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AN INVESTIGATION OF THE CORROSION RESISTANCE OF BRAZING ALLOYS FOR AUSTENITIC STAINLESS STEEL FUEL ELEMENTS FOR SERVICE IN 565°F PRESSURIZED WATER

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OAK RIDGE NATIONAL LABORATORY
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for the
U.S. ATOMIC ENERGY COMMISSION

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R. J. Beaver, C. F. Leitten, Jr., and J. L. English[1]

ABSTRACT

Since brazing was the method selected for joining the stainless steel SM-1 reactor fuel element, corrosion studies were conducted on various potential brazing alloys to evaluate their resistance under the approximate pressurized-water conditions of the SM-1. The program consisted mainly of testing type 304L stainless steel "T" joints brazed with selected alloys in quiescent, degassed, and deionized autoclaved water at 565°F under 1200-psi pressure. In the initial phase of the investigation, tests were limited in duration to 1000 hr in order to quickly screen some 18 potential alloys for longer time testing. Based on weight-change data and the metallographic examinations, five of the 18 alloys exhibited sufficient corrosion resistance to warrant further investigation. These alloys, generally identified as: General Electric No. 81, General Electric No. 75, Coast Metals N.P., Low-Melting Nicrobraz, and a palladium-base alloy containing 37 wt % Ni—3 wt % Si, were subjected to autoclave tests of 12 and 16 months. In these extended tests, 1 cc O_2/liter and a mixture of 1 cc O_2/liter plus 50 cc H_2/liter, respectively, were added to the water to more closely simulate SM-1 reactor water conditions and to evaluate the effect of different gaseous additions on the corrosion behavior of the alloys.

On the basis of weight-change data and metallographic examination after long-term exposure of the tested stainless steel-base joints, General Electric No. 81, General Electric No. 75, Coast Metals N.P., Low-Melting Nicrobraz, and the palladium-base alloy were considered to have acceptable corrosion resistance. No significant differences in the corrosion behavior of these alloys were noted between testing in oxygenated water and water

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[1]Reactor Chemistry Division.

containing the oxygen-hydrogen mixture. Since no significant differences were observed in the corrosion resistance of these brazing alloys in autoclaved water at 565°F under 1200 psi, Coast Metals N.P. was selected as the reference brazing alloy for the SM-1 fuel element. This particular alloy was preferred because it was more amenable to the brazing method established for this fuel element.

INTRODUCTION

The SM-1 reactor (formerly designated APPR-1), which is located at Fort Belvoir, Virginia, and commenced operation in the spring of 1957, is fueled with dispersion-bearing stainless steel-clad fuel elements. The elements which are designed for 1.5 yr of full-power operation are cooled by 454°F water under 1200-psi pressure that flows through the element channels at a velocity of 4 fps.[2] The basic fuel unit, as illustrated in Fig. 1, consists of 18 flat composite fuel plates with a water coolant gap of 0.133 in. between plates. Each plate is securely fastened to grooved side plates by brazing. The 0.030-in.-thick fuel plate contains a dispersion of 26 wt % UO_2 and 0.13 wt % B_4C distributed in a low-carbon type 302B stainless steel which is clad with 0.005-in.-thick type 304L stainless steel by roll bonding.[3] End fittings are subsequently attached to fix the position of the fuel element in the reactor core. The appearance of a finished stationary fuel component with accessory spring and retaining ring, ready for loading into the reactor, is illustrated in Fig. 2.

A key problem in the development of the stainless steel-uranium dioxide dispersion fuel element for operation in the SM-1 reactor was that of selecting a suitable brazing material for use in manufacture of the component. Despite the fact that much was known about the corrosion performance of austenitic stainless steels in pressurized-water

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[2] Nucleonics 15(8), Reactor File No. 2 - facing p 60 (Aug. 1957).

[3] J. E. Cunningham et al., Specifications and Fabrication Procedures for APPR-1 Core II Stationary Fuel Elements, ORNL-2649 (Jan. 29, 1959).

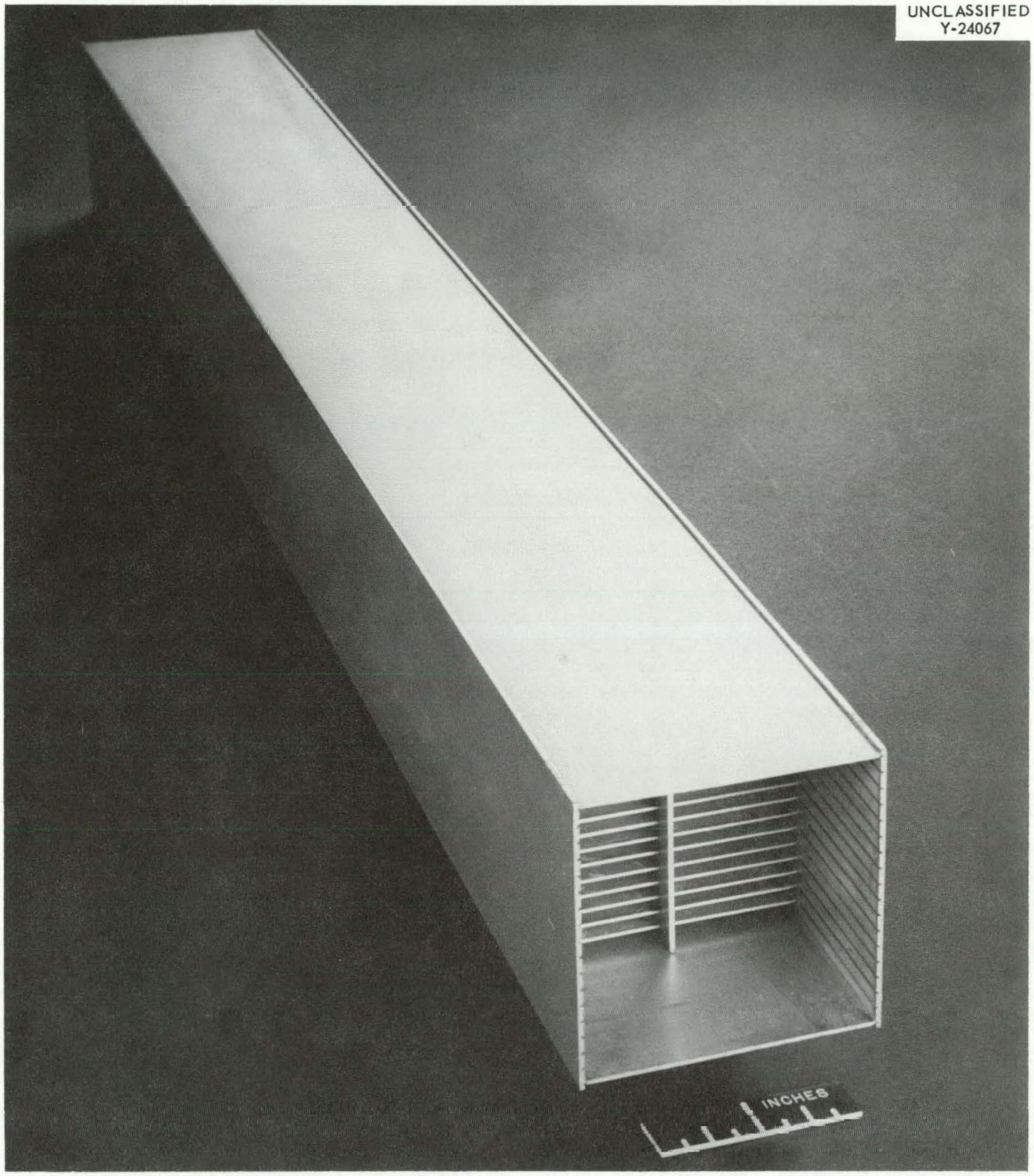

Fig. 1. As-Brazed SM-1 Stationary Fuel Unit.

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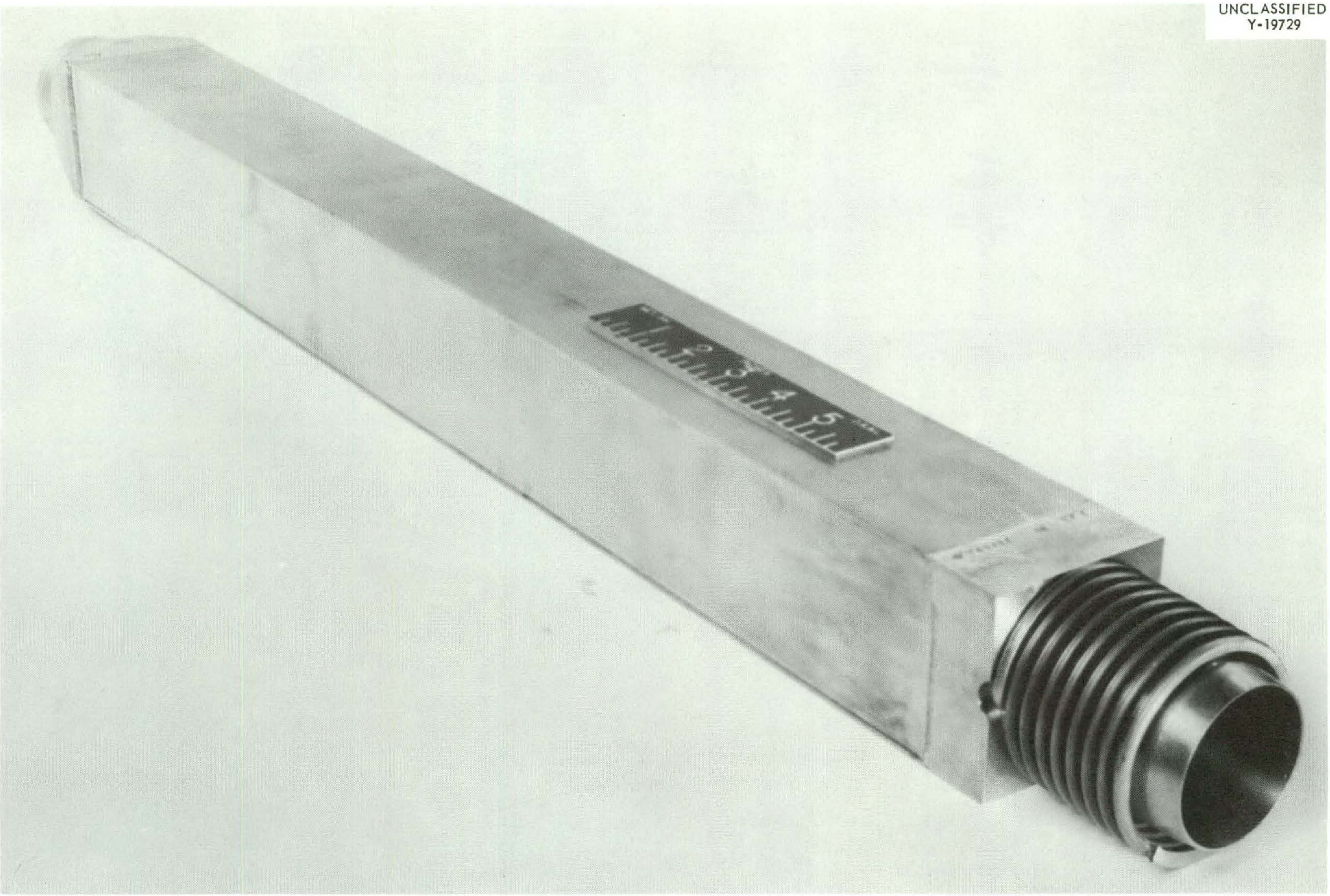

Fig. 2. Fully Assembled SM-1 Stationary Fuel Element.

environments,[4] little or no information was available on the corrosion behavior of brazing alloys, per se, or galvanically coupled with stainless steel. Consequently, a program was initiated in 1954 to evaluate the corrosion resistance of various brazing alloys under the approximate water conditions expected of the SM-1 reactor. The corrosion program consisted of testing type 304L stainless steel "T" joints brazed with the selected alloys in quiescent, degassed, and deionized autoclaved water at 565°F under 1200-psi pressure. The initial phase of study was limited to 1000-hr test on 18 selected brazing alloys. From these results, the most corrosion resistant alloys were selected and tested for periods as long as 16 months (11,616 hr). In these latter tests, 1 cc O_2/liter and a mixture of 1 cc O_2/liter plus 50 cc H_2/liter, respectively, were separately added to the water in order to evaluate the corrosion effect of utilizing such gases in overpressuring the primary coolant system.

The evaluation of the corrosion resistance of the various brazing alloys was based on weight-change data and metallographic examination of a representative cross section of the brazed joint after testing. The experimental conditions in which the specimens were exposed to distilled autoclaved water at 565°F under 1200-psi pressure with or without addition agents represented at best an approximation of conditions which may develop during reactor operations. The data obtained, therefore, are limited to laboratory-scale tests in which the effects of radiation-induced stresses and "crud" deposition were not evaluated.

SELECTION AND PREPARATION OF MATERIALS FOR CORROSION TESTING

Selection of Brazing Alloys

Eighteen potentially acceptable brazing alloys were selected for evaluation in the 1000-hr, 565°F autoclaved-water corrosion tests. The main criteria for alloy selection were: (1) amenability with the fuel

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[4] L. Scheib, Investigation of Materials for a Water Cooled and Moderated Reactor, ORNL-1915 (July 20, 1955).

element brazing process, (2) structural stability in service, (3) availability, and (4) cost. Specific properties of the brazing alloys, such as thermal neutron capture cross section, ductility, and flow temperature, were also deemed important selection criteria.

The compositions and approximate flow temperatures of the brazing alloys selected for corrosion testing are listed in Table 1. One of the alloys listed, Coast Metals N.P., had previously exhibited outstanding corrosion resistance in 500°F pressurized water where the flow rate was 38 fps.[5] After 6245 exposure hours, the attack to this alloy was negligible.

Preparation of Test Specimens

As illustrated in Fig. 3, "T" joint specimens were prepared from type 304L stainless steel sheet to simulate the SM-1 fuel plate-side plate brazed joint. The base of the specimen was 0.060 in. thick, while the upright or section perpendicular to the base was 0.040 in. thick. Both sections were 3/4 in. wide x 5 in. long. A groove, 0.050 in. wide and 0.025 in. deep, was machined along the longitudinal center line of the base. The tongue section was inserted into the groove perpendicular to the base and held in position by tack welding to the base plate at the ends of the specimen. The powdered brazing alloys were preplaced on each side of the joint between the base and tongue sections and fixed with Nicrobraz cement. In the case of preparing specimens brazed with copper-base alloys, commercial alloy wire of 0.060-in. diam was placed at the joints and fixed by tack welding at each end of the specimen.

All joints were brazed in a hydrogen atmosphere of -60°F dew point (minimum) in a 2-in.-diam muffle furnace at the flow temperatures designated in Table 1 for each respective brazing alloy. Holding time at temperature was 10 min. After removal from the furnace, the 5-in.-long specimen was cut transversely into samples of 1/2 in. in length. A

[5]Met. Div. Semiann. Prog. Rep. Oct. 10, 1956, ORNL-2217, p 172 (declassified with deletions Nov. 4, 1959).

Table 1. Brazing Alloys Selected for Autoclave Screening Tests

Alloy Designation	Composition (wt %)	Flow Temperature (°C)
Gold-Nickel	82 Au–18 Ni	1100
Nicrobraz	70 Ni–15 Cr–5 Fe–5 Si–5 B	1150
Low-Melting Nicrobraz	80 Ni–5 Cr–5 Fe–5 Si–5 B	1050
Nicrobraz No. 10	90 Ni–10 P	1000
Palladium-Nickel	60 Pd–40 Ni	1250
Palladium-Nickel-Silicon	60 Pd–37 Ni–3 Si	1180
Nickel-Chromium-Phosphorus	80 Ni–10 Cr–10 P	1050
Coast Metals N.P.	50 Ni–30 Fe–12 Si–4 P–4 Mo	1130
Coast Metals No. 51	91 Ni–5 Si–3 B–1 Fe	1150
Coast Metals No. 50	93 Ni–4 Si–3 B	1150
Coast Metals No. 52	89 Ni–5 Si–4 B–2 Fe	1150
General Electric No. 81	66 Ni–19 Cr–10 Si–4 Fe–1 Mn	1150
General Electric No. 75	75 Ni–25 Ge	1160
Nickel-Tin	68 Ni–32 Sn	1150
Manganese-Nickel	60 Mn–40 Ni	1100
Copper	100 Cu	1100
B.T. Silver Solder	72 Ag–28 Cu	850
Copper-Silicon	92 Cu–8 Si	1000

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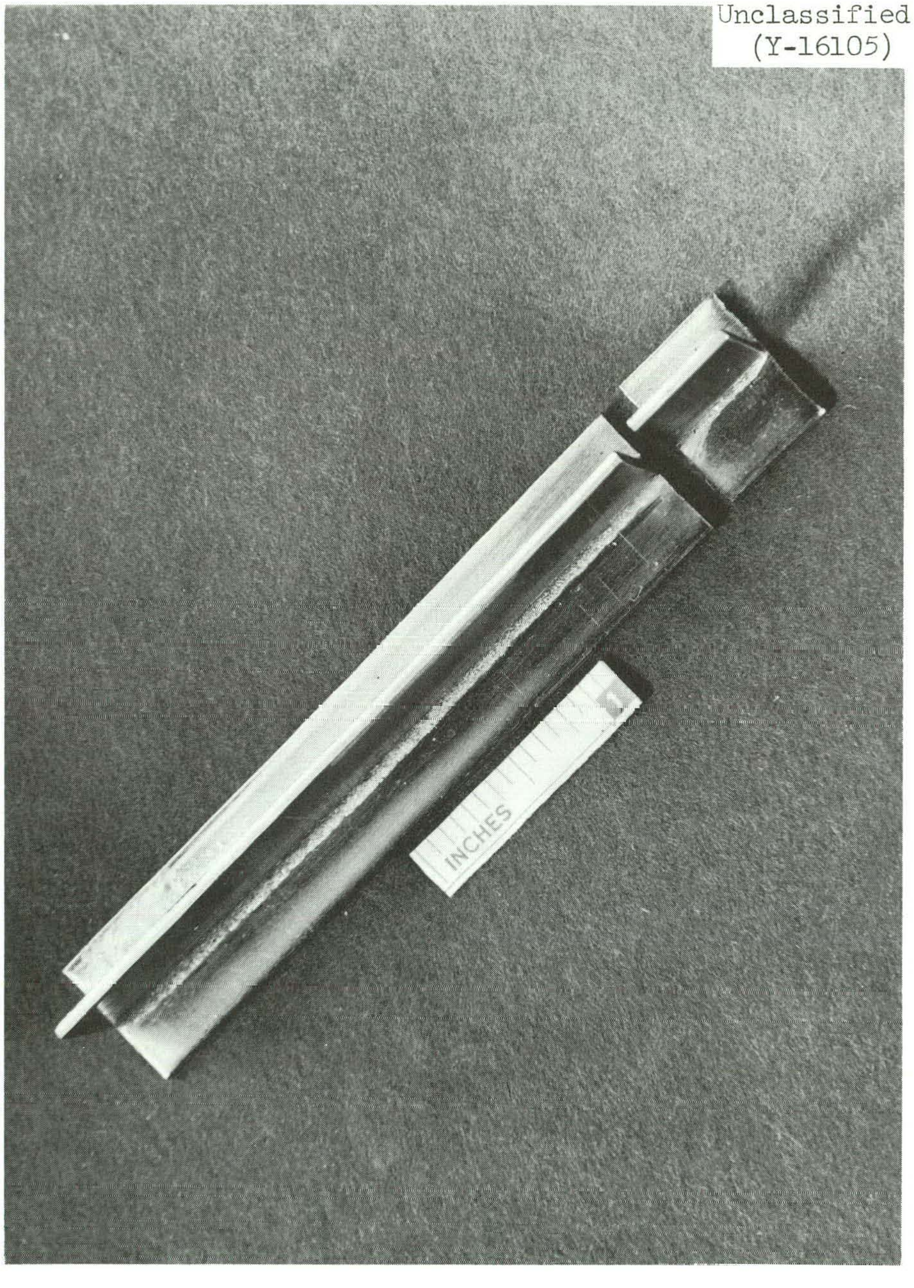

Fig. 3. Brazed Stainless Steel Corrosion Test Specimen.

representative sample was subsequently examined metallographically to serve as the reference joint in evaluating the corrosion tested specimens.

CORROSION TESTING EQUIPMENT AND PROCEDURES

Testing Equipment

The corrosion tests were conducted in 225-ml capacity, type 347 stainless steel autoclaves which were fabricated in accordance with the pictorial sketch shown in Fig. 4. Each autoclave was equipped with an entry tube and a valve to admit controlled amounts of oxygen and/or hydrogen gas into the system. No subsequent additions were made unless leaks developed. The actual autoclave components are illustrated in Fig. 5.

As shown in Fig. 6, eight autoclaves were contained in an insulated cast-aluminum block, 16 in. wide x 29 in. long x 16 in. high, and each was equippped with calrod heaters and copper cooling coils. The temperature was controlled by thermocouples inserted into each heating unit. Three of these insulated blocks which contained a total of 24 autoclaves were utilized during the investigation.

Testing Procedures

Because of the large number of potentially acceptable brazing alloys for stainless steel, a screening test was necessary to isolate a smaller number of alloys for more extensive testing. The screening tests were limited to 1000-hr exposure in distilled and degassed water with no oxygen or hydrogen additions. Pertinent data for this medium are listed below:

Resistivity, ohm-cm at 25°C	650,000/750,000
Total solids, ppm	1 to 2
Chlorides, ppm	< 0.2
Carbon dioxide, ppm	< 5
pH	6.5 to 7.2

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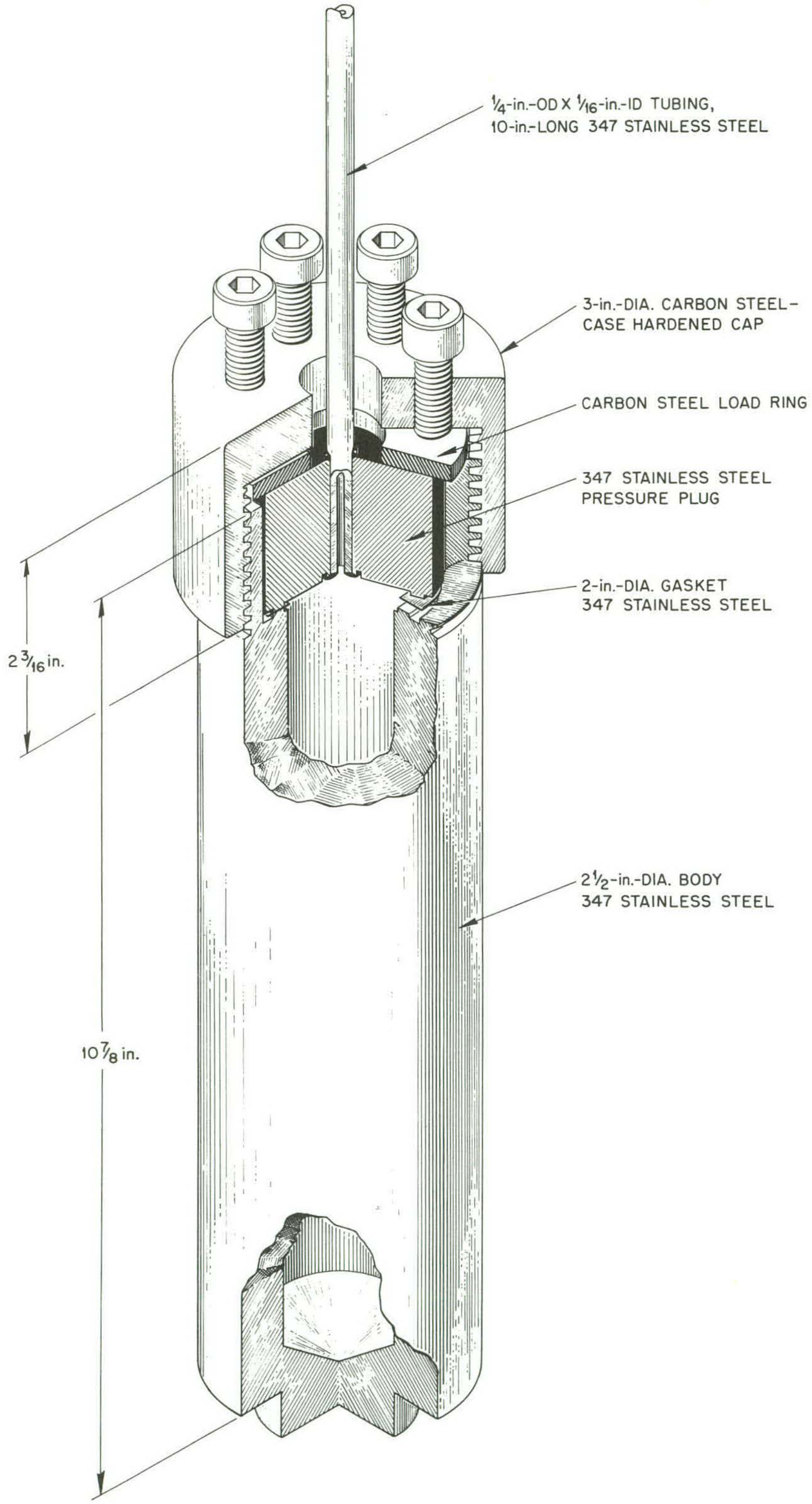

Fig. 4. Stainless Steel Autoclave Used for Corrosion Testing.

Fig. 5. Autoclave and Accessories Used in APPR Corrosion Testing Program.

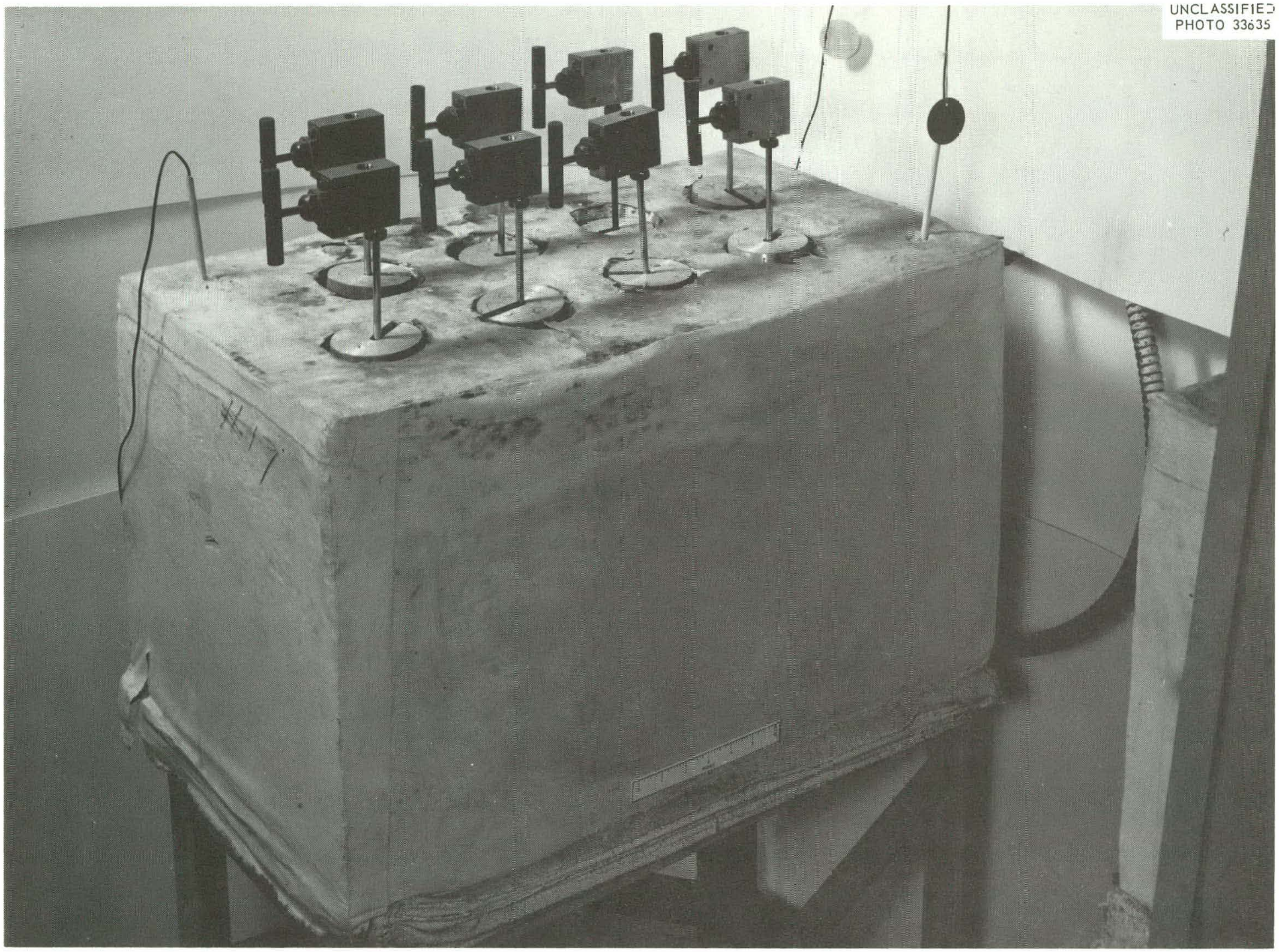

Fig. 6. Equipment Setup for APPR Autoclave Corrosion Testing.

Alloys selected from results of the screening tests were tested for at least 12 months. In one test, the water conditions were the same as cited above except that 1 cc O_2/liter was added. In another experiment, the alloys were tested in distilled water which contained additions of 1 cc O_2/liter and 50 cc H_2/liter. The hydrogen was added to evaluate the effect of different gaseous additions on corrosion behavior.

The procedure for charging the autoclaves is listed below:

1. The distilled water was boiled for 5 min.

2. The test specimen and 125 ml of water were added to the autoclave which was quickly sealed.

3. The autoclave and contents were frozen for 4 hr in dry ice.

4. After connecting the line to a vacuum manifold, the valve on the autoclave was opened and the system evacuated for 10 min.

5. Measured quantities of the desired hydrogen and/or oxygen were added to the autoclave by means of a system of valves and calibrated glass bulbs.

6. The valve on the autoclave was closed and the entire unit weighed to the nearest gram.

7. When tests continued in excess of one month, the autoclaves were cooled and weighed at monthly intervals to determine whether or not leakage of water had occurred. If a leak was encountered, the autoclave was recharged in accordance with the above procedures.

EVALUATION OF THE CORROSION RESISTANCE OF THE BRAZING ALLOYS

Evaluation of the corrosion resistance of the brazing alloys was based primarily on the results obtained from the metallographic examination of attack to the brazed fillets at the stainless steel joints. Subsequent to corrosion testing, each specimen was carefully bisected in an abrasive cutoff machine. To prevent rounding off of the fillet during polishing and thus destroying possible surface corrosion details, each section was plated with a thick layer of nickel. Examination of the metallographically prepared samples was conducted on a microscope equipped with a calibrated eyepiece. All specimens were examined in the as-polished condition and the depth of corrosive attack measured perpendicular to the fillet surface. Many of the samples were subsequently etched to determine, if possible, the nature of attack. Prior to examining the tested specimens, however, a representative brazed joint for each alloy was metallographically prepared to serve as the reference joint in performing the postcorrosion evaluation.

Weight-change data were obtained by weighing specimens before and after testing to within 0.1 mg. The comparative value of these results is masked, however, by the large ratio of stainless steel-to-brazing alloy surface area of the specimens used in these tests. The sample weight change was deemed necessary to detect whether uniform dissolution of the joint had occurred during corrosion testing.

EXPERIMENTAL RESULTS

1000-Hr Autoclave Screening Tests

A summary of the 1000-hr screening test results, which include weight-change data and comments from microstructural examination of the exposed joints, is presented in Table 2. The alloys were divided into two distinct groups on the basis of their corrosion resistance. Group I denotes alloys which offer good corrosion resistance, while Group II represents alloys which are inadequate for the proposed application, and hence, were not given further consideration. Although it appeared likely that all of the alloys in Group I would prove to be corrosion resistant after the planned long-time tests in static autoclaves, the list was further pared to the five (Nos. 2, 3, 6, 7, and 11) that offered the best potential of economical processing and good corrosion behavior in pressurized water.

Twelve- and Sixteen-Month Autoclave Tests

A summary of data for "T" joints brazed with the alloys selected from Table 2 and copper-base alloys containing 10 and 20 wt % Ni, respectively, is listed in Table 3. The copper-nickel alloys were added because of their

Table 2. Results of Autoclave Screening Tests of Brazed "T" Joints of Type 304L Stainless Steel and Various Brazing Alloys After 1000 Hr in 565°F Distilled Water at 1200 psi

Rating	Alloy Designation	Weight Change mg/cm^2	Nature of Attack	Depth of Attack (in., max)
		Group I (Good Corrosion Resistance)		
1	Gold-Nickel	-0.01	General	0.001
2	Low-Melting Nicrobraz	-0.01	Localized	0.0005
3	Palladium-Nickel-Silicon	-0.02	Localized	0.002
4	Palladium-Nickel	+0.03	General	0.0005
5	Nickel-Chromium-Phosphorus	+0.03	Localized	0.004
6	Coast Metals N.P.	-0.04	General	0.0015
7	General Electric No. 81	-0.05	General	0.0015
8	Coast Metals No. 51	-0.05	Localized	0.002
9	Coast Metals No. 50	-0.07	General	0.0015
10	Nicrobraz	-0.08	Intergranular	0.004
11	General Electric No. 75	-0.10	General	0.0015
12	Nicrobraz No. 10	-0.12	Localized	0.0005
13	Nickel-Tin	-0.17	General	0.002
		Group II (Poor Corrosion Resistance)		
14	Copper	-0.21	General	0.0015
15	Manganese-Nickel	-0.21	Complete destruction of fillet	
16	B.T. Solder	-0.50	Complete destruction of fillet	
17	Copper-Silicon	-0.79	Severe intergranular attack	
18	Coast Metals No. 52	-1.04	Severe intergranular attack	

Table 3. Weight-Change Data on Selected Brazed Specimens[a] Tested for 12 and 16 Months in 565°F, 1200-psi Water

Specimen Identification by Brazing Alloy	Weight Change (mg/cm^2)	
	Test Condition No. 1[b]	Test Condition No. 2[c]
Coast Metals N.P.	negligible	-0.42
General Electric No. 81	+0.47	-0.07
Low-Melting Nicrobraz	negligible	-0.08
General Electric No. 75	+0.14	-0.13
Palladium-Nickel-Silicon	-0.07	negligible
80 Cu–20 Ni	-0.46	negligible
90 Cu–10 Ni	-0.62	-0.05

[a]Base metal was type 304L stainless steel.

[b]11,616 hr with 1 cc O_2/liter added.

[c]7,536 hr with 1 cc O_2/liter and 50 cc H_2/liter added.

inherent ductility and potential corrosion resistance.[6] Weight-change data admittedly reflect the corrosion resistance of the stainless steel and little correlation with effects observed metallographically can be made. Emphasis in analyzing the results was, therefore, placed on the condition of the corrosion tested joints as observed through the microscope. The metallographic evaluation for each of the brazing alloys listed in Table 3 is subsequently presented.

Coast Metals N.P.

Figures 7 and 8 illustrate the general effect on the brazed joint when exposed for 16 months in pressurized water with 1 cc O_2/liter added. Corrosion at the fillets is evident. As illustrated in Fig. 8, the corrosion attack appears solely in the matrix with localized penetration to

[6]Taylor Lyman (ed.) Metals Handbook, vol I, p 1030, American Society for Metals, Novelty, Ohio, 1961.

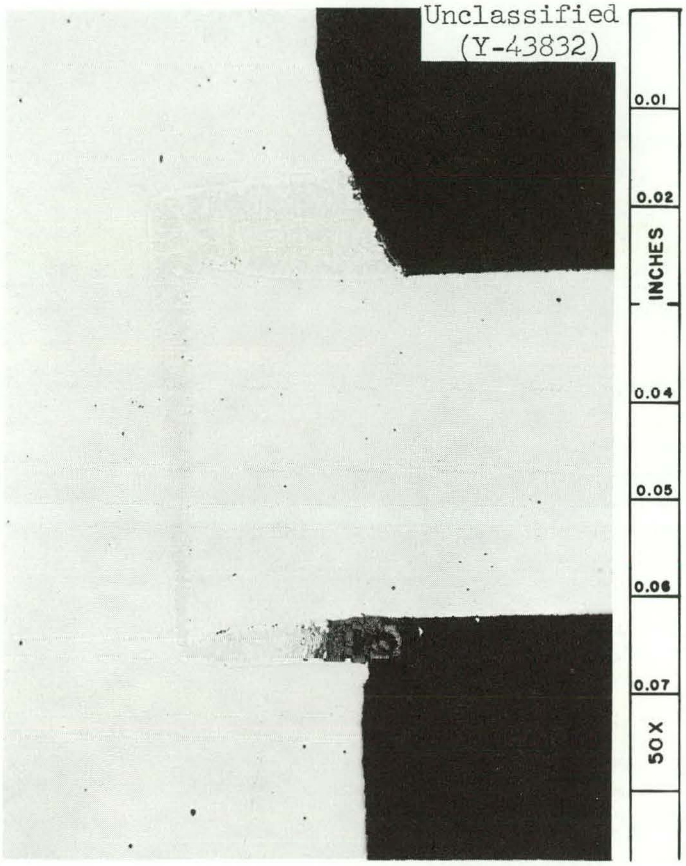

Fig. 7. Type 304L Stainless Steel Joint Brazed with Coast Metals N.P. and Autoclave Tested for 16 Months in Distilled Water Containing 1 cc O_2/liter at 565°F and 1200 psi. Etchant: 10% oxalic acid.

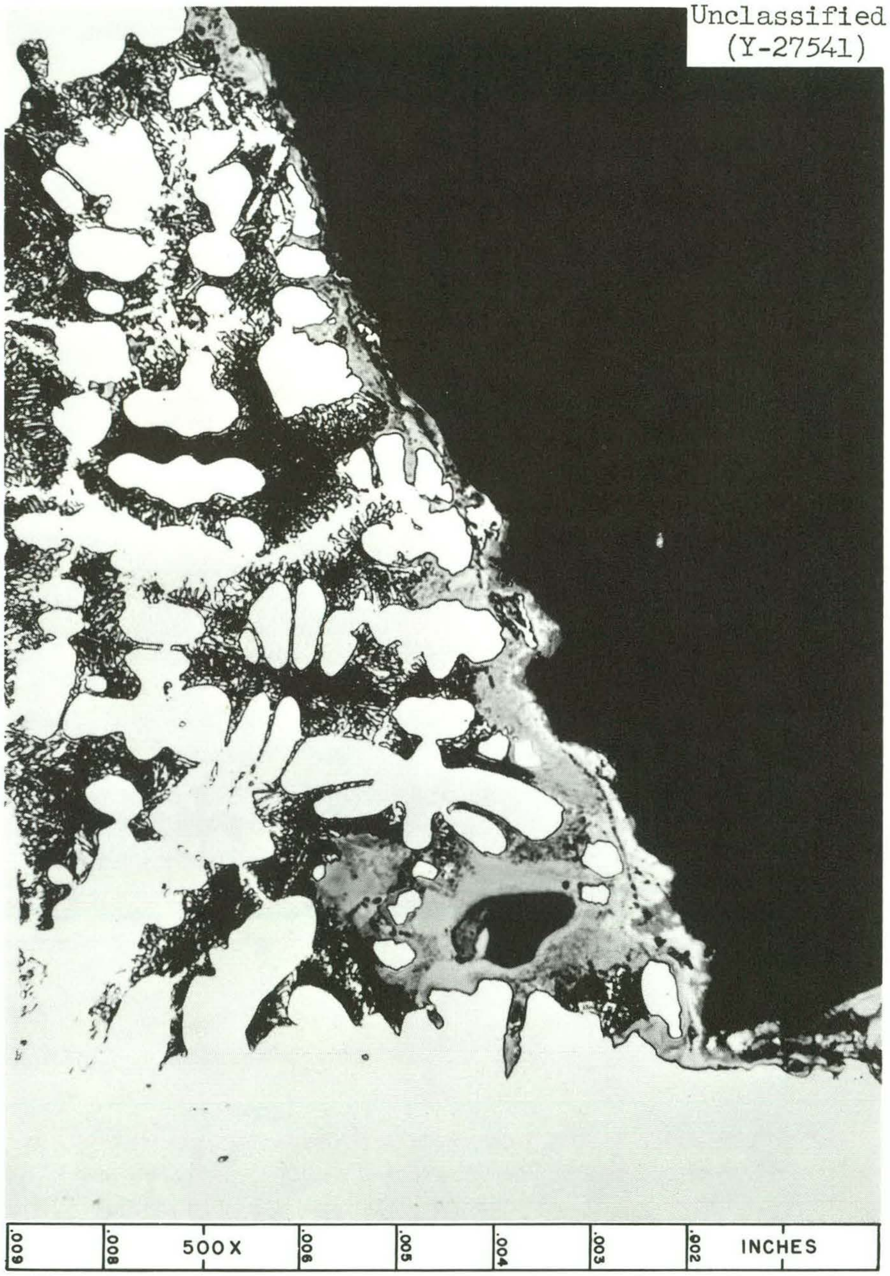

Fig. 8. Corrosion of Brazed Fillet of Coast Metals N.P. Joined to Type 304L Stainless Steel After 16 Months in Static 565°F, 1200 psi Distilled Water Containing 1 cc O_2/liter. Etchant: 10% oxalic acid.

a depth of 0.002 in. The white primary phase exhibited excellent corrosion resistance. The corrosion does not seem to be catastrophic in nature and it is anticipated that the joint would not be severely weakened after exposures as long as 24 months. Figure 9 and 10 show the effect of corrosion when 50 cc H_2/liter are added. The addition of hydrogen does not appear to change the corrosion rate significantly.

General Electric No. 81

The corrosion of this alloy was quite similar to that of Coast Metals N.P. The additions of hydrogen made no significant change in appearance of the joint. Figures 11, 12, and 13, which show the effect after exposure for 16 months in pressurized water with 1 cc O_2/liter added, are representative of those exposed in water with hydrogen additions. Figure 11 illustrates the general appearance of the General Electric No. 81 brazed joint while the general attack to the matrix of the braze metal is illustrated in Fig. 12. Specific detail can be seen in Fig. 13. As with Coast Metals N.P., penetration into the matrix to a depth of 0.002 in. is evident with the primary phase exhibiting excellent corrosion resistance.

General Electric No. 75

The corrosion resistance of this alloy appeared to be somewhat better than Coast Metals N.P. and General Electric No. 81. The corrosion mechanism was quite similar (attack of the matrix with the primary phase highly corrosion resistant). Penetration appeared to be 0.001 in. These effects are illustrated in Figs. 14, 15, and 16.

Low-Melting Nicrobraz

This alloy exhibited good corrosion resistance in the 16-month test. Corrosion appeared to be the same whether the water contained 1 cc O_2/liter or 1 cc O_2/liter and 50 cc H_2/liter. As shown in Fig. 17, the good behavior

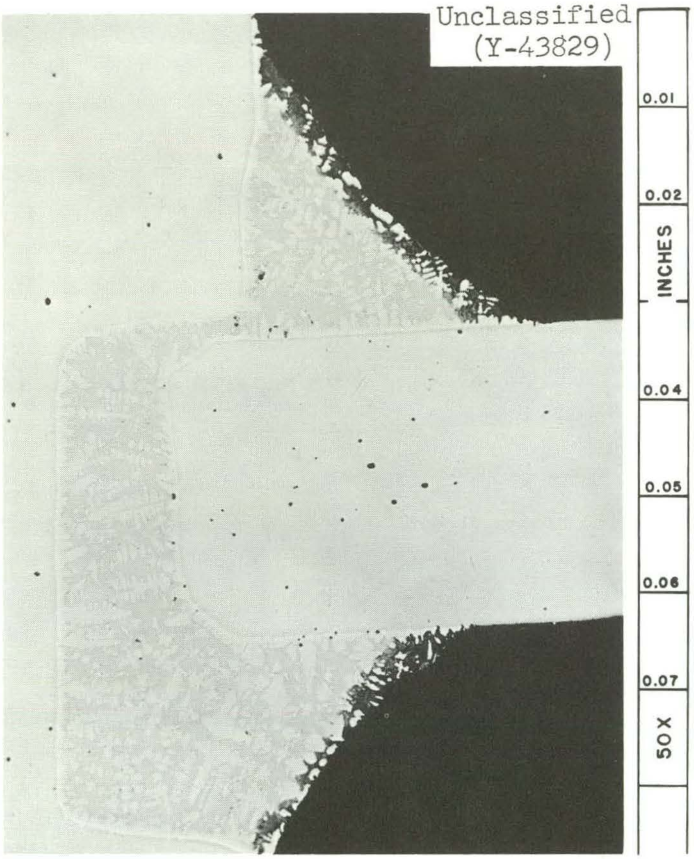

Fig. 9. Type 304L Stainless Steel Joint Brazed with Coast Metals N.P. and Autoclave Tested for 12 Months in Distilled Water Containing 50 cc H_2/liter and 1 cc O_2/liter. Etchant: 10% oxalic acid.

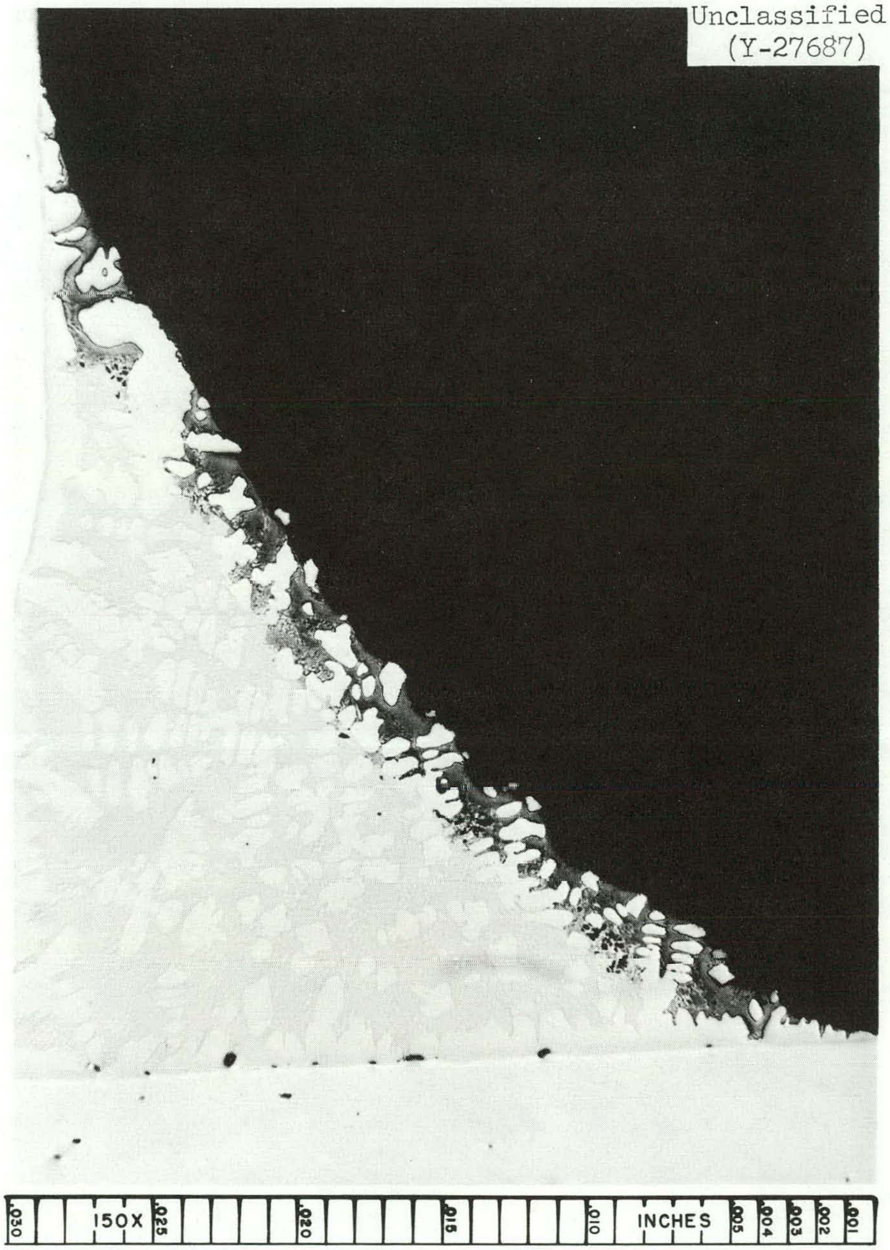

Fig. 10. Corrosion of Brazed Fillet of Coast Metals N.P. Joined to Type 304L Stainless Steel After 12 Months in Static 565°F, 1200 psi Distilled Water Containing 50 cc H_2/liter and 1 cc O_2/liter. Etchant: 10% oxalic acid.

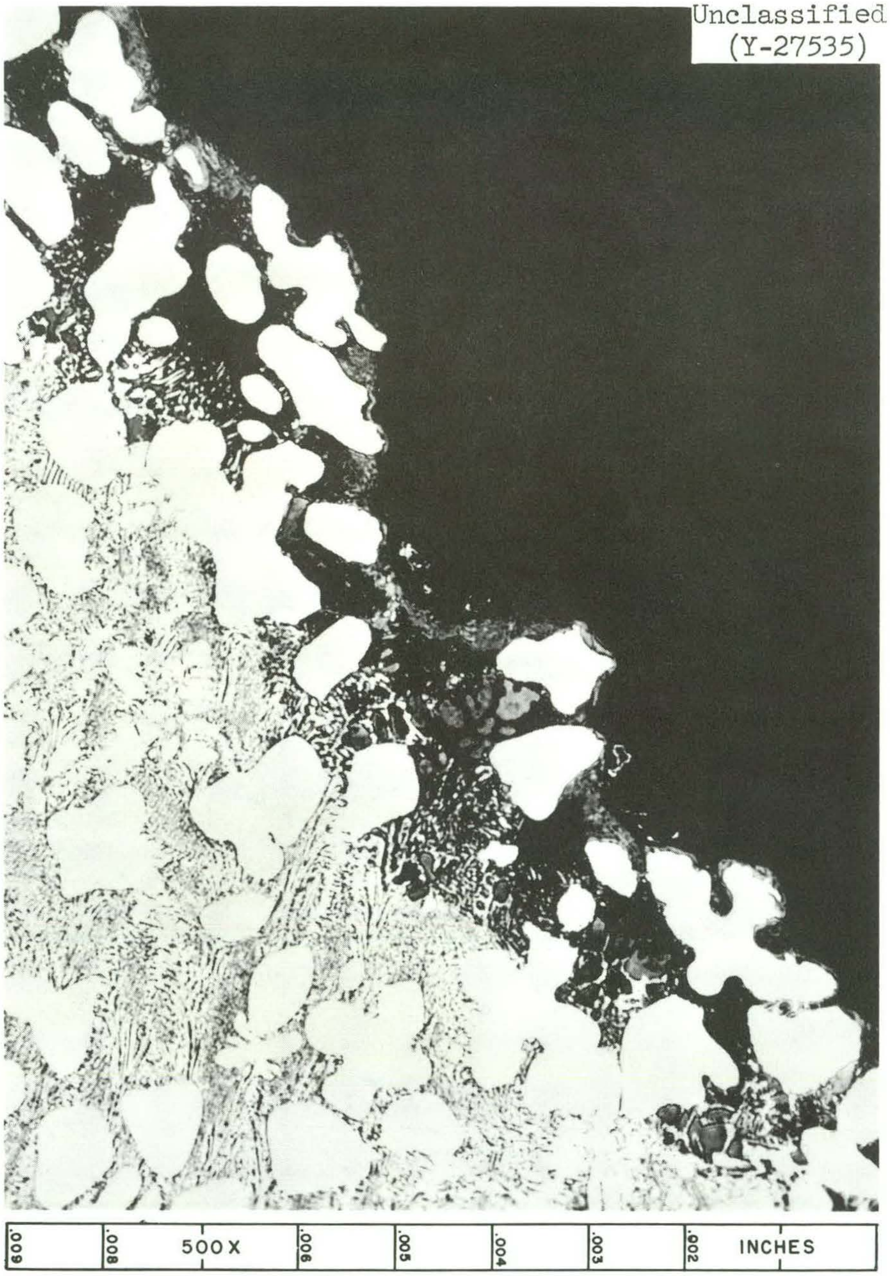

Fig. 11. Corrosion of Brazed Fillet of Coast Metals N.P. Joined to Type 304L Stainless Steel After 12 Months in Static 565°F, 1200 psi Distilled Water Containing 50 cc H_2/liter and 1 cc O_2/liter. Etchant: 10% oxalic acid.

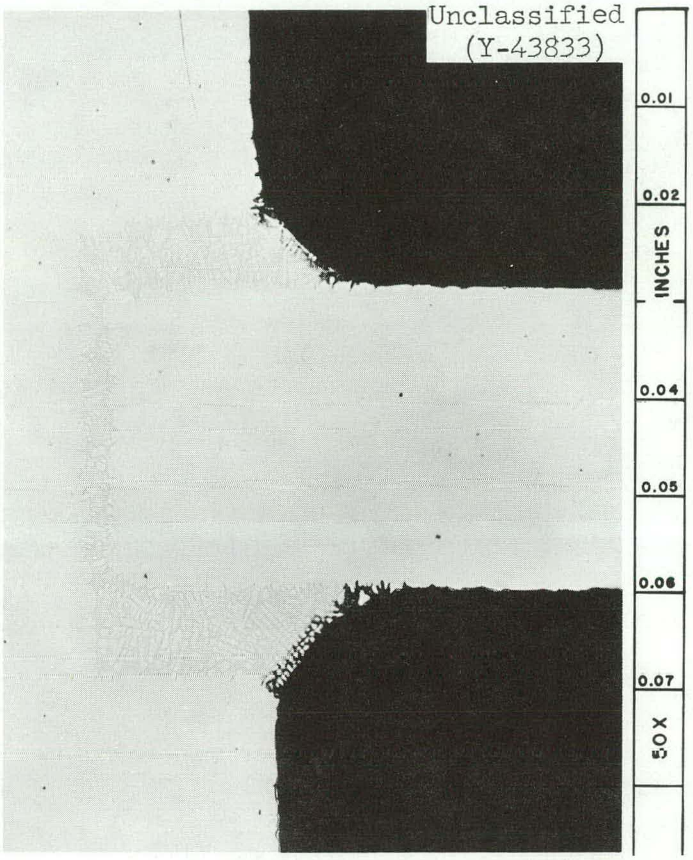

Fig. 12. Type 304L Stainless Steel Joint Brazed with General Electric No. 81 and Autoclave Tested for 16 Months in Distilled Water Containing 1 cc O_2/liter at 565°F and 1200 psi. Etchant: 10% oxalic acid.

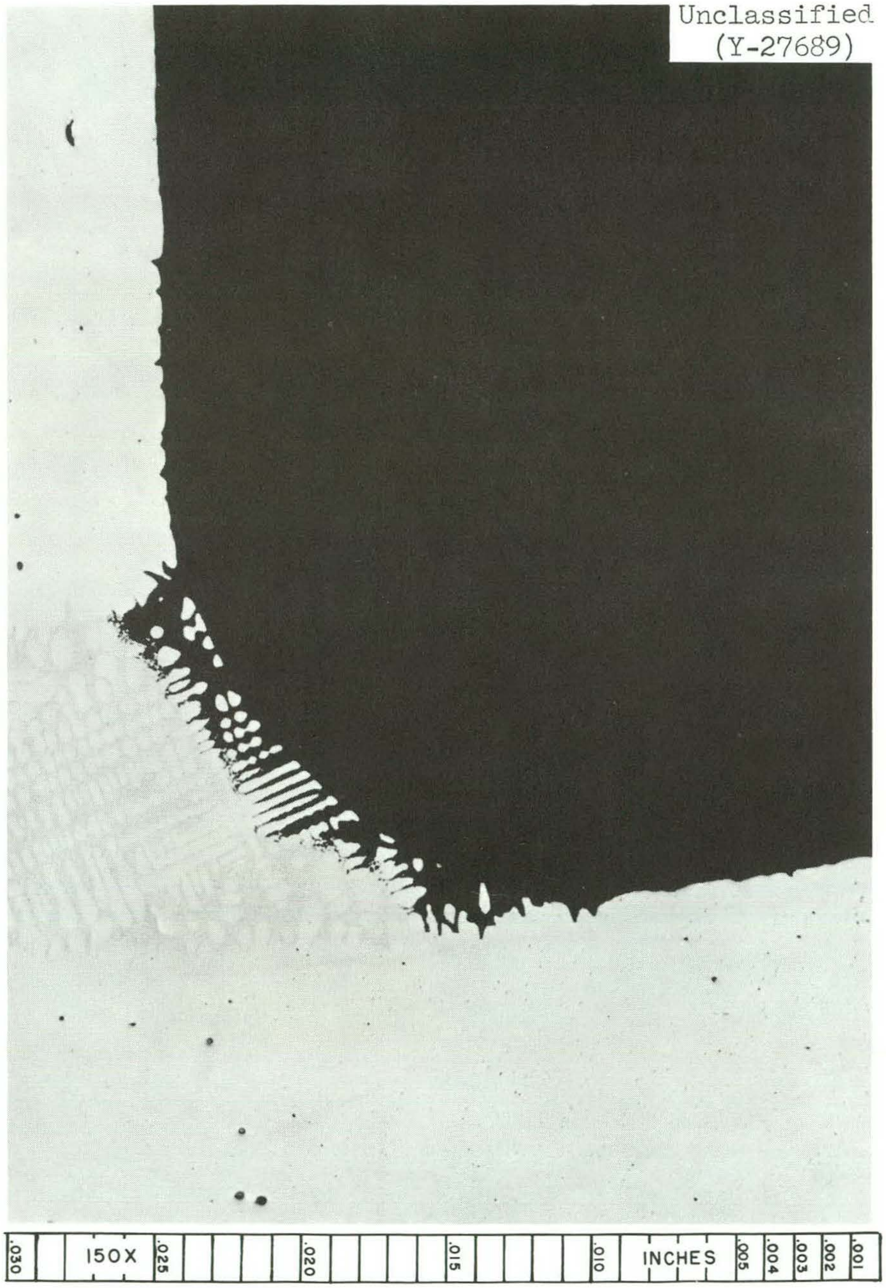

Fig. 13. Corrosion of Brazed Fillet of General Electric No. 81 Joined to Type 304L Stainless Steel After 16 Months in Static 565°F, 1200 psi Distilled Water Containing 1 cc O_2/liter. As polished.

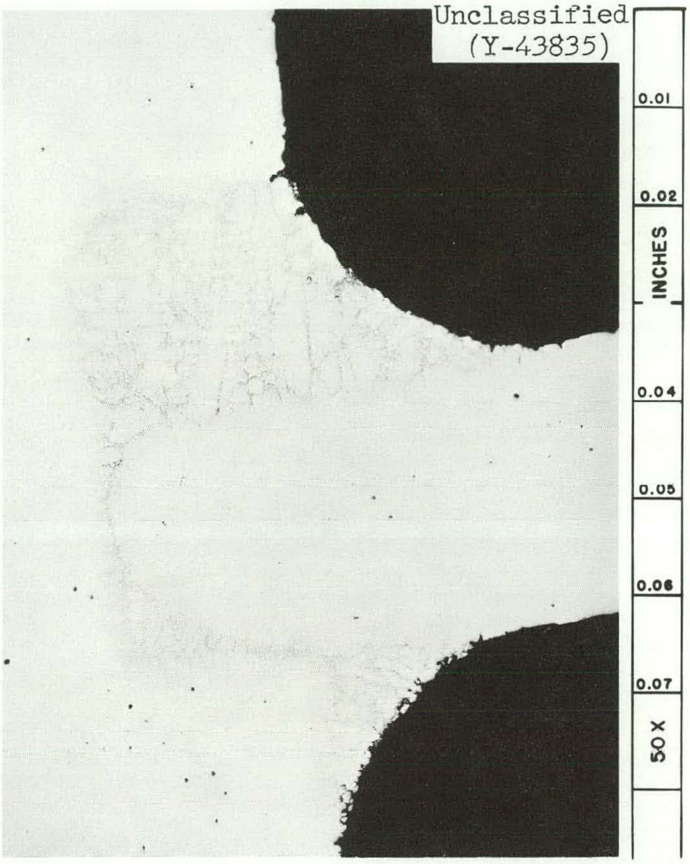

Fig. 14. Type 304L Stainless Steel Joint Brazed with General Electric No. 75 and Autoclave Tested for 16 Months in Distilled Water Containing 1 cc O_2/liter at 565°F and 1200 psi. Etchant: 10% oxalic acid.

Fig. 15. Corrosion of Brazed Fillet of General Electric No. 75 Joined to Type 304L Stainless Steel After 16 Months in Static 565°F, 1200 psi Distilled Water Containing 1 cc O_2/liter. As polished.

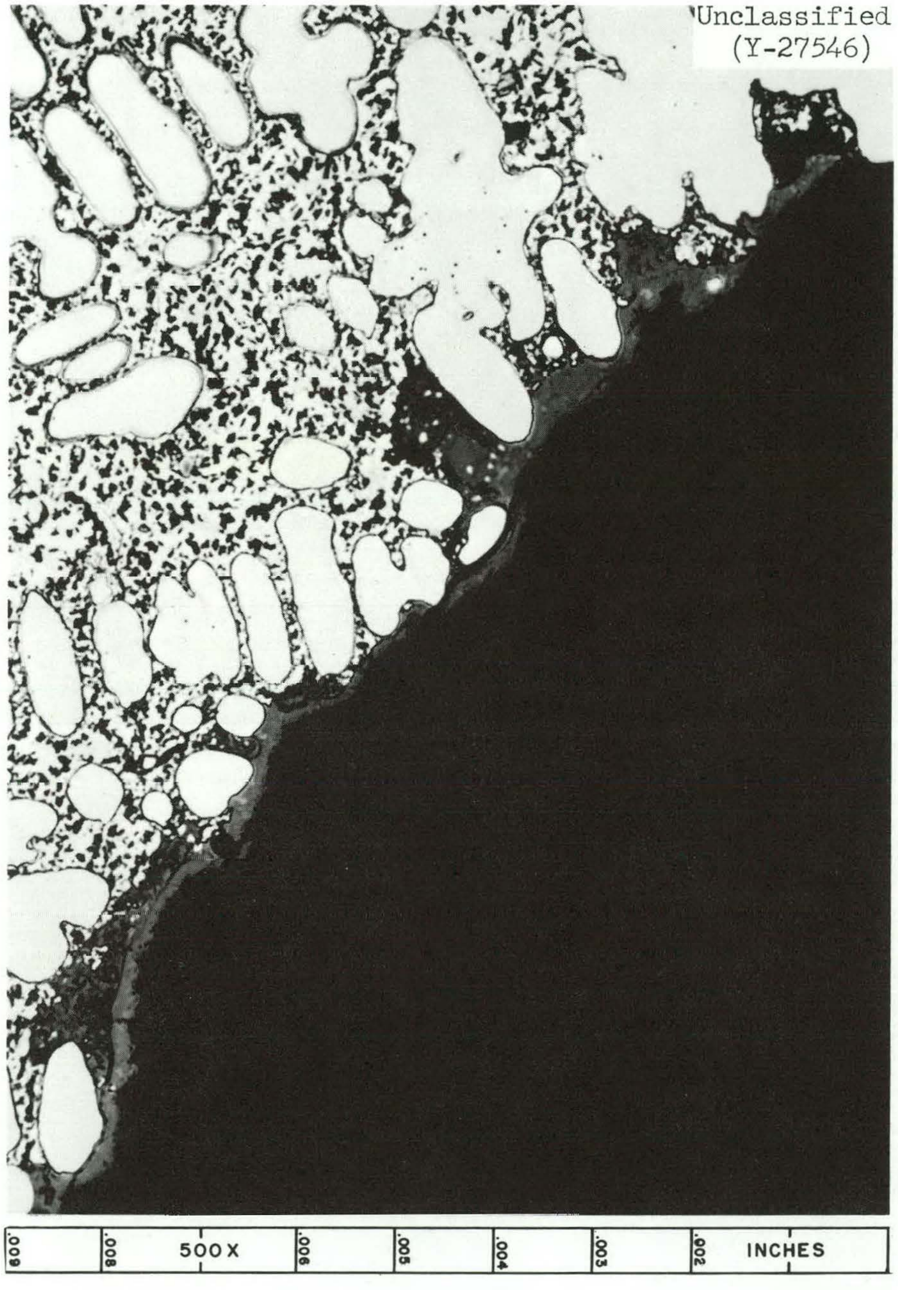

Fig. 16. Corrosion of Brazed Fillet of General Electric No. 75 Joined to Type 304L Stainless Steel After 16 Months in Static 565°F, 1200 psi Distilled Water Containing 1 cc O_2/liter. Etchant: 10% oxalic acid.

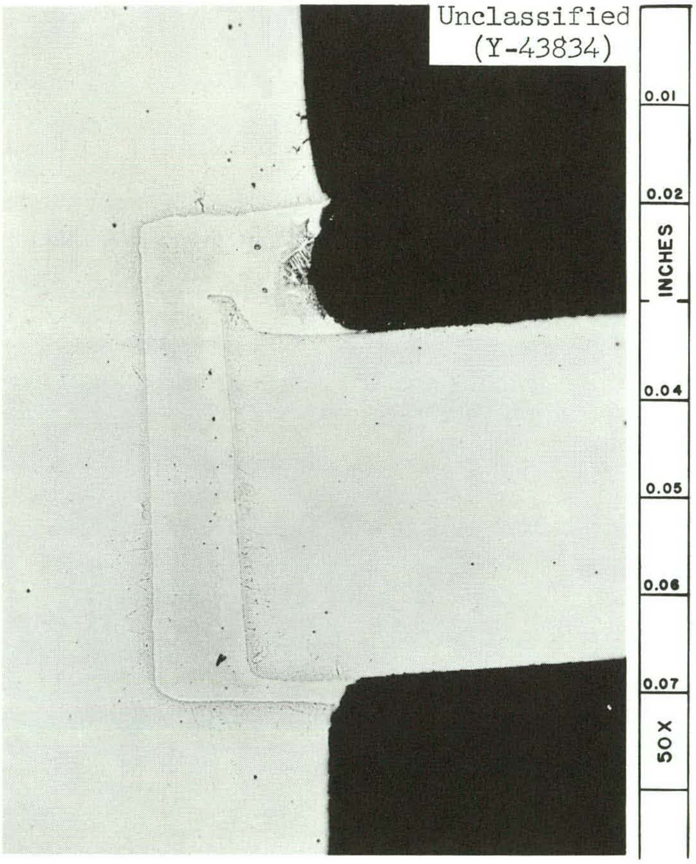

Fig. 17. Type 304L Stainless Steel Joint Brazed with Low-Melting Nicrobraz and Autoclave Tested for 16 Months in Distilled Water Containing 1 cc O_2/liter at 565°F and 1200 psi. Etchant: 10% oxalic acid.

of this alloy may be due to the presence of a single, apparently very corrosion resistant phase, particularly in locations where joint clearances were less than 0.003 in.

Palladium-Nickel-Silicon

This alloy exhibited excellent corrosion resistance in the 16-month test. Corrosion appeared to be the same regardless of oxygen and/or hydrogen additions. As illustrated in Fig. 18, there is some evidence of localized fissuring extending 0.007 in. into the brazed fillet. General attack, however, appeared to be limited to less than 0.001 in.

Copper-Nickel Alloys

The corrosion resistance of an 80% Cu–20% Ni alloy in pressurized water with 1 cc O_2/liter added was poor, as evidenced by the attack illustrated in Fig. 19. A marked improvement was observed when 50 cc H_2/liter were added. This is evident in a comparison of Fig. 19 with Fig. 20. Increasing the copper content to 90% appeared to somewhat decrease the corrosion resistance in the water containing 50 cc H_2/liter. This effect can be seen by comparing Fig. 21 with Fig. 20. It is to be observed, however, in the specimen brazed with the 90% Cu–10% Ni alloy that small clearances at the stainless steel joints appear to be desirable.

GENERAL EVALUATION OF BRAZING ALLOYS

Based on these tests, it was felt that there was no great difference between Coast Metals N.P., General Electric No. 81, General Electric No. 75, Low-Melting Nicrobraz, and the palladium-nickel-silicon alloy. They all appeared to be sufficiently corrosion resistant for the required application. Copper containing 10 and 20 wt % Ni seemed to offer some promise if the hydrogen in the reactor coolant could be controlled. Coast Metals N.P. and General Electric No. 81 were considered more favorable selections than the others by the following reasoning:

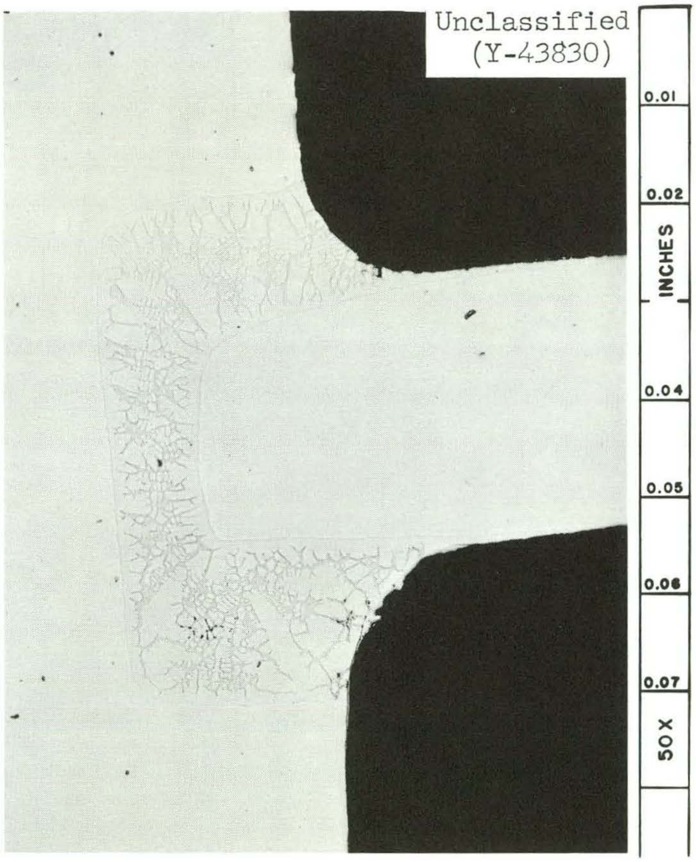

Fig. 18. Type 304L Stainless Steel Joint Brazed with 60% Pd–37% Ni–3% Si Alloy and Autoclave Tested for 16 Months in Distilled Water Containing 1 cc O_2/liter at 565°F and 1200 psi. Etchant: 10% oxalic acid.

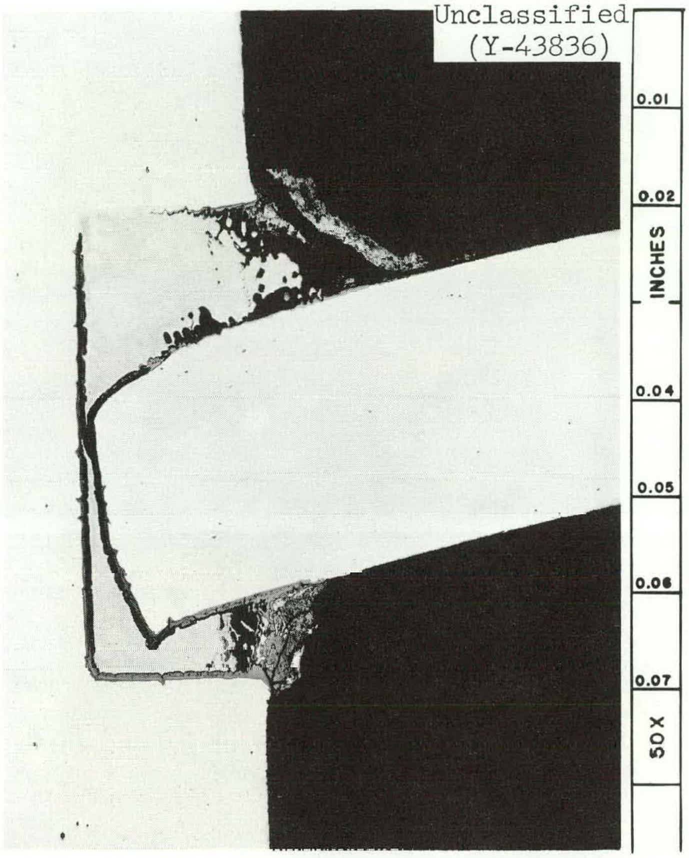

Fig. 19. Type 304L Stainless Steel Joint Brazed with 80% Cu–20% Ni Alloy and Autoclave Tested for 16 Months in Distilled Water Containing 1 cc O_2/liter at 565°F and 1200 psi. Etchant: 10% oxalic acid.

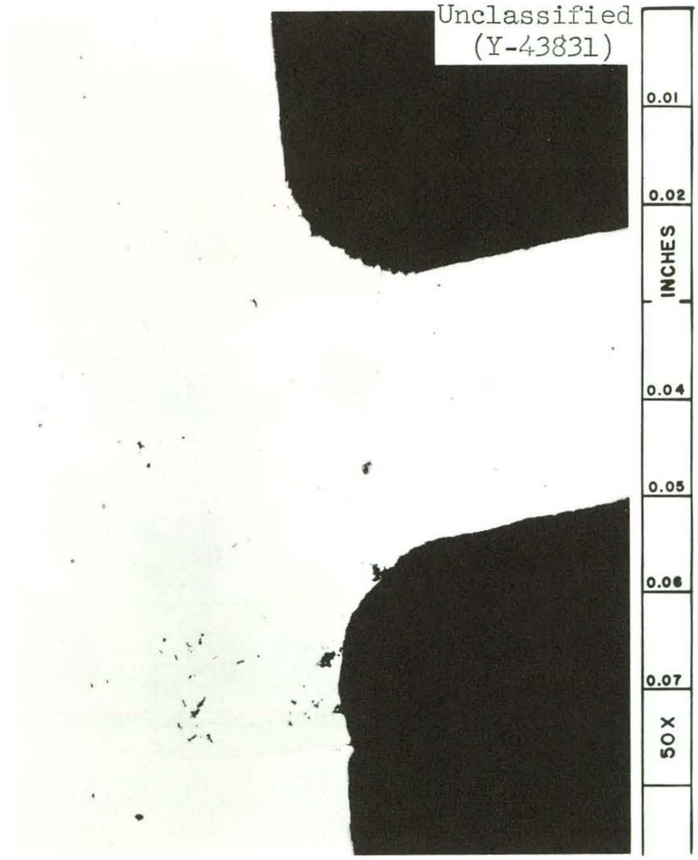

Fig. 20. Type 304L Stainless Steel Joint Brazed with 80% Cu-20% Ni Alloy and Autoclave Tested for 12 Months in Distilled Water Containing 50 cc H_2/liter and 1 cc O_2/liter at 565°F and 1200 psi. Etchant: 10% oxalic acid.

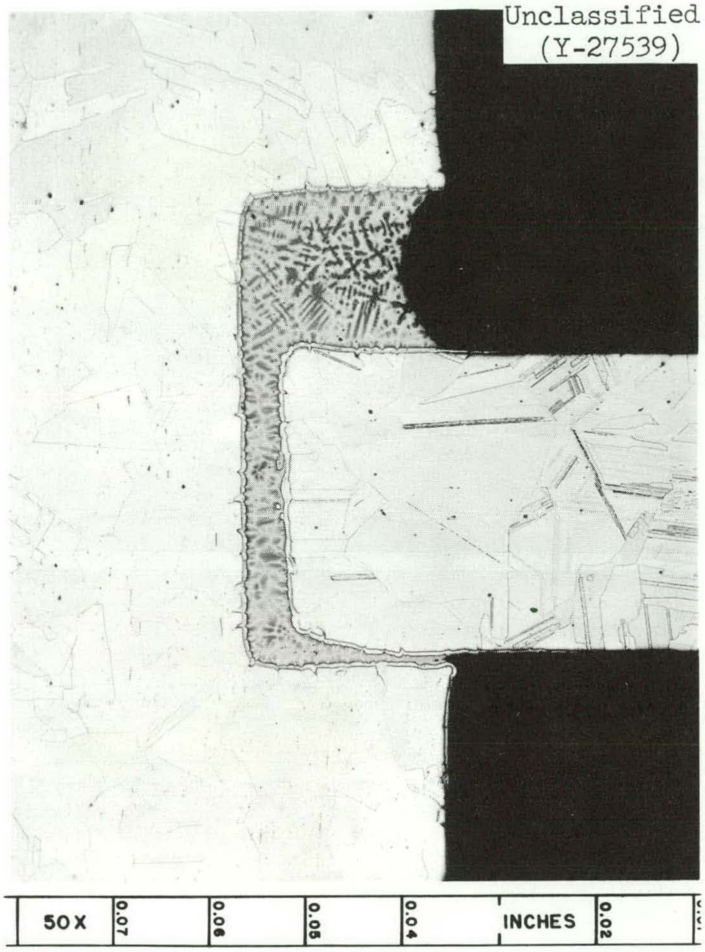

Fig. 21. Type 304L Stainless Steel Joint Brazed with 90% Cu–10% Ni Alloy and Autoclave Tested for 12 Months in Distilled Water Containing 50 cc H_2/liter and 1 cc O_2/liter at 565°F and 1200 psi. Etchant: 10% oxalic acid.

1. Palladium-nickel-silicon and General Electric No. 75 contain expensive alloying elements and have inconveniently higher melting temperatures.

2. Low-Melting Nicrobraz contains boron which is generally undesirable from the standpoint of its high absorption of thermal neutrons and susceptibility to radiation damage from generated helium.

3. Copper-nickel alloys have marginal corrosion resistance.

CONCLUSIONS

The main conclusions which are a direct outgrowth of this corrosion testing program and of interest to the Pressurized Water Reactor Program of the Army are enumerated below:

1. Coast Metals N.P. shows good performance in quiescent 565°F pressurized water. Metallographic examination indicates degradation by corrosion. It is preferred over other alloys as the reference brazing alloy for the SM-1 fuel element because it is more amenable to the brazing operation required in the manufacture of this fuel element.

2. Several other alloys exhibit good corrosion resistance in quiescent 565°F pressurized water. Prominent in this group are General Electric No. 81, General Electric No. 75, Low-Melting Nicrobraz, and a palladium-base alloy containing 37 wt % Ni and 3 wt % Si.

3. Hydrogen and oxygen additions in the range studied have little effect on the corrosion resistance of the brazing alloys cited above.

4. The corrosion resistance of copper-nickel alloys containing 10 and 20 wt % Ni, respectively, is marginal in quiescent 565°F pressurized water.

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