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SUBJECT: M-25, Butt Welds in Process Piping

TO: J. L. Matherne

FROM: A. P. Litman

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Summary

A comparison of the results of two common welding processes for circumferential butt welding austenitic stainless steel process pipe has been made. Metal-arc and inert-gas shielded tungsten-arc processes were used by qualified welders under bench conditions. Test samples were prepared from 1/2 inch - Schedule 40 type 347 pipe with some variation in joint design, fit up, and the employment of backing gas.

Inert-gas tungsten-arc welding, when done as prescribed by ORNL procedure specifications, was superior to the other techniques.

The Chemical Technology Division of ORNL uses large quantities of austenitic stainless steel as a material of construction. Service requirements generally demand joining of stainless piping by fusion welding. The brief test series herein reported compares fusion weld joining techniques which are prevalent or have been considered for use at the above facility.

The base material used throughout this test series was annealed 1/2 inch - Schedule 40 type 347 pipe. Joining was accomplished by techniques described below using lime-coated type 347 electrodes in the case of metal-arc welding and bare type 347 filler wire in the inert-gas tungsten-arc welding processes.

Table 1 presents all welding process details pertinent to this test series. All welds were made under bench conditions by qualified welders at ORNL. Photographs of the finished welds are shown in Fig. 1.

After joining, the specimens were subjected to visual, radiographic, and metallographic examination. The results are presented in Table 2 and typical longitudinal cross sections are shown in Fig. 2.

Maximum weld corrosion resistance is contingent upon having a finished joint free from crevices, porosity, inclusions and other non-uniformities. Under conditions of thermal cycling and high temperatures these defects become particularly hazardous. If radioactivity makes periodic inspection of welded joints impractical, and strong decontaminating solutions are used, acceptance of anything less than the most homogeneous weldments appears to be imprudent.

Two of the most common discontinuities of metal-arc welding were noted in Samples 1 and 2. Fig. 2 shows entrapped slag at the top of the first pass for the former and root porosity in the latter. Either defect can be the origin of a weld crack to which austenitic stainless steels are particularly susceptible. The particular position of the porosity in Sample 2 lends itself to rapid preferential corrosive attack.

Sample No.	Welding Process	Electrode	Electrode Size Inches	Position	Current D.C. Amp	Spacing Inches	Land Inches	Bevel Degrees Included Angle	Filler Wire	Filler Wire Size Inches	Gas Cup Size	Cup Gas	Cup Gas CFH	Backing Gas	Backing Gas CFH	Welder
1	Metal-arc Reverse Polarity	Arcos 347 S.S. Lime-Coated	5/64	2G	55/60-1st Pass 55/60-2nd Pass	1/16	1/16	75	-	-	-	-	-	-	-	V. Houchin
2	Metal-arc Reverse Polarity	Arcos 347 S.S. Lime-Coated	3/32	1G	~ 45-1st Pass ~ 45-2nd Pass	3/32	1/16	90	-	-	-	-	-	-	-	L. Ratliff
3	Inert-gas tungsten-arc Straight Polarity	2% Thoriated Tungsten	1/8	1G	35/40-1st Pass 55/60-2nd Pass	1/16	1/16	90	347 S.S.	1/16	8A	Argon	20	None	None	L. Stinnett
4	Inert-gas tungsten-arc Straight Polarity	2% Thoriated Tungsten	1/8	1G	35/40-1st Pass 55/60-2nd Pass	1/32	1/16	None	347 S.S.	1/16	8A	Argon	20	None	None	L. Stinnett
5	Inert-gas tungsten-arc Straight Polarity	2% Thoriated Tungsten	1/8	1G	35/40-1st Pass 55/60-2nd Pass	3/32	1/16	90	347 S.S.	1/16	8A	Argon	20	Helium	15/30	L. Ratliff
6	Inert-gas tungsten-arc Straight Polarity	2% Thoriated Tungsten	1/8	2G	40-1st Pass 50-2nd Pass	3/32	3/64	100	347 S.S.	1/16	8A	Argon	20	Argon	5/10	V. Houchin

TABLE 1

Butt Welds in Process Piping

All Material 1/2" Schedule 40 Type 347 Stainless Steel Pipe

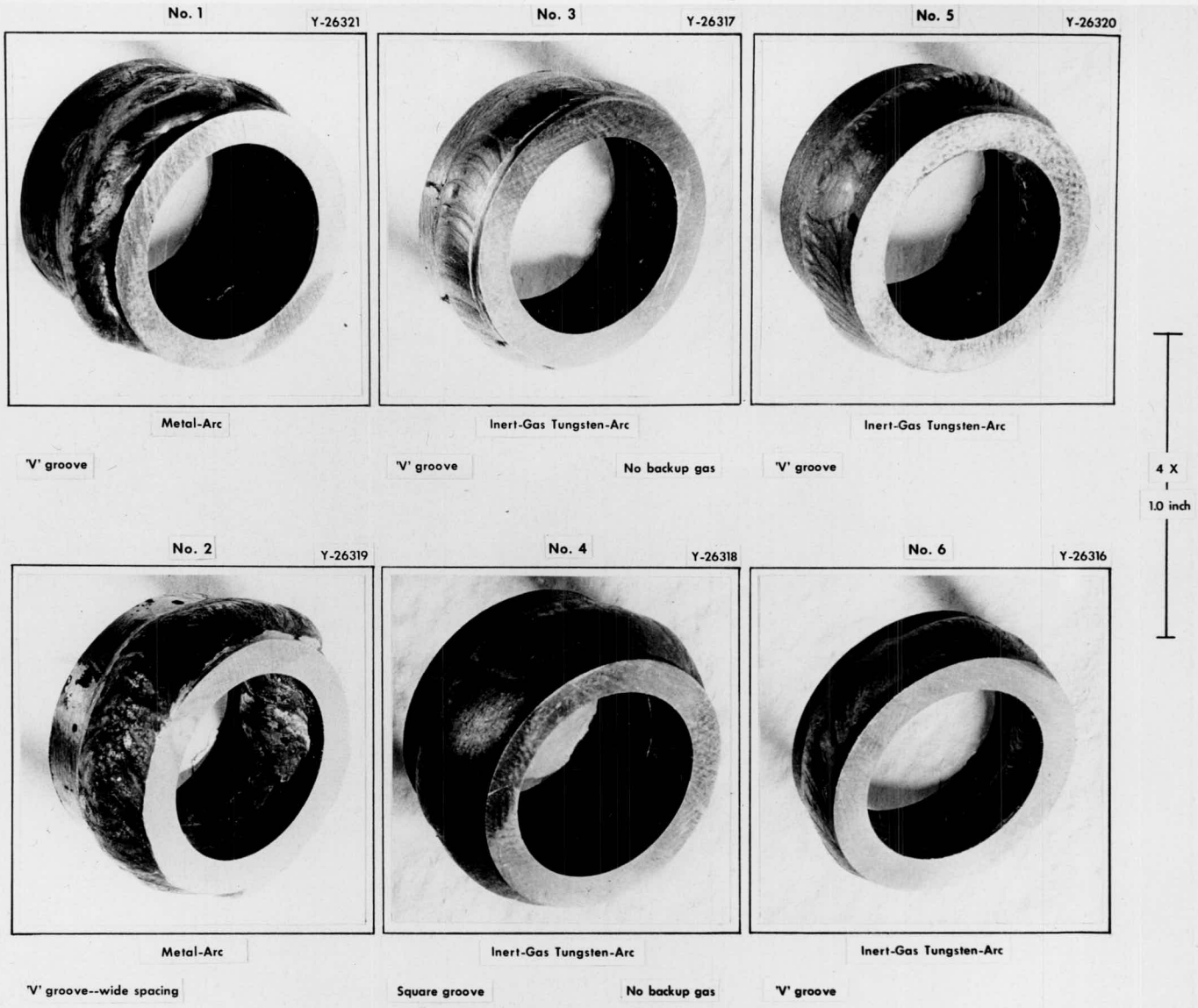


Figure 1

BUTT WELDS IN PROCESS PIPING

Cross-reference to Table 1

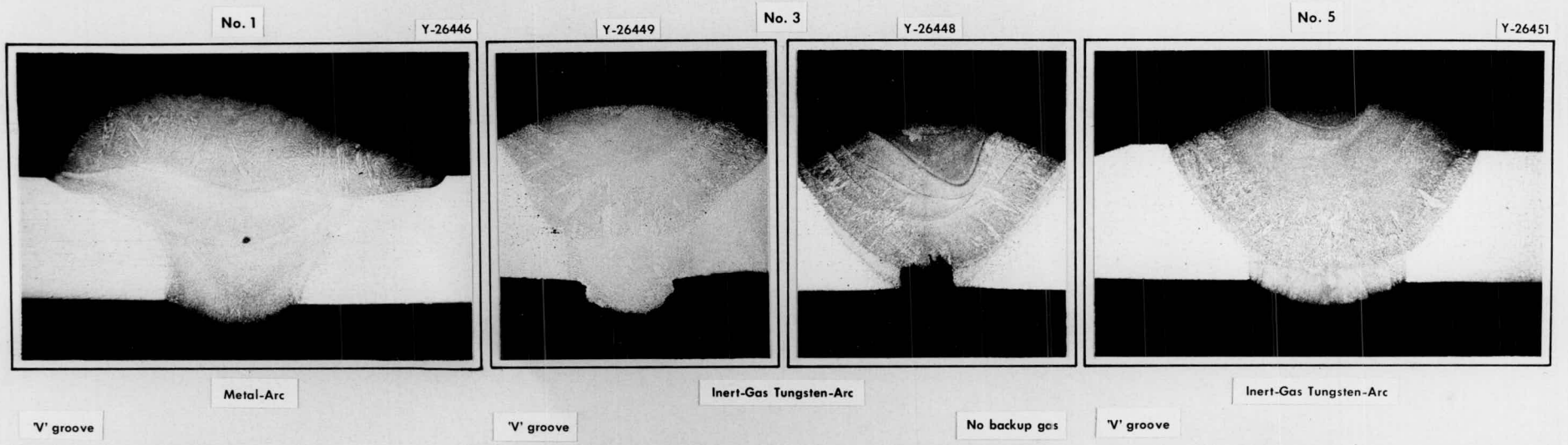
Sample No.	Weld Classification	Visual Examination	Radiographic Examination	Metallographic Examination[1]
1	Metal-arc	Generally satisfactory appearance--non-uniform width of root and cover passes--normal metal-arc oxidation on root and cover passes	No defects visible	Generally satisfactory structure noted with entrapped slag visible at the top of first pass
2	Metal-arc	Fair appearance--excessive penetration--non-uniform width of root penetration--normal metal-arc oxidation on root and cover passes	Burned root edges visible--non-uniform penetration--3 or 4 spots of ASME medium to large porosity noted	Excessive penetration noted with porosity at maximum penetration
3	Inert-gas tungsten-arc No backing gas	Satisfactory cover appearance--unsatisfactory root appearance showing non-uniform penetration with "grape" formations--severe oxidation on root pass	Non-uniform root with "grape" formations--possible slag inclusions-1 spot of ASME fine porosity	Two sections illustrated show adjacent root areas with inadequate penetration and excessive penetration--a few voids present adjacent to the fusion zone which are believed to be former inclusions--high magnification showed a heavy oxide layer covering the root penetration
4	Inert-gas tungsten-arc No backing gas	Wide but generally satisfactory cover--unsatisfactory root showing incomplete penetration and non-fused crevice	Inadequate penetration visible--some very fine spots of porosity visible	Incomplete penetration resulted in a sharp crevice at the weld root approx. 35 mils deep.--high magnification showed a heavy oxide layer covering the root penetration
5	Inert-gas tungsten-arc With backing gas	Satisfactory appearance--slight non-uniformity in width of root penetration	Generally satisfactory--a few very fine spots of porosity visible	Satisfactory structure
6	Inert-gas tungsten-arc With backing gas	Satisfactory appearance--no obvious irregularities	No defects visible	Satisfactory structure

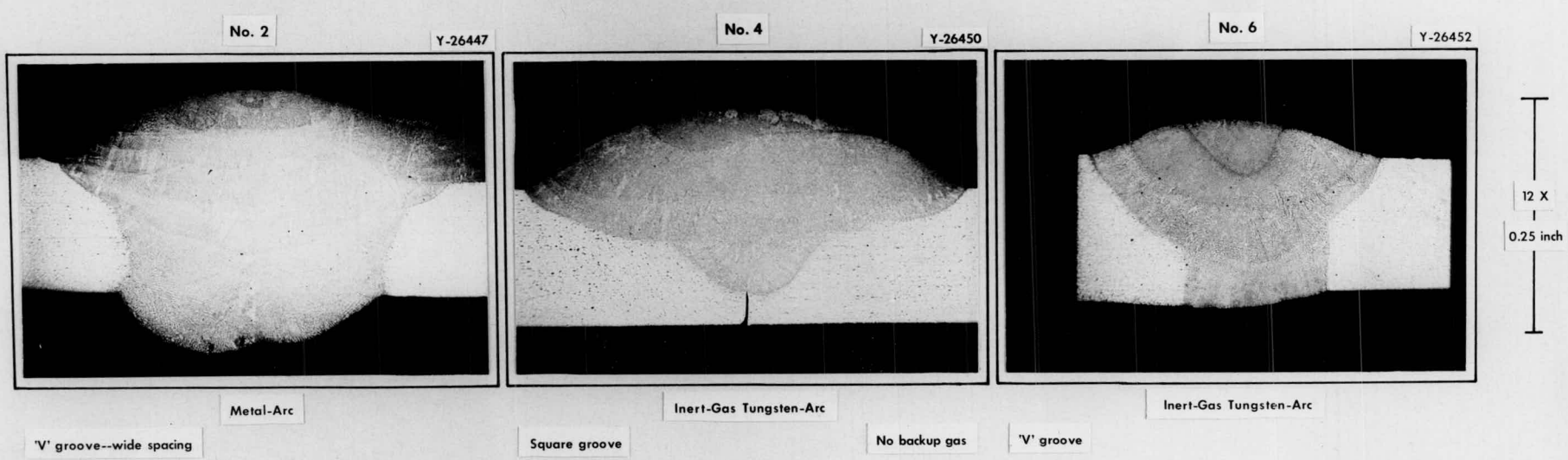
TABLE 2

Butt Welds in Process Piping

All Material 1/2" Schedule 40 Type 347 Stainless Steel Pipe

[1] Random longitudinal cross-sections





Etch....Electrolytic 5% Chromic Acid

Figure 2

BUTT WELDS IN PROCESS PIPING

Cross-reference to Table 2