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DIVISION SNAP-8

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TECHNICAL MEMORANDUM

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TITLE: MATERIALS EVALUATION OF TRANSITION JOINTS FOR TRANSFORMER REACTOR ASSEMBLY

ABSTRACT

The chemical compatibility of tubular transition joints connecting aluminum and 304 SS when exposed to mix-4P3E polyphenyl ether was determined at 250°F for times up to 2500 hours. Several metallic coating materials, utilized to cover the copper portion of a multi-metal transition joint, were evaluated, as was a co-extruded direct-bonded aluminum-304 SS joint.

All of the materials tested appeared to be completely compatible with the mix-4P3E. However, the coatings were unsatisfactory due to either the coating technique or inherent properties of the coating. The co-extruded, direct-bonded aluminum-304 SS joint appeared unaffected.

The effects of the metals on the mix-4P3E were so slight that measured property changes can be attributed to experimental technique.

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INTRODUCTION

A tubular transition joint between aluminum (Al) and 304 stainless steel (SS) is required in the SNAP-8 system for connecting the heat sink (Al tubing) of the transformer/reactor (T/R) assembly to the L/C loop (304 SS tubing). At the beginning of 1965, development of the T/R was discontinued and consequently the need for such a joint disappeared. However, evaluation of candidate transition joints was continued to completion; firstly because the program was very close to being completed, and secondly because reactivation of the development of the T/R would require availability of a joint almost immediately.

Direct joining of Al to SS by welding is not an established state-of-the-art procedure. However, an experimental sample of a direct joint between SS and Al was furnished by Nuclear Metals, Inc., Concord, Massachusetts. It was fabricated by hot coextrusion and was included in this evaluation program.

An acceptable transition joint between Al and 304 SS (including intermediate metal transition sections) utilizing proven state-of-the-art procedures is available. A transition is made from Al to copper (Cu) by the "Koldweld" (pressure welding) process of Kelsey-Hayes Co., from Cu to nickel (Ni) by TIG welding, and from Ni to 304 SS by TIG welding. Previous evaluation tests at VKC, Ref. 1, indicated the "Koldweld" joint is acceptable for SNAP-8 use.

The coolant used to extract heat from the T/R heat sink is mix-4P3E polyphenyl ether. There is evidence that Cu is attacked and property changes of the mix-4P3E occur (Ref. 2) if the system operates while under nuclear irradiation. Although the mix-4P3E degradation from irradiation is not sufficient to detrimentally affect system operation or life, the Cu tube may rupture due to pit-type corrosion resulting from exposure to the mix-4P3E during nuclear irradiation.

Coated specimens were exposed to mix-4P3E and mix-4P3E + 1% (volume) water at the system operating temperature, 250°F, to evaluate the efficacy of candidate coatings in protecting the Cu and the effect of the specimens on the fluid. Water was added to one set of specimens because a small amount of water is generated as a by-product during irradiation of mix-4P3E, and water can cause detrimental effects on Cu and Al. The coatings evaluated were electroless Ni, "Electrolized" chromium (Cr) and duplex layer of electrodeposited silver (Ag) over electroless Ni.

SPECIMEN DESCRIPTION

The "Koldweld" Cu-Al joint was manufactured by the Utica Turbine Parts Division of Kelsey-Hayes Co. A Ni tube was TIG welded to the Cu end of the "Koldweld" section utilizing Monel filler metal per ASTM-B304, CL-34N-60. A section of 304 SS tube was TIG welded to the Ni using Inco A filler metal per AMS 5675. The specimens were then coated with selected metals by commercial vendors. A description of the coatings appears below.

CANDIDATE COATINGS FOR PROTECTION OF COPPER PORTION OF Al-304 SS TRANSITION JOINTS

Type	Thickness (mils)	Specification	Vendor
"Electrolized" Cr	0.4	QQ-S-320-C12	Electrolizing Sales, Inc., Los Angeles
Electroless Ni	1-2	MIL-C-26074 Cl.1	Hixson Metal Finishing, Newport Beach
Electrolytic Ag over electroless Ni	Ag 0.5 Ni 1-2	Ag per QQ-S-365 Type 1, Cl.1; Ni per MIL-C-26075, Cl.1	Hixson Metal Finishing, Newport Beach

The coated specimen configuration is shown schematically in Figure 1. Uncoated specimens were also exposed to the fluids to provide a control for differentiating effects of reactions between fluid and specimen, fluid and coating, or coating and specimen.

The sample of 304 SS bonded directly to Al was a tubular specimen. The two materials were butt-joined using a hot coextrusion process. Longitudinal elements of the tube, approximately 3/32 x 5/32 x 4 inches, were cut from the tube sample for evaluation.

Prior to testing, each as-received plated specimen was visually examined to ascertain the conditions of the deposited coating.

TEST CAPSULE PREPARATION

The specimens and specimen capsules, Pyrex (Grade 7740), were degreased in clean, liquid trichloroethylene. Each specimen was weighed to the nearest 0.1 mg, placed in a specimen capsule and the top of the capsule was partially necked-down. Twenty-five milliliters of either of the test fluids, mix-4P3E or mix-4P3E + water, was added to each capsule. The capsule was placed in a liquid nitrogen bath and the

interior evacuated to 10^{-3} to 10^{-4} torr.* The tube was sealed by fusing the necked-down area. After sealing, the capsules were warmed to room temperature. Table 1 lists the distribution of test specimens and conditions of exposure. Figure 2 shows a sealed test capsule.

TEST PROCEDURE

The capsules were placed in a holding rack, Fig. 3, and the rack placed in the test oven at a temperature of 250 ± 10°F. One group of specimens was exposed for 1000 hours and the second group for 2500 hours.

After exposure, the capsules were removed from the oven, cooled to liquid nitrogen temperature, and broken open. The capsules were warmed to room temperature in a desiccator. The specimens were then removed and reweighed to nearest 0.1 mg. Fluid samples were analyzed by gas chromatography utilizing the procedure described in Ref. 3. Selected specimens were sectioned, mounted and photographed. Tables 2 and 3 contain a summary of the test results.

EVALUATION OF THE FLUIDS

Small changes of the fluid were experienced as shown in Table 2. The very small fluctuations in the distribution of the various isomers and volatiles is such that it can be attributed to experimental error. Comparison of the data for viscosity change of the fluid control specimens and those containing the joints indicate some small change may have occurred, but the change is well within experimental error. The acid numbers are essentially unchanged.

These changes indicate that the material would be essentially unaffected by similar exposure for 10,000 hours.

EVALUATION OF UNCOATED SPECIMENS

Figure 4 shows a comparison of the uncoated specimens subjected to the 2500-hour exposure with the unexposed specimen. There was no apparent effect on any of the joint materials due to the exposure.** The exposed specimens lost a small amount of weight, see Table 3, but this loss is considered insignificant. The extrapolated corrosion rate, based on aluminum, is less than 1×10^{-5} inches per year, and this would be much less for any of the other metals involved.

* Liquid nitrogen freezing is utilized to prevent evaporation of the mix-4P3E during vacuum because vapors could prevent adequate fusion of the glass.

** No visual evidence such as pitting or general corrosion when area was magnified to 75X.

EVALUATION OF ELECTROLESS Ni COATING

There was no apparent overall surface attack of the coating by either fluid over the full 2500-hour exposure period. However, coating discontinuities were found on the specimens exposed to the two fluids, see Figs. 5a and b. The weight change was very small, see Table 3, and is considered insignificant. Galvanic corrosion at the Ni/Al interface was found on all specimens, the unexposed control specimen as well as those exposed for 1000 and 2500 hours to the mix-4P3E and the mix-4P3E and water. The effect apparently was not due to exposure as evidenced by the presence of the defect on the unexposed specimen. It appears to be inherent in the plating process and may have resulted from one or a combination of the following conditions.

Al by itself is difficult to plate because the surface oxidizes very rapidly. The surface problem is accentuated when a bimetal part is plated because the surface preparations for the individual metals is generally different. Poor coating adhesion on one or all of the metals may result because of this less-than-optimum surface condition.

The transition joint consists of metals which individually require different plating bath compositions. Al is plated in an alkaline bath, whereas Ni and Cu base materials are plated in an acid bath (Refs. 4 and 5). Thus, depending on the plating bath selected, one or another of the metals will be treated improperly.

When Ni is plated, it is cathodic to the Al. If any plating solution is trapped in porous areas, corrosion could be initiated.

The literature reports (Ref. 6) that in the electroless plating of bimetallic systems, galvanic effects may be produced during plating, leading to galvanic corrosion.

EVALUATION OF ELECTROLIZED Cr COATING

Apparently, the normal electrodeposition Cr plating baths are not used for deposition of this coating. It is observed in Figure 6 that the process has excellent throwing power while conventional plating baths have poor throwing power. The Cr, as deposited, is essentially crack-free, unlike standard Cr plating. Finally, hydrogen embrittlement of the substrate does not appear to be a problem since no post-plating embrittlement relief is required. The vendor reported some difficulty in plating the specimens because the I.D. was smaller than what is considered a minimum for the process.

Metallographic examination showed that the coating exhibited satisfactory adherence, but coating voids were found on the unexposed specimen and coating cracks on those which were exposed (Figs. 6a and 6b). Exposure to both fluids did not appear to adversely affect the coating. The coating cracks in the exposed specimens may have been present prior to the test because of the vendor-reported plating difficulty, or they may have been produced by the temperature of exposure. These coating defects preclude the use of Electrolized chromium unless additional tests show that they can be avoided in plating and that subsequent exposure does not, in fact, detrimentally affect the layer.

EVALUATION OF COATING OF ELECTRODEPOSITED Ag OVER ELECTROLESS Ni

The Ag deposited over the electroless Ni undercoat was not affected, and the weight change was very small.

The Al/Ni interface contained areas of attack similar to that found on the electroless Ni plated specimens. Again, the defects were found in the unexposed specimen, indicative of a plating defect. The Ag appeared to cover the Ni undercoat satisfactorily.

The Ag coating had the same lustrous appearance after test as on the pre-test specimen. There was no evidence of attack during exposure. The weight change was small.

The vapor zone of one specimen exposed to the mix-4P3E + 1% water showed an area of attack on the uncoated Al end of the specimen. None of the other Al areas subjected to the mix-4P3E + 1% water appeared similarly affected.

EVALUATION OF DIRECT BONDED (Al-304 SS) JOINTS

The direct-bonded specimens appeared unaffected by the exposure conditions. Metallographic examination showed no surface reaction with either of the fluids, mix-4P3E or mix-4P3E with water (Figure 7). In mix-4P3E, the specimen weight changed such that if one assumed that total attack was confined to the aluminum (the lighter of the two metals) the exposed surface was dissolved to a depth of 0.2×10^{-5} inches. Assuming attack of only the 304 SS (the denser material) the conversion of the weight change to depth of penetration results in even less surface penetration. In mix-4P3E + 1% (by volume) H_2O a positive weight change of the specimen occurred. But it was so slight that a surface reaction was not apparent through metallographic examination of the specimen. Thus, the exposure effects are regarded as insignificant.

There was no evident cross-bond diffusion at the Al-304 SS interface resulting from the 2500-hour exposure to the 250°F test temperature. This joint should be given further consideration as an alternative to the coated four-metal transition joints discussed above. Because it represents an advance in the state of the art (the four-metal transition joint represents available state-of-the-art procedures), further environmental effects testing would be required. These tests should consist of tensile determination in the aged and unaged conditions and of temperature cycling effects.

CONCLUSIONS

1. None of the coated specimens were completely satisfactory due either to coating technique or inherent properties of the coating. However, there was no apparent surface attack on any of the specimens by the mix-4P3E.

2. The least-affected coating was the "Electrolizing" chromium, but it had some cracks and voids. The defects may have been due to a less-than-satisfactory tube I.D. dimension which prevented proper metal deposition.

3. Metals that form galvanic cells cannot be plated with electroless nickel becuase the more active metal is corroded at the interface between the metal and the deposited nickel.

4. The coextruded aluminum-304 stainless steel joint was least affected by the test environment.

5. The effects of the metal on the mix-4P3E was so slight that the property changes can be attributed to experimental techniques and that under the same conditions, the life of the mix-4P3E should be at least 10,000 hours.

RECOMMENDATIONS

1. The coextruded aluminum-304 SS should be fully evaluated as an alternative to the four-metal transition joint if development of the T/R is reactivated. Evaluation should consist of post-elevated temperature aging mechanical property tests and thermal aging tests.

2. Additional evaluation of the "Electrolizing" coating should be performed on transition joints containing a larger I.D. to ascertain whether specimen configuration was the only deterrent to producing a satisfactory coating.

3. Any SNAP-8 test operation requiring a T/R which excludes a reactor, and thus a radiation environment at the transition joint should be conducted utilizing an umplated joint. Under such an environment the copper portion of the joint is compatible with mix-4P3E, the L/C fluid.

TABLE 1

SPECIMEN DISTRIBUTION OF TRANSITION JOINTS FOR TRANSFORMER/REACTOR ASSEMBLY HEAT SINK

Specimen Identification Number	Fluid*	Time Exposed to 250°F (hrs)
	Ag Over Electroless Ni	
1	None	-
2	mix-4P3E + 1% H_2O	2500
3	mix-4P3E	1000
4	mix-4P3E + 1% H_2O	1000
5	mix-4P3E	2500
	Electrolized Cr	
6	mix-4P3E	2500
7	mix-4P3E + 1% H_2O	2500
8	mix-4P3E	1000
9	mix-4P3E + 1% H_2O	1000
10	None	-
	Electroless Ni	
11	mix-4P3E	2500
12	mix-4P3E + 1% H_2O	2500
13	mix-4P3E	1000
14	None	-
15	mix-4P3E + 1% H_2O	1000
	Specimen Control (No Coating)	
16	mix-4P3E	2500
17	mix-4P3E + 1% H_2O	2500
18	mix-4P3E	1000
19	mix-4P3E + 1% H_2O	1000
20	None	-
	Fluid Control (No Specimen)	
21	mix-4P3E	2500
22	mix-4P3E + 1% H_2O	2500
23	mix-4P3E	1000
24	mix-4P3E + 1% H_2O	1000
	Al-304 SS Coextruded Transition Joint**	
25	mix-4P3E	2500
26	mix-4P3E + 1% H_2O	2500
27	mix-4P3E	1000
28	mix-4P3E + 1% H_2O	1000
29	None	-

* 1% water (by volume) was added to the mix-4P3E to simulate water generation in mix-4P3E resulting from irradiation.

** Furnished by Nuclear Metals, Inc., Concord, Mass. Tested in as-received condition. No coating required because of absence of Cu.

TABLE 2

COMPATIBILITY TESTS OF ALUMINUM-TO-304 SS TRANSITION JOINTS IN MIX-4P3E - FLUID EVALUATION RESULTS

Coating	Fluid: Mix-4P3E	Fluid: Mix-4P3E + 1% H_2O (by vol.)	Time @250°F (Hrs.)	Gas Chromatography of Mix-4P3E Isomers* (% by Wt.): Volatiles Wt. %	oo-4P3E	mo-4P3E	op+mm 4P3E	mp-4P3E	pp-4P3E	Viscosity in Centistokes: 100°F	210°F	Acid No.	Fluid Evaluation - Visual
				PLATED SPECIMENS: ALUMINUM/COPPER/NICKEL/304 SS - WELDED									
Ag over Electroless Ni	X		1000	0.57	0.1	5.2	51.6	39.5	3.0	68.0	6.3	0.16	No change
Ag over Electroless Ni	X		2500										No change
Ag over Electroless Ni		X	1000	0.52	0.2	5.7	51.7	38.5	3.4	67.2	6.3	0.17	Solution hazy
Ag over Electroless Ni		X	2500										Solution water-clear. Al corrosion products on bottom of capsule
"Electrolizing" Cr	X		1000	0.51	0.1	5.2	52.3	38.5	3.5	66.8	6.5	0.16	No change
"Electrolizing" Cr	X		2500	.36	0.2	5.2	52.4	38.3	3.5				No change
"Electrolizing" Cr		X	1000	0.19	0.03	4.7	51.3	40.1	3.6	68.1	6.2	0.15	Capsule broke during test
"Electrolizing" Cr		X	2500	0.40	0.2	5.0	52.2	38.6	3.6				Solution hazy
Electroless Ni	X		1000	0.48	0.1	5.0	52.1	38.6	3.7	68.4	6.1	0.17	No change
Electroless Ni	X		2500	0.44	0.1	5.4	51.7	38.7	3.7				No change
Electroless Ni		X	1000	0.54	0.2	5.2	51.9	39.2	3.1	68.9	6.6	0.17	Solution hazy
Electroless Ni		X	2500	0.46	0.2	5.1	51.9	39.0	3.4				Solution hazy
Uncoated Control	X		1000	0.60	0.1	5.3	54.1	36.3	3.7	68.1	6.2	0.16	No change
Uncoated Control	X		2500	0.44	0.2	5.0	52.6	38.5	3.4				No change
		X	1000	0.48	0.2	5.1	52.2	38.7	3.4	69.1	6.3	0.16	Solution hazy
		X	2500	0.46	0.2	5.3	52.3	38.3	3.4				Solution hazy

* Composition of the mix-4P3E consists of 6 isomers of different weight percent of each - and a small amount of volatiles. The volatiles are similar in chemical structure, are lower boiling, and generally consist of things like phenol, phenolyphenol, and the isomers of diphenoxybenzene. The isomer definitions of mix-4P3E are as follows:

oo-4P3E: ortho-ortho phenoxyphenyl ether
mo-4P3E: meta-ortho phenoxyphenyl ether
op-4P3E: ortho-para phenoxyphenyl ether
mm-4P3E: meta-meta phenoxyphenyl ether
mp-4P3E: meta-para phenoxyphenyl ether
pp-4P3E: para-para phenoxyphenyl ether

Table 2 (continued)

Coating	Fluid: Mix-4P3E	Fluid: Mix-4P3E + 1% H_2O (by vol.)	Time @250°F (Hrs.)	Gas Chromatography of Mix-4P3E Isomers* (% by Wt.): Volatiles Wt. %	oo-4P3E	mo-4P3E	op+mm 4P3E	mp-4P3E	pp-4P3E	Viscosity in Centistokes 100°F	Viscosity in Centistokes 210°F	Acid No.	Fluid Evaluation - Visual
UNPLATED SPECIMENS: ALUMINUM-304 SS COEXTRUDED SPECIMENS													
No coating	X		1000	0.57	0.2	5.3	52.0	38.7	3.3	69.4	6.5	0.16	No change
No coating	X		2500	0.50	0.1	5.3	52.2	38.4	3.5				Slightly more buff color than original solution
No coating		X	1000	0.44	0.1	5.1	52.3	38.4	3.6	68.4	6.5	0.16	No change
No coating		X	2500	0.52	0.1	4.8	51.9	38.9	3.7				Solution hazy
FLUID CONTROL: - NO SPECIMENS													
No coating or specimen	X		1000	0.56	0.1	5.6	51.3	38.5	3.9	67.2	6.4	0.16	No change
No coating or specimen	X		2500	0.44	0.1	5.3	52.2	38.5	3.5				No change
No coating or specimen		X	1000	0.55	0.2	5.2	52.3	38.0	3.7	67.1	6.4	0.15	Solution hazy
No coating or specimen		X	2500	0.46	0.1	5.1	52.5	38.5	3.4				Solution hazy
No coating or specimen	X		**	0.46	0.1	4.9	52.3	39.0	3.2	68.9	6.3	0.16	No change
		X	**	0.48	0.2	5.1	52.0	38.7	3.5	68.1	6.3	0.15	No change

** Fluid kept at 70 to 75°F.

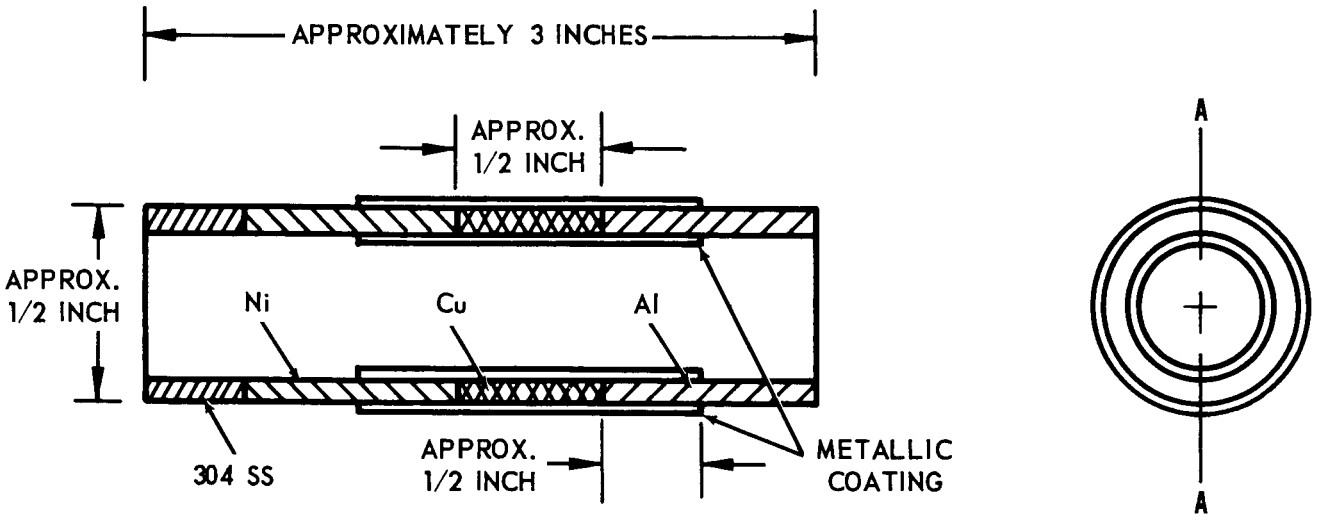
TABLE 3

COMPATIBILITY TESTS OF ALUMINUM-TO-304 SS TRANSITION JOINTS IN MIX-4P3E - MATERIAL EVALUATION RESULTS

Specimen Coating	Fluid: Mix-4P3E	Fluid: Mix-4P3E + 1% H_2O (by vol.)	Time @250°F (Hrs.)	Specimen Evaluation: Weight Change %	Specimen Evaluation: Visual Appearance After Test	Specimen Evaluation: Corrosion Rate* inches/yr	Visual Appearance of Fluid After Test
Ag over Electroless Ni	X		1000	+0.019	No change	**	No change
Ag over Electroless Ni	X		2500	+0.012	No change	**	No change
Ag over Electroless Ni		X	1000	+0.053	No change	**	Solution hazy
Ag over Electroless Ni		X	2500	+0.024	Some areas of Al above fluid had white corrosion products	**	Solution water-clear. Al corrosion products on bottom of capsule
"Electrolizing" Cr	X		1000	+0.009	No change	**	No change
"Electrolizing" Cr	X		2500	-0.002	No change	$< 4 \times 10^{-5}$	No change
"Electrolizing" Cr		X	1000	+0.002	No change	**	Capsule broken during test
"Electrolizing" Cr		X	2500	+0.027	No change	**	Solution hazy
Electroless Ni	X		1000	+0.010	No change	**	No change
Electroless Ni	X		2500	-0.001	Nickel was somewhat darker	$< 2 \times 10^{-5}$	No change
Electroless Ni		X	1000	+0.029	Stained bluish-black	**	Solution hazy
Electroless Ni		X	2500	+0.031	Stained bluish-black	**	Solution hazy
Uncoated Control	X		1000	0	No change	**	No change
Uncoated Control	X		2500	-0.004	No change	$< 1 \times 10^{-5}$	No change
Uncoated Control		X	1000	+0.001	No change	**	Solution hazy
Uncoated Control		X	2500	+0.019	No change	**	Solution hazy
Al-304 SS Joint	X		1000	-0.013	No change	$< 2 \times 10^{-4}$	No change
Al-304 SS Joint	X		2500	-0.002	No change	$< 1 \times 10^{-5}$	Slightly more buff color than original solution
Al-304 SS Joint		X	1000	+0.002	No change	**	No change
Al-304 SS Joint		X	2500	+0.031	No change	**	Solution hazy

* Calculation of the corrosion rate was based on the assumption that the complete weight loss came from the aluminum to maximize the corrosion effect. Only the exposed surface area of aluminum was used in the calculations. Nomograph (Ref. 7) was employed to calculate corrosion rates.

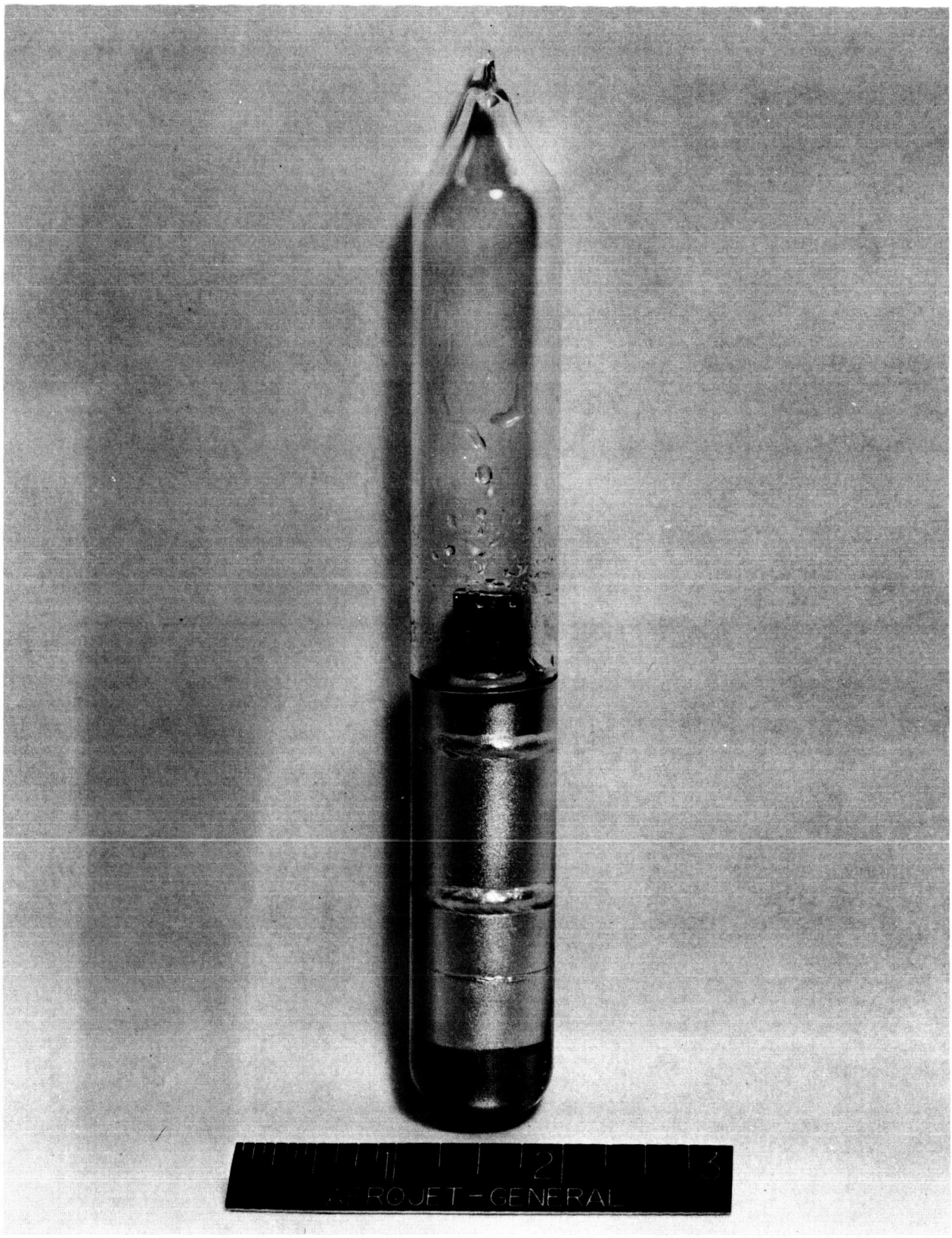
** Corrosion rate is defined as weight loss and therefore these values are omitted.



SECTION A-A
(DRAWING NOT TO SCALE)

NOTE A: METALLIC COATING TO BE ON THE OUTSIDE AND INSIDE OVER APPROXIMATE AREA SHOWN

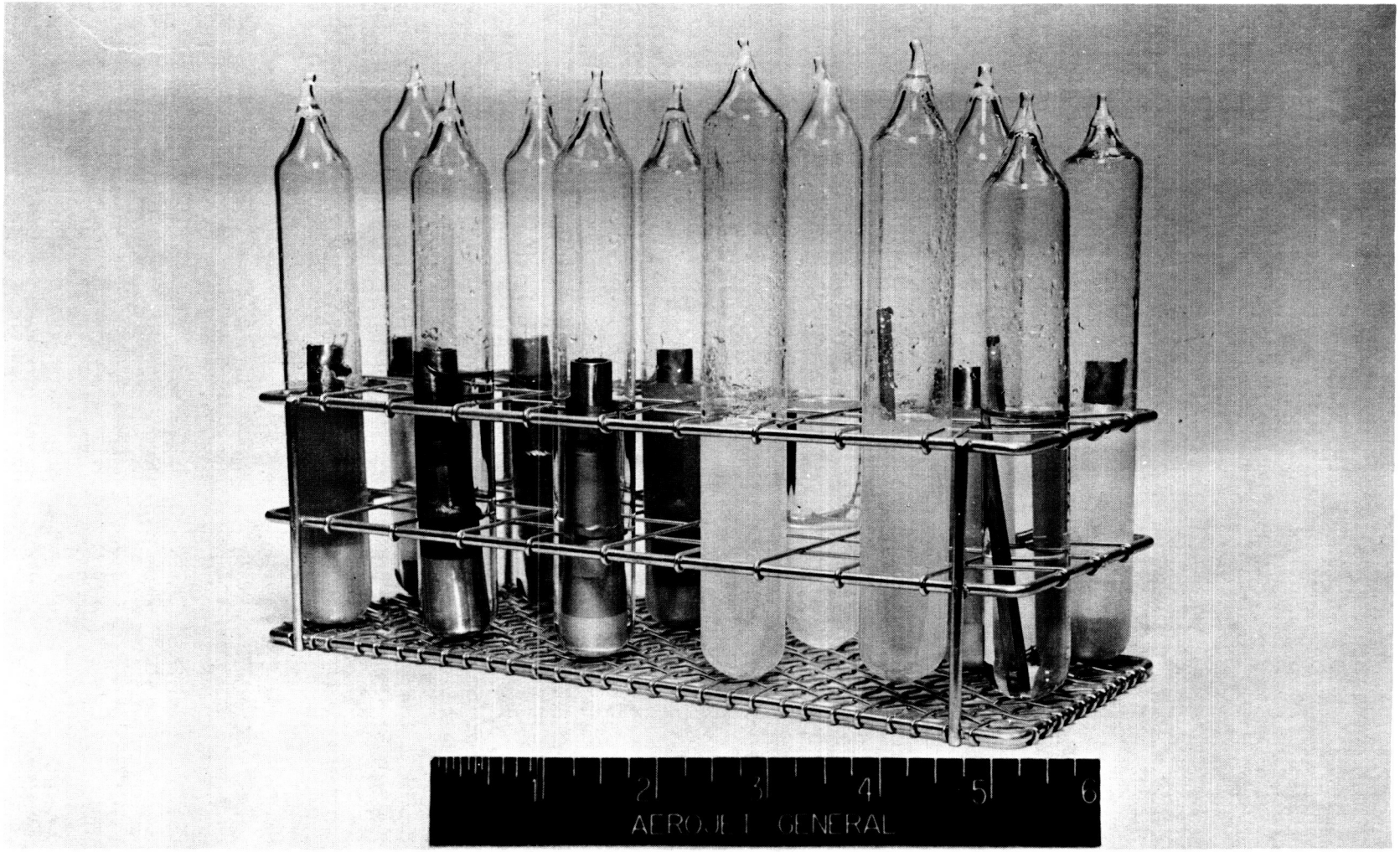
Figure 1



1294-0095 1.2X

HERMETICALLY SEALED PYREX CAPSULE
CONTAINING MIX-4P3E AND TRANSITION JOINT

Figure 2

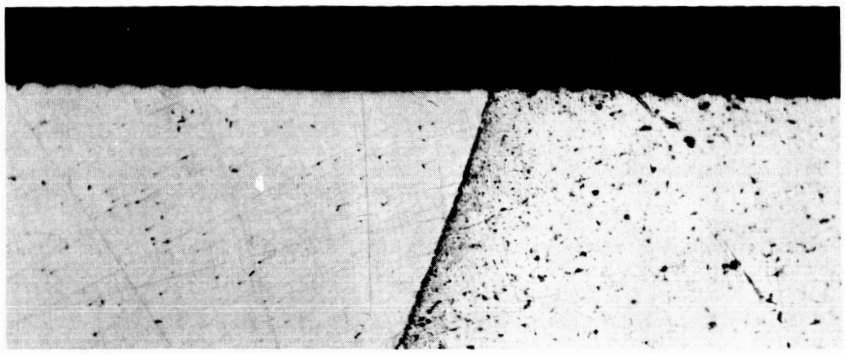


1264-0096

.8X

HERMETICALLY SEALED PYREX CAPSULES USED FOR DETERMINING EFFECTS OF MIX-4P3E ON TRANSITION JOINT MATERIAL

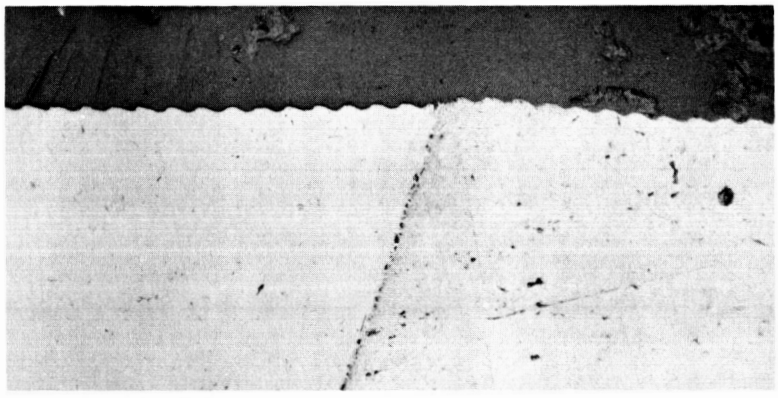
Figure 3



L-8598
As polished

75X

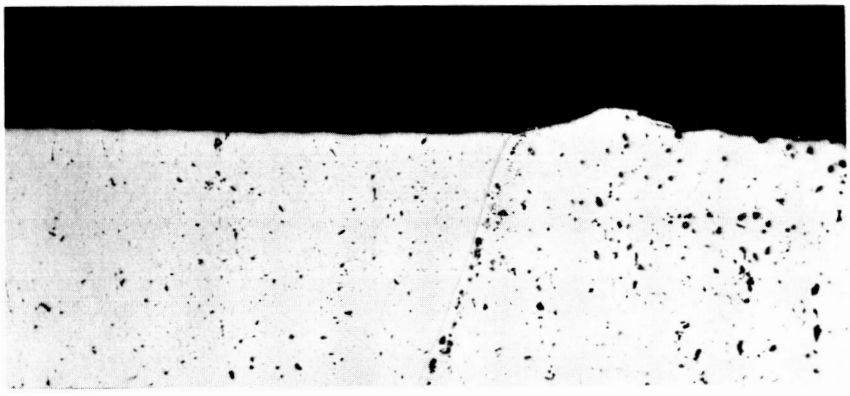
(a) Exposed to mix-4P3E - Specimen 16



L-8510
As polished

75X

(b) Exposed to mix-4P3E + 1% (vol.) water - Specimen 17



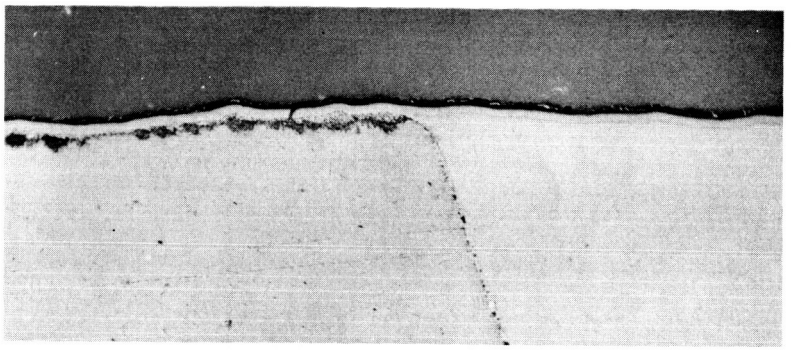
L-8600
As polished

75X

(c) Unexposed - Specimen 20

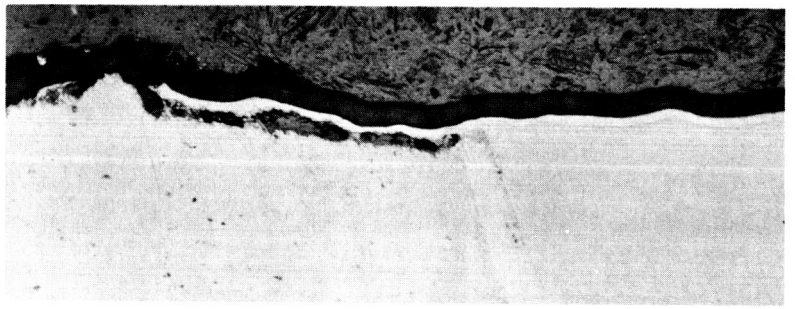
UNCOATED Al-Cu INTERFACE (Cu at left) OF T/R HEAT SINK TO L/C LOOP TRANSITION JOINT - BEFORE AND AFTER EXPOSURE FOR 2500 HOURS AT 250°F

Figure 4



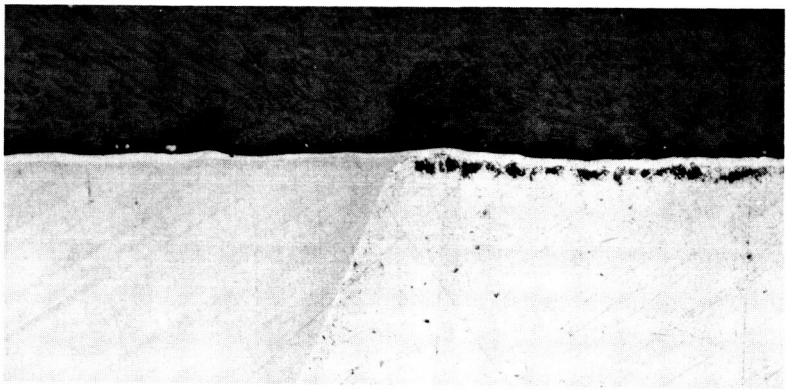
L-8490 75X
As polished

(a) Exposed to mix-4P3E - Specimen 11



L-8508 75X
As polished

(b) Exposed to mix-4P3E + 1% (vol.) H_2O - Specimen 12



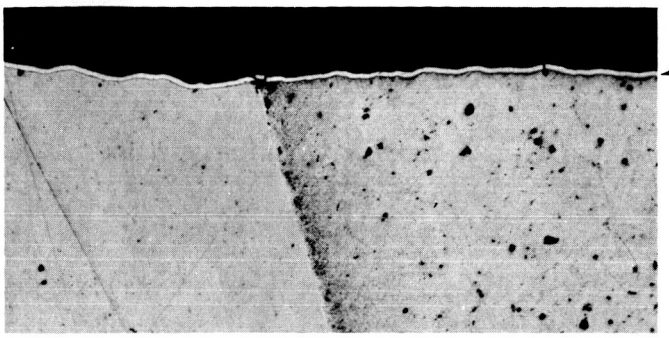
L-8528 75X
As polished

(c) Unexposed - Specimen 14

Al-Cu INTERFACE OF T/R HEAT SINK TO L/C LOOP TRANSITION JOINT PLATED WITH ELECTROLESS NICKEL - BEFORE AND AFTER EXPOSURE FOR 2500 HOURS AT 250°F

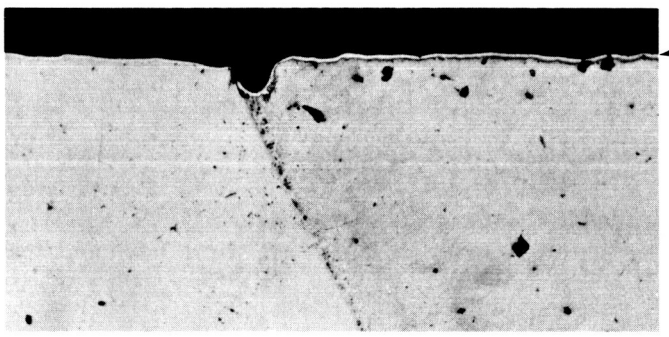
Figure 5

BEFORE AND AFTER EXPOSURE FOR 2500°F AT 250°F



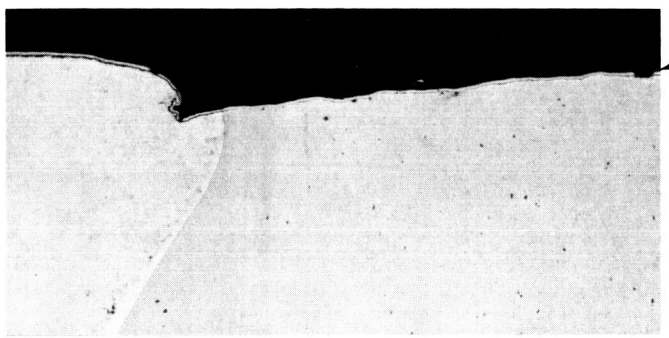
AS POLISHED L-8613 150 X

(a) EXPOSED TO MIX-4P3E - Specimen 6



AS POLISHED L-8612 150 X

(b) EXPOSED TO MIX 4P3E + 1% (Vol.) H_2O - Specimen 7



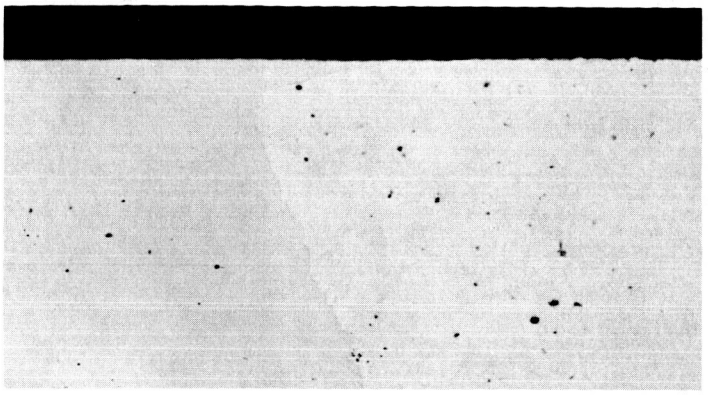
AS POLISHED L-8616 150 X

(c) UNEXPOSED - Specimen 10

Aluminum-to-Copper Interface (Aluminum on Right) Transformer-Reactor Heat Sink to L/C Loop Transition Joint Plated with Electrolized Chromium - Before and After Exposure for 2500 Hours at 250°F

Figure 6

304 SS

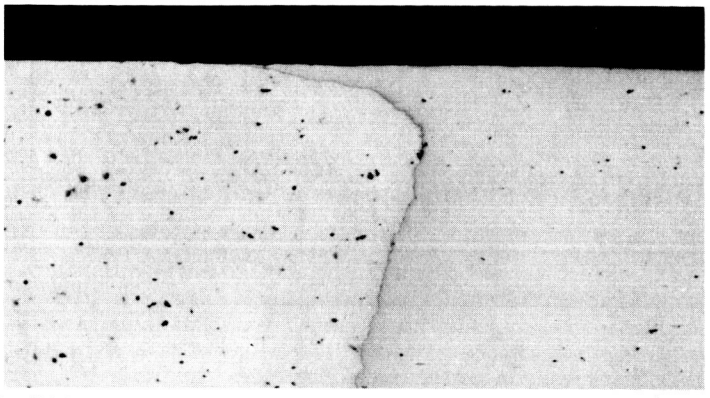


Al

AS POLISHED L-8731 150X

a. UNEXPOSED SPECIMEN - Specimen 29

Al

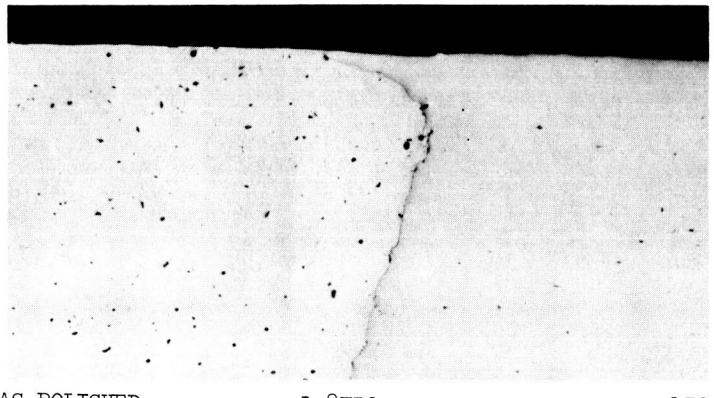


304 SS

AS POLISHED L-8729 150X

b. SPECIMEN EXPOSED TO MIX-4P3E - Specimen 25

Al



304 SS

AS POLISHED L-8730 150X

c. SPECIMEN EXPOSED TO MIX-4P3E +1% (vol) H_2O - Specimen 26

Aluminum/304 SS Hot-Coextruded Transition Joint After Exposure to Mix-4P3E Solutions for 2500 Hours at 250°F in an Evacuated Glass Capsule. The Surface Exposed to the Liquid Appears at the Top

Figure 7

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