joined by welding shall be beveled and fitted in accordance with the joint design shown in Figure P.S.-38-A.

2. If machine preparation is impractical, grinding, filing, or other means may be employed to obtain the same results as machining. Before making the welds, all filings, grease, etc., shall be removed and the material cleaned.

CLEANING:

Before assembling any joints to be welded, the mating surfaces and adjacent areas shall be thoroughly cleaned by wiping with clean clothes saturated with acetone, alcohol, or other approved solvents.

Caution:

After cleaning with trichloroethylene, allow time for fluid to evaporate before welding is started.

NATURE OF WELDING CURRENT:

The welding current shall be direct current (D.C.). The base metal shall be on the negative side and the electrode on the positive side of the line (reverse polarity).

WELDING TECHNIQUE:

1. The electrode size, number of passes, pass sequence, and the mean amperage and voltage shall be as shown in Figure P.S.-38-A. A variation of plus or minus 10% is permissible for welding currents listed.

2. All welding electrodes should be kept in the manufacturers sealed containers until time to be used by the welder. All electrodes remaining in an open package and not in immediate use shall be kept in a dry place and a temperature of approximately 125°F. Where there is a question of the electrode coating having absorbed moisture, the electrodes shall be heated to 500°F in an oven and held at that temperature for 2 hours before using.

3. When breaking the arc it should be shortened and the rate of travel increased. The restrike shall be ahead of the previously deposited metal and then moved back to fill the crater.

4. It is mandatory that all flux or slag be removed before laying down each succeeding bead. This can be accomplished by chipping and brushing with a stainless steel wire brush.

5. All defects such as cracks, blowholes, crater cracks, cold laps,etc., shall be removed by grinding, filing, or chipping followed by brushing with a stainless steel wire brush before laying down each succeeding bead.

PREHEAT AND POSTHEAT:

The preheat and postheat requirements shall be in accordance with the recommendations presented in the Welding Research Council book, Weldability of Steels, by R. D. Stout and W. D. Doty, 1953 edition, pp. 318-361.

IDENTIFICATION OF WELDS:

Identification of each weld shall be maintained on the inspection report and on the record copies of the shop drawings. Permanent marking of the material with stencils or like methods shall not be used as a means of identification.

GENERAL:

1. At all times during welding of joints in accordance with this specification the authorized inspector shall evaluate the weld quality in terms of the soundness requirements of Qualification Test Specification QTS-38. This shall include the right to remove and test questionable welds. If the joint is substandard to the soundness requirements of QTS-38 the operator shall be disqualified until a satisfactory re-test is made.

2. It shall be the duty of the welding operator using this procedure to report to his foreman any irregularities which might impair the quality of workmanship desired by this procedure.

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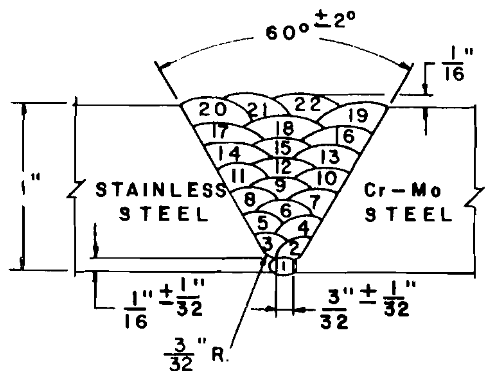
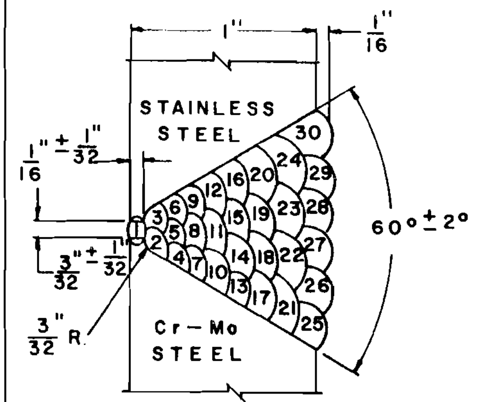
FIG. P.S. 38-A
JOINT DESIGN FOR GROOVE WELDS IN PLATE AND PIPE

POSITION 1G — JOINT DETAILS

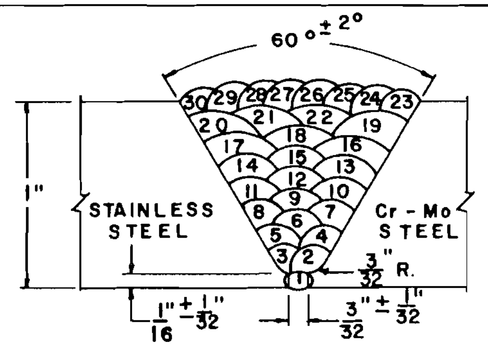


POSITION 2G — JOINT DETAILS

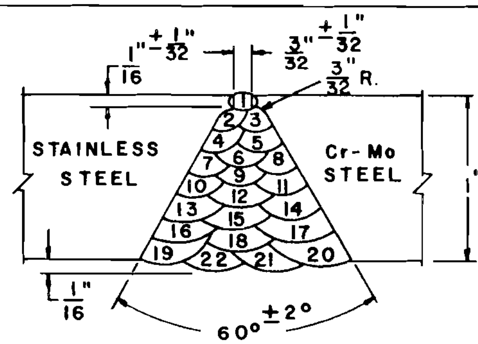


JOINT THICKNESS	POSITION 1G NO. OF PASSES	ROD SIZE	PASS NUMBER AND TYPE	AMPS.	VOLTS	POSITION 2G NO. OF PASSES	ROD SIZE	PASS NUMBER AND TYPE	AMPS	VOLTS
3/8"	4	1/8"	# 1 STRING	70	21	6	1/8"	# 1 STRING	70	21
		1/8"	# 2-4 "	90	23		1/8"	# 2-6 "	90	23
5/8"	12	1/8"	# 1 "	70	21	16	1/8"	# 1 "	70	21
		1/8"	# 2-3 "	90	23		1/8"	# 2-3 "	90	23
		5/32"	# 4-12 "	120	24		5/32"	# 4-16 "	115	24
1"	22	1/8"	# 1 "	70	21	30	1/8"	# 1 "	70	21
		1/8"	# 2-3 "	90	23		1/8"	# 2-3 "	90	23
		5/32"	# 4-22 "	120	24		5/32"	# 4-30 "	115	24

POSITION 3G — JOINT DETAILS



POSITION 4G & 5G — JOINT DETAILS



JOINT THICKNESS	POSITION 3G NO. OF PASSES	ROD SIZE	PASS NUMBER AND TYPE	AMPS	VOLTS	POSITION 4G & 5G NO. OF PASSES	ROD SIZE	PASS NUMBER AND TYPE	AMPS	VOLTS
3/8"	6	1/8"	# 1 STRING	70	21	5	1/8"	# 1 STRING	70	21
		1/8"	# 2-6 "	80	22		1/8"	# 2-5 "	80	22
5/8"	15	1/8"	# 1 "	70	21	15	1/8"	# 1 "	70	21
		1/8"	# 2-30 "	80	22		1/8"	# 2-15 "	80	22
1"	30	1/8"	# 1 "	70	21	22	1/8"	# 1 "	65	21
		1/8"	# 2-3 "	80	22		1/8"	# 2-18 "	80	22
		5/32"	# 4-30 "	105	23		1/8"	# 19-22 "	75	22

ORNL OPERATOR'S QUALIFICATION TEST SPECIFICATION QTS-38 FOR METAL ARC WELDING OF ASTM A-387 CHROMIUM-MOLYBDENUM STEEL GRADE-C PLATE, PIPE, AND FITTINGS TO TYPES 304, 304L, 308, 316, 316L, AND 347 STAINLESS STEEL PLATE, PIPE, AND FITTINGS

SCOPE:

This specification covers the qualification of operators for approval to metal arc weld ASTM A-387 chromium-molybdenum grade-C plate, pipe, and fittings to types 304, 304L, 308, 316, 316L, and 347 stainless steel plate, pipe, and fittings in accordance with ORNL Procedure Specification P.S.-38.

REFERENCES:

Procedure Specification P.S.-38.
Procedure Specification Figure P.S.-38-A.
Qualification Test Specification Figure QTS-38-A.
ASTM A-387 (latest revision).
ASTM A-167 (latest revision).
Operator's Qualification Test Specification QTS-11.
ASME Boiler & Pressure Vessel Code Section IX.

PRIOR QUALIFICATION OF WELDER:

The operator shall meet the requirements of Operator's Qualification Test Specification QTS-11 before taking the qualification test.

MATERIAL REQUIRED:

Unless prior approval is obtained, test weldments shall be made using ASTM A-387 grade-C and ASTM A-167 type 304 material as noted below.

For groove welds:

Two pieces of 10" diameter schedule 140 pipe made from ASTM A-387 grade-C material and two pieces of 10" diameter schedule 140 pipe made from ASTM A-167 type 304 material are required. Each piece shall be approximately five inches long and beveled as shown on Fig. QTS-38-A.

FILLER METAL:

The filler metal shall be Inconel 182-T International Nickel Company alloy.

TEST POSITIONS:

Groove welds:

Test # 1 - Position 2G - A groove weld shall be made between one piece of ASTM A-387 grade-C pipe and one piece of ASTM A-167 type 304 stainless steel pipe placed with the axis in the vertical position and the welding groove in a horizontal plane as shown on Figure QTS-38-A, test # 1. After welding, the pipe shall be stamped with numbers 1, 2, 3, and 4, clockwise and approximately 90° apart and the proper identification of the operator and position.

Test # 2 - Position 5G - A groove weld shall be made between one piece of ASTM A-387 grade-C pipe and one piece of ASTM A-167 type 304 stainless steel pipe placed with the axis in the horizontal position and the welding groove in the vertical plane as shown on QTS-38-A. Test # 2. Before welding, the pipe shall be stamped with numbers 1, 2, 3, and 4, clockwise and approximately 90° apart starting with number 1, 45° clockwise from the top when arranged for welding and the proper identification of the operator and position.

WELDING REQUIREMENTS:

1. The welding operator shall be required to follow procedure specification P.S.-38 in making the test welds and shall not be allowed to rotate or turn the weldment during welding.

2. An inspector shall be present at all times while the qualification test is in progress. The inspector may refuse acceptance of a test weldment if the operator does not comply with the standard procedure in all respects.

NON-DESTRUCTIVE INSPECTION OF WELDMENTS:

Visual Inspection:

The finished weldments shall be inspected for deviation from the procedure specification and for the points listed below:

1. The appearance of the completed welds shall indicate that the welds were made in a workmanlike manner. Undercutting and overlapping shall be kept to a minimum. The reinforcement shall be uniform in width and height and shall not be less than 1/16" or more than 1/8" above the surface of the base metal.

2. There shall be complete penetration. Any weldment having weld metal protruding through the root more than 3/32" will not be accepted.

Radiographic Inspection:

The completed weldment shall be radiographed and meet the requirements as stated below:

1. Techniques as specified in UW 51 of the 1959 ASME Code for Unfired Pressure Vessels shall be used.

2. The welds shall show no cracks or lack of fusion. Porosity or slag inclusions shall not exceed one-half the limitations as defined in Section VIII, ASME Boiler and Pressure Vessel Code, Appendix IV porosity charts, for plate 1/2" to 1-1/4" in thickness.

DESTRUCTIVE INSPECTION OF WELDMENTS:

Test Specimens:

1. The weldments shall be machine cut and specimens removed in accordance with paragraph Q-24, Figure Q-13.2 (b), Section IX, ASME Boiler and Pressure Vessel Code. The specimens shall be stamped with the proper identification number of the operator, position, and specimen. Additional specimen cutting is required in paragraph (3) below.

2. Each specimen shall be machined in accordance with Figure Q-7.1, Side Bend Specimens for Ferrous Materials, Section IX, ASME Boiler and Pressure Vessel Code.

3. A sample piece approximately 1" wide shall be removed as welded from each weldment and these shall be stamped with the proper identification number of the position and operator. The welds shall then be prepared for metallographic evaluation of the transverse section and examined in the as-polished and etched condition for evidence of flaws.

4. Weld reinforcement on the specimens shall be removed flush with the surface of the pipe by machining, filing, or grinding, and it will not be permissible to remove undercutting or other defects below the surface of the base metal.

5. Neither will it be permissible to remove any base metal from the under side of the pipe in order to conceal any evidence of lack of penetration or fusion at the root of the weld. The edges of all groove weld specimens shall be rounded by removal of the burr with a file.

6. A guided bend jig proportioned for 3/8" material shall be used to conduct bend test as follows. Each specimen shall be given a guided side bend test in accordance with paragraph Q-8 (b), Section IX, ASME Boiler and Pressure Vessel Code.

RESULTS REQUIRED:

1. The convex surface of the bend specimens shall be free of cracks or other open defects exceeding 1/16" in any direction. The total number of all cracks or open defects shall not exceed 3 in any one specimen. Cracks occurring at corners of specimens during testing shall not be considered unless it is indicated that the origination was from a welding defect.

2. The metallographic examination shall show no evidence of cracking or incomplete fusion. Gas pockets or inclusions shall not exceed one-half the limitations as defined in Section VIII, ASME Boiler and Pressure Vessel Code, Appendix IV porosity charts.

RETESTS:

In case a welding operator fails to meet the requirements as stated, a retest may be allowed under the following conditions:

1. An immediate retest may be made which shall consist of two test welds of each type and test position that has been failed, all of which shall meet the requirements specified for such welds, or

2. A complete retest may be made at the end of a minimum period of one week, providing there is evidence that the operator has had further training and/or practice.

ASSIGNMENT OF CODE UPON PASSING QUALIFICATION TEST:

Welding operators passing the above test will be qualified and his operator's card so marked for welding as specified under Procedure Specification P.S.-38.

RECORD OF TEST:

A record shall be kept of all pertinent test data with results thereof for each operator meeting these requirements. This record shall be originated by the inspector.

Tested specimens shall be identified and made available for examination by interested parties until all fabrication requiring the use of this specification has been completed and the system has been accepted.

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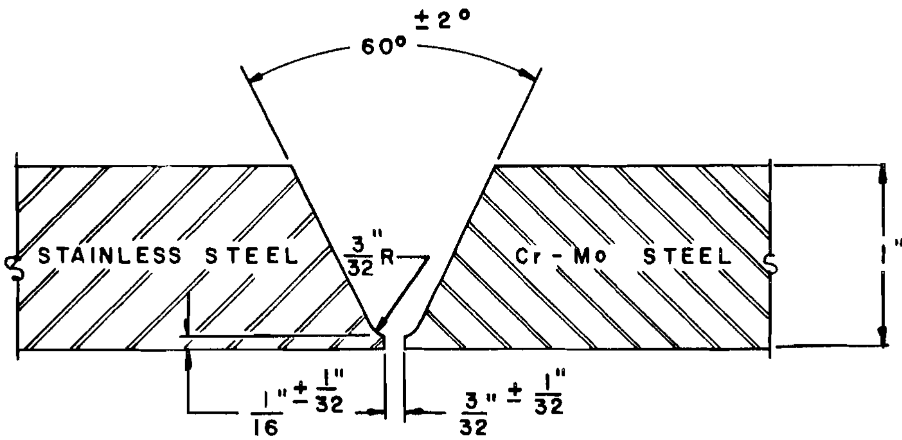
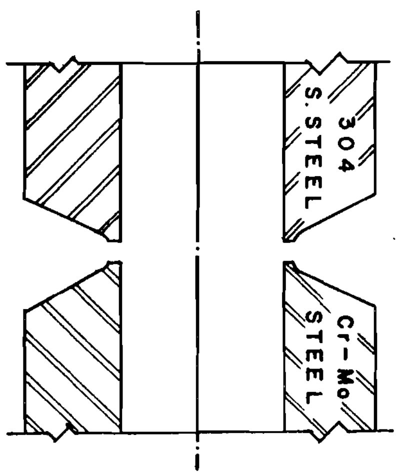
Metallurgy Division

FIG. QTS – 38-A

DESIGN FOR GROOVE WELDS IN PLATE AND PIPE ALL POSITION

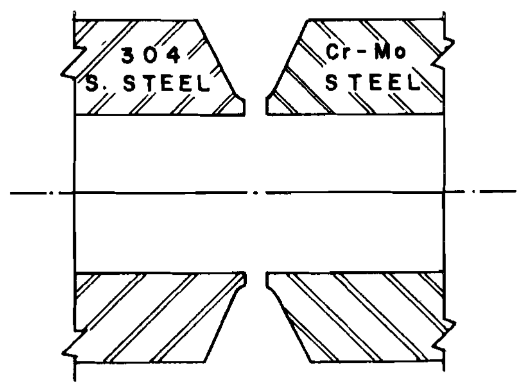




POSITION 2G

(Pipe axis vertical fixed)

TEST NO I



POSITION 5G

(Pipe axis horizontal fixed)

TEST NO 2

APPENDIX IV

RECOMMENDATIONS TO KAISER ENGINEERS PERTAINING TO DISSIMILAR-METAL WELDS IN EGCR

RECOMMENDATIONS TO KAISER ENGINEERS PERTAINING TO DISSIMILAR-METAL WELDS IN EGCR

At the request of Kaiser Engineers, recommended procedures for making the dissimilar-metal welds in the EGCR have been considered. These joints are: (1) primary reactor coolant outlet-to-stainless steel piping, (2) burst-slug-detection nozzle steel extension-to-vessel, (3) thermocouple nozzle steel extension-to-vessel, and (4) stainless steel coolant piping-to-chromium-molybdenum steam generator shell.

From the examination of the applicable EGCR drawings, it appears that field welding of these joints will probably be required. It is recommended that the joints for applications (1), (2), and (3) be made using the procedures specified in ORNL Procedure Specification P.S.-32 (Metal Arc Welding of Carbon Steel Plate ASME P-Number 1 to Types 304, 308, 316, and 347 Stainless Steel Plate), see Appendix I for applications (1), (2), and (3) above. The operators should be qualified in accordance with the corresponding Operator's Qualification Test Specification, QTS-32. After deposition of the first 1/4 in. of weld metal with no preheat, visual, dye-penetrant, and radiographic inspection of the root pass should be made from the interior for any imperfections. In the event of any such imperfections (incomplete penetration, voids, cracks, etc.), the root should be grooved to sound metal and repairs made from the inside. Complete reinspection should then be conducted.

All welding after the deposition of this 1/4 in. of weld metal shall be performed with the material preheated to 200–300°F. Complete inspection, including dye-penetrant and radiographic, should be performed when the weld is approximately half completed and when completed. All imperfections exceeding the limits specified for "C type" welds in Specification No. RMIS-1 (Procedure Specification for the Inspection of Welds for Reactor Service), see Appendix V, shall be removed, repaired, and reinspected. A weld stress relief of 1100–1250°F shall be performed after welding is completed.

For application (4) above, it is assumed that the steam generator inlet will be constructed of ASTM A-387, grade C, material. The procedures outlined in ORNL Specification P.S.-38 and Operator's Qualification Test QTS-38 (Metal Arc Welding of ASTM A-387 Chromium-Molybdenum, Grade C, Steel Plate to Types 304, 304-L, 308, 316, 316-L, and 347 Stainless Steel Plate), see Appendix III, are applicable.

APPENDIX V

PROCEDURE SPECIFICATION FOR THE INSPECTION OF WELDS FOR REACTOR SERVICE

REACTOR MATERIAL SPECIFICATION
METALLURGY DIVISION
OAK RIDGE NATIONAL LABORATORY

Union Carbide Nuclear Company
A Division of Union Carbide Corporation
Oak Ridge, Tennessee

Subject: PROCEDURE SPECIFICATION FOR THE INSPECTION OF WELDS FOR REACTOR SERVICE

I. SCOPE: This specification is applicable to the inspection of welds fabricated for use in reactor service or reactor experimental tests. The following six types of welds shall be used as designated on the drawing. The type of weld to be used shall be determined by the designated representative of the Metallurgy Division and the designer.

A. "C" Type - For all critical welds wherein optimum soundness is required (e.g., sealing between corrosive environments, thermal gradients or high strength requirements).

B. "CN" Type - For welds which normally would be considered "C" but cannot be given a complete inspection due to design or fabrication requirements.

C. "B" Type - For welds which need to meet the integrity requirements of ASME Boiler and Pressure Vessel Code, Section VIII.

D. "BN" Type - For welds which normally would be considered "B" but cannot be given a complete inspection due to design or fabrication requirements or where leak tightness only is required.

E. "LT" Type - Welds which need be only leak tight. Type of inspection will be specified by project engineer. (Shall not be used in any critical area, as defined in "A" above.)

F. "S" Type - For structural welds wherein leak tightness is not required. (Shall not be used for welds attaching structural members to any containment vessels.)

Deviation from the inspection requirements shall be made only after a review of the individual weld has been performed by the designated representative of the Metallurgy Division and the project engineer.

II. REFERENCES:

A. TID-7017- Reactor Materials Specifications - Sections 1 through 4

B. ASTM-E-142-59T - Tentative Method for Controlling Quality of Radiographic Testing

C. ASTM-E109-57T - Tentative Method For Dry Powder Magnetic Particle Inspection

D. MIL-1-6870A - Inspection Requirements, Non-Destructive.

II. REFERENCES (continued):

E. ASME Boiler and Pressure Vessel Code, Section VIII, 1959 Edition.

F. ASME Boiler and Pressure Vessel Code Case Interpretations, Nos. 1270N-1, 1272N, 1273N.

G. ASA Code for Pressure Piping - Latest Edition.

H. ASTM E165-60T - Tentative Methods for Liquid Penetrant Inspection.

I. Dye Penetrant Operating Instructions, Magna-Flux Corp.

III. WELDER QUALIFICATIONS:

A. The welder shall be qualified in accordance with the applicable Reactor Material Welding Specification or other specifications as may be required.

B. If, during the evaluation of a weld, the inspector finds evidence to question the ability of a welder to make the weld according to the applicable specification, the inspector shall have the right to call for and witness tests by the welder to determine his ability. If qualified and retest made in accordance with appropriate Procedure Specification.

IV. INSPECTION PROCEDURE DURING FABRICATION:

Base metal, filler metal, joint designs, shielding gas, welding methods specified in the designated welding procedure, and inspection procedures shall be used as designated on certified shop drawings unless otherwise approved by an authorized representative of the Metallurgy Division. Any deviation from this specification shall be cause for rejection of the welds. In addition, the following shall be performed as specified:

A. Weld setups are to be examined for alignment, cleanliness of materials, sufficient coverage of shielding gas and proper positioning.

1. Alignment - Misalignment is not acceptable on "C" and "CN" type welds. Misalignment on "B" and "BN" type welds shall be held in accordance with Par. 629, Chapter 4, ASA Code for Pressure Piping B-31-1, 1955.

2. Cleanliness of Materials - Cleaning of materials shall be carried out in accordance with requirements of RMIS-5.

REACTOR MATERIAL SPECIFICATION
METALLURGY DIVISION
OAK RIDGE NATIONAL LABORATORY

Subject: PROCEDURE SPECIFICATION FOR THE INSPECTION OF WELDS FOR REACTOR SERVICE

IV. INSPECTION PROCEDURE DURING FABRICATION (continued):

B. The root pass and finished weld of all "C", "CN", "B", and "BN" welds shall be inspected for defects using a liquid penetrant method, as described in Section V. Any defects shall be examined and removed as specified under the inspection procedure. The weld must be rechecked after repair.

V. WELDING INSPECTION:

A. Visual - Visual inspections shall be performed on all welds with the following exceptions: "LT" and "S" welds will be inspected as requested by the project engineer.

1. All "C", "CN", "B", and "BN" type welds shall be given a careful visual examination upon the completion of tack welds. The root pass will be examined from the inside if accessible. The completed weld will be carefully examined and any of the following defects will be cause for rejection.

a. Cracks - All cracks and crack-like conditions shall be removed by mechanical means and repaired, or complete removal of the weld.

b. Excessive Oxidation - Oxidation other than superficial discoloration of the weld.

c. Excessive Penetration - Penetration of "C" and "CN" welds shall not be in excess of 1/16 inch when material of 0.100 in. or greater is used; or 0.035 in. when material of less than 0.100 in. is used. The penetration of "B" and "BN" welds shall not exceed those specified in Section VIII, ASME Code - 1959 Edition.

d. Excessive Reinforcement - Reinforcement on "C" and "CN" welds shall not be in excess of 1/16 in. when material is 0.100 in. or greater is used or 0.035 in. when material of less than 0.100 in. thickness is used.

The reinforcement of "B" and "BN" welds shall not exceed those specified in Section 8, ASME Code - 1959 Edition.

e. Lack of Penetration - The weld shall be at least flush with the base metal where joint design permits and shall be continuous and uniform.

Subject: PROCEDURE SPECIFICATION FOR THE INSPECTION OF WELDS FOR REACTOR SERVICE

V. WELDING INSPECTION (continued):

f. Undercut - Undercut shall not be allowed on "C", "CN", "B", and "BN" type welds.

g. Lack of Reinforcement - Reinforcement of weld shall be at least flush with the outside surface of the base metal.

h. Pin Holes - Pin holes on "C", "CN", "B", and "BN" type welds must be removed and repaired.

i. Lack of Fusion - The weld shall have complete and uniform fusion at the bottom of the joint and for the full length and depth of the weld.

j. Misalignment - Misalignment on "C" and "CN" welds will be cause for rejection. "B" and "BN" welds shall conform to the requirements of ASA B-31-1, 1955 Code for Pressure Piping (Par. 629, Chapter 4, Section 6).

B. Liquid Dye Penetrant:

Penetrant inspection shall be performed on all welds with the following exceptions: "S" welds and "LT" welds will be liquid dye penetrant inspected if requested by the project engineer. An approved fluorescent penetrant may be used in substitution for liquid dye penetrant procedure. Substitution must be approved by authorized representative of the Metallurgy Division.

1. Penetrant materials shall consist of "Spotchek"* penetrant, cleaner and developer.

2. Tentative methods for liquid penetrant inspection, ASTM E165-60T shall be used as penetrant inspection guide.

3. Prior to use of penetrant, the area to be inspected must be completely clean of any scale, grease or dirt.

4. Dye penetrant shall remain on the area for a minimum of 15 minutes prior to removal.

5. The weld area temperature during the dye-penetrant application shall be between 50°F and 100°F.

6. The penetrant shall be removed by wiping with a clean cloth saturated with dye-penetrant cleaner. In no case shall the penetrant be washed off by applying the cleaner directly to the weld area.

* Magna-Flux Corp.

V. WELDING INSPECTION (continued):

7. The developer shall remain on the weld area for a minimum of 20 minutes prior to interpretation of any defects.

8. The dye-penetrant inspection shall be conducted in a lighting of at least 10 candlepower per square foot as measured from a white card placed at the weld.

9. A 5X magnifying glass shall be used to search for positive indications.

10. All dye indications shall be removed. Any indication that cannot be removed shall be cause for rejection.

C. Radiography:

Radiographic inspection shall be performed on all "C" and "B" welds using a technique as described in ASTM E-142-59T, Controlling Quality of Radiographic Testing. All exposures shall be made using X-rays whenever possible. The following procedure shall govern the radiographic inspection.

1. Welds are to be 100% inspected. For welds on pipe and tubing, having an outside diameter of 2 inches or less, three evenly spaced exposures shall be made. For welds on pipe and tubing having an outside diameter size of greater than 2 inches through 5 inches, five exposures shall be made. Welds having a diameter greater than 5 inches shall be radiographed sufficiently to obtain the desired quality specified in Part 3, following. The radiographs shall be taken so that a minimum amount of material shall be between the film cassette and the focal spot (e.g., for pipe, the film would be positioned on the inside surface when possible).

2. The radiographs are to include all of the weld, the heat affected zone, and proper identification showing the project number and other pertinent data that may be required. NOTE: The identification shall not be positioned so that it will interfere with the inspection. In order that radiographs taken after repairs may be distinguished from the original exposures, they shall be identified as RX-1, RX-2, etc., for each subsequent inspection. All exposures shall be maintained as part of the permanent records for the system. When a weld has been found to be rejectable and is to be removed from the system and replaced with a new weld, the subsequent weld, or welds, shall be identified by adding A, B, C, etc., to the weld number each time the weld is replaced.

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V. WELDING INSPECTION (continued):

3. The following techniques shall be used in order to obtain acceptable radiographs:

   a. A radiographic technique which will indicate the size of defects having a thickness equal to and greater than 2% of the thickness of the base metal as defined in ASTM E142-59T shall be used.

   b. Penetrameters, as described in ASTM E-142-59T, shall be used unless otherwise stated.

   c. An approved "very fine-grain" film shall be used when radiographing thicknesses of 1/2-inch and less, and an approved "fine-grain" film shall be used on thicknesses greater than 1/2-inch.

   d. The use of gamma radiography shall be approved by the designated representative who shall also approve the source and techniques to be used so that the desired quality can be maintained.

4. Interpretation of the Radiographs

   a. Any indication of a defect such as those shown in Part A, Visual Inspection, shall be investigated and the weld rejected if the condition is found to be in excess of the tolerances specified.

   b. Porosity, slag, or tungsten inclusions shall be considered as porosity.

   c. The presence of porosity, slag, or tungsten inclusions greater in size than "medium", as defined in the Porosity Charts of Appendix IV of Section VIII, ASME Boiler and Pressure Vessel Code, shall be cause for rejection on "C" welds of material thicknesses greater than 0.100 inch.

      Porosity, slag or tungsten inclusions will not be permitted in "C" welds of material thicknesses less than 0.100 inch.

      Porosity found in "B" weldments shall be limited in size to those shown in Appendix IV, Section VIII, ASME Boiler and Pressure Vessel Code.

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V. WELDING INSPECTION (continued):

4. Interpretation of the Radiographs (continued)

d. Indications of defects observed during the interpretation and subsequently found to be a result of processing the film or conditions found to be acceptable shall be identified and so noted on the radiograph and inspection report form.

D. Other Inspections:

Inspection of welds by methods such as ultrasonic, magnetic particle, etc., other than those described shall be done by a method approved by the designated representative of the Metallurgy Division when specified on the drawing or inspection request.

VI. GENERAL:

A. If, during the inspection of a weld, a defect is discovered in the base metal, it shall be investigated in accordance with the applicable Reactor Material Inspection Specification or other specifications which may be applicable.

B. The decision of the inspector shall be final unless conditions exist which give reason for the decision to be reviewed. In this event, the inspector, the project engineer, and the Metallurgy representative shall review the data and resolve the disposition either by rejection or acceptance on written waiver, which will accompany the inspection report.

VII. RECORDS:

A. A standard approved inspection form is to be maintained on each weld which shall include:

1. Project number

2. Weld number

3. Welder's name

4. Material type and sizes

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Date: Dec. 1, 1957
Revised: Aug. 15, 1960

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VII. RECORDS (continued):

5. Filler material and sizes

6. Cover and back-up gases (if used)

7. Inspections performed and signature of inspector

8. Disposition of each inspection

9. Dates of inspections.

B. These forms, along with any radiographs made, shall be maintained by the inspector along with a print showing the location of each weld and the disposition thereon. These records shall be made available upon request. Upon completion of the system, the records are to be transmitted to the Metallurgy representative for permanent record purposes.

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