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EXPERIMENTAL STUDY TO EVALUATE CORROSION OF THE F-CANYON DISSOLVER DURING THE UNIRRADIATED MARK-42 CAMPAIGN

Kerry A. Dunn
John I. Mickalonis

Savannah River Technology Center
Strategic Materials Technology Department
Materials Applications & Corrosion Technology

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Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

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Experimental Study To Evaluate Corrosion Of The F-Canyon Dissolver During The Unirradiated Mark-42 Campaign (U)

Task Leaders: K. A. Dunn and J. I. Mickalonis

APPROVALS:

K. A. Dunn ____________________ Date ______________
Task Leader

J. I. Mickalonis ____________________ Date ______________
Task Leader

G. T. Chandler ____________________ Date ______________
Manager Materials Performance And Corrosion Technology Group

N. C. Iyer ____________________ Date ______________
Manager Materials Technology Section

J. Greggi, Jr. ____________________ Date ______________
NMSS Customer

1 Summary

Unirradiated Mark 42 fuel tubes are to be dissolved in an upcoming campaign in F-canyon. Savannah River Technology Center (SRTC)/Chemical & Hydrogen Technology Section (CHTS) identified a flow sheet for the dissolution of these Mark 42 fuel tubes which required a more aggressive dissolver solution than previously required for irradiated Mark 42 fuel tubes. Subsequently, SRTC/MTS was requested to develop and perform a corrosion testing program to assess the impact of new flow sheets on corrosion of the dissolver wall. The two primary variables evaluated were the fluoride and aluminum concentrations of the dissolver solution. Fluoride was added as Calcium Fluoride (CaF_2) while the aluminum was added either as metallic aluminum, which was subsequently dissolved, or as the chemical aluminum nitrate ($Al(NO_3)_3$). The dissolved aluminum metal was used to simulate the dissolution of the aluminum from the Mark 42 cladding and fuel matrix. Solution composition for the corrosion tests bracketed the flow sheet for the Mark 42.

Corrosion rates of AISI Type 304 stainless steel coupons, both welded and non-welded coupons, were calculated from measured weight losses and post-test concentrations of soluble Fe, Cr and Ni. The corrosion rates, which ranged between 2.7 and 32.5 mpy, were calculated from both the one day and the one week weight losses. These corrosion rates indicated a relatively mild corrosion on the dissolver vessel. The welded coupons consistently had a higher corrosion rate than the non-welded coupons. The difference between the two decreased as the solution aggressiveness decreased. In these test solutions, aggressiveness corresponded with the fluoride concentration. Based on the results of this study, any corrosion occurring during the Mark 42 Campaign is not expected to have a deleterious effect on the dissolver vessel.

2 Introduction

Unirradiated Mark 42 fuel tubes are to be dissolved in an upcoming campaign in F-canyon. SRTC/CHTS has identified a flow sheet for the dissolution of the unirradiated Mark 42 fuel tubes [1]. This flow sheet identifies that a more aggressive dissolver solution will be required for the unirradiated Mark 42 campaign than was needed for the previous irradiated Mark 42 campaigns. The dissolver solution for the unirradiated fuel tubes will contain boron to prevent criticality and higher fluoride concentrations than previously required. Higher fluoride concentrations will accelerate corrosion and limit the lifetime of the dissolver. SRTC/MTS developed a corrosion testing program [2] to assess the impact of the new flow sheet solutions on dissolver corrosion. The program involves conducting coupon immersion corrosion tests in solutions with chemistries that bracket those specified in the flow sheet. The results from this program will be used to modify the technical standards for unirradiated Mark 42 fuel tubes.

For the unirradiated Mark 42 fuel tubes, the primary variables that affect dissolver corrosion are the fluoride, aluminum, and boron concentrations. The aluminum is present from the Mark 42 fuel tube cladding and fuel matrix. Boron is added to minimize the occurrence of criticality and the higher fluoride concentrations are required because of the longer dissolution times and the complexing of the fluoride by boron and aluminum

For the corrosion testing program, the primary test variables were the aluminum concentration of the dissolver solution and the weld condition of the test samples. The fluoride and boron were added at constant concentrations that are presently being used by Nuclear Materials Stabilization and Storage (NMSS) personnel. Two sources of aluminum were used to prepare the test solutions; either metallic aluminum, which was subsequently dissolved, or aluminum nitrate. The dissolved aluminum was used to simulate the dissolution of the aluminum from the Mark 42 cladding and fuel matrix. Dissolved aluminum reduces the molar acidity of the dissolution solution which should impact corrosion. Compositional ranges for fluoride and aluminum were tested to evaluate the impact of these variables on the corrosion rate. The test samples were made from non-welded and welded AISI Type 304 stainless steel.

2 Experimental Setup

The experimental program was conducted following the guidelines in the Conduct of Research and Development–Savannah River Technology Center [3]. All steps in the program, including solution and coupon preparation, test setup, and solution and coupon analyses were carefully documented and are described below. The corrosion testing program was patterned after ASTM standard practice G31-72 [4]. Experimental details and results have been recorded in notebook, WSRC-NB-97-00510 [5].

An important aspect of the experimental program was determining the effective fluoride concentration. The complexing of the fluoride, by boron, aluminum, and hydronium ions, reduces the fluoride concentration for dissolution of the fuel. These measurements which are discussed below involved the measurement of free fluoride concentrations with an ion selective electrode both before and after testing.

3.1 Solution Preparation

The compositional ranges for the test solutions bracketed those specified by the SRTC/CHTS flowsheet. These ranges are shown in Table 1. Solution preparation was performed using task specific instructions.

All solutions were made from a master solution containing 8M nitric acid with 1.8g/L boron (2.2 M). Two groups of solutions, designated by the source of aluminum, were prepared from the master solution. The aluminum was added as either dissolved metallic aluminum (Type 6063) or aluminum nitrate ($Al(NO_3)_3 9H_2O$). Three batches of master solution were prepared for each solution group to which a different fluoride concentration was added. A quantity of calcium fluoride was used to obtain 0.2, 0.3, and 0.4M fluoride concentrations. Finally, each fluoride solution was divided into three portions to which one of the molar quantities of aluminum (0.2, 0.3, and 0.5M) was added. Metallic aluminum was added to boiling solutions. Glass vessels were not used to minimize glass dissolution. The complete matrix of 18 test solutions is shown in Table 2. Analyses of the fluoride concentration and overall solution chemistry were performed prior to and after testing. These analyses are described below.

3.2 Coupon Preparation

The F-Canyon dissolver is made from AISI Type 304L (304L) stainless steel. Type 304L stainless steel is a low carbon alternative to Type 304 (304) stainless steel. The F-Canyon dissolver vessel contains several types of welds and corrosion of weld regions can differ from base material since microstructural and chemical changes occur during the welding process. Consequently, several coupon types and materials were used including non-welded 304L, and both welded and non-welded 304. The 304 coupons were used because of availability and time restraints for testing. A lower carbon content in 304L minimizes carbide precipitation in the heat-affected zones of the weld region. Carbide precipitates make the material more susceptible for intergranular attack. As a result, the 304 coupons provided an added measure of conservatism to the testing.

Dimensions of the 304 non-welded coupons were 0.755”x3.002”x0.114” and dimensions of the 304 welded coupons were 1.0”× 2.0” × 0.0625” with a 0.25” central hole. The surface of each coupon was prepared using standard metallographic techniques to obtain a 600 grit surface finish. Each coupon was weighed on a calibrated digital balance to the thousandth decimal place (0.0000 g). After weighing, a Teflon string was attached to each coupon through the small hole near one end. All coupons were stored in a dessicator until they were placed into test.

3.3 Test Setup

Teflon® bottles were used as the test vessels to hold each solution. Teflon® was chosen since it is chemically resistant to nitric acid and fluoride ions and can withstand the test temperature. A welded and a non-welded coupon were hung in each bottle. The coupons were attached to the bottle lid so they could be easily removed from the bottle to be weighed. Each coupon was suspended to ensure complete immersion in the solution. A Teflon® tape was used on the bottleneck to minimize evaporation. All 18 bottles were placed on a stainless steel tray and positioned within an oven at 90°C.

After one day of testing, the coupons were weighed to determine a short-term corrosion rate. Each bottle was removed one at a time from the furnace. Coupons were detached, rinsed with distilled water, and dried prior to weighing. After weighing, the coupons were re-attached to the cap, immersed in the same solution, then placed in the 90°C oven for the remainder of the test.

After one week exposure, the bottles were removed from the furnace and cooled to room temperature. The coupons were detached from the lid, rinsed with distilled water, dried, and weighed. The one-week weight loss was used to calculate an extended corrosion rate. Each coupon was then stored in a dessicator for further metallurgical evaluation. A post-test chemical analysis was performed on select solutions.

3.4 Solution Analyses

Chemical analysis was performed by SRTC/Analytical Development Section (ADS). The solutions were analyzed for the following constituents: Al, Fe, Cr, Ni, and B by Ion Chromatograph Plasma Enhanced Spectroscopy (ICPES); nitrates, chlorides, and total fluorides by Ion Chromatograph for Anions; fluoride by Ion Selective Electrode (ISE), and total acid by titration. For the ISE measurements, CDTA is added to the test samples to buffer the solution to a neutral pH. CDTA breaks the complexes formed with fluorides by aluminum and iron. Eight solutions were analyzed including Group I-1 A&C, I-3 A&C and Group II-1 A&C, and II-3 A&C (see Table 2).

3.5 Free Fluoride Measurements

The "effective" free fluoride concentration was measured in the test solutions using the ISE technique. The terminology of "effective" free fluoride is used because solution fluoride is complexed by the aluminum, boron and hydronium ions. These fluoride atoms are not active in the corrosion process. The ISE measurement is a solution potential (mV) which varies depending on solution composition, i.e. fluoride concentration. Standard calibrating solutions were prepared using known fluoride concentrations (ppm) and 8M nitric acid. This calibrated solution chemistry matched the test solution matrix, which affects the "effective" free fluoride concentration. The calibrating fluoride concentrations ranged from 9.5 to 4,750 ppm. During the tedious preparation of these standard solutions, care was exercised to minimize cross contamination of containers or stirring medium. These standard solutions were used to generate a calibration curve, solution potential versus "effective" free fluoride concentration. Solution potentials of the test solutions were then measured and "effective" free fluoride concentrations were determined from the calibrating curve.

3.6 Coupon Analysis

The coupons were evaluated visually for characterizing the corrosion process(es). The coupons were photographed to document this condition. Two welded coupons were also evaluated on a microscopic scale using standard metallographic techniques. The coupons were sectioned transversely to the length, mounted in an epoxy resin, ground, and polished. Prior to observation, the coupons were electrolytically etched with a 10 wt% oxalic acid solution. The degradation and microstructure were evaluated using an optical metallograph. Micrographs were taken to document the findings.

4 Results

From the experimental program, calculated corrosion rates were found to increase for 304 stainless steel with increasing fluoride concentration, either total or "effective" free. These relationships differ and show the complexity of the fluoride chemistry on the corrosion and dissolution. A better understanding of these relationships and the expected effect on the dissolver were obtained from the test results including weight losses, solution analysis, and visual evaluations of coupons.

4.1 Corrosion Rates

The corrosion rates for 304 in the dissolution solutions were calculated from the coupon weight losses. The weight losses were determined from the initial, one-day, and final weight measurements. The corrosion rate in mils per year (mpy) was calculated from the following equation:

$$CorrosionRate = [C * (W)] \div [\rho * A * t] \qquad (1)$$

where C = corrosion constant ($3.45x10^6$)
W = weight loss (g)
ρ = density of stainless steel (g/cc)
A = surface area of coupon (cm^2)
T = time (hr)

The corrosion rates for the welded and non-welded coupons are shown for all the test solutions in Tables 3 and 4, respectively. The "effective" free fluoride measurement is also given. For both the one day and the one week data, the corrosion rates indicated a relatively mild corrosion on the dissolver vessel. Corrosion rates for the welded coupons were consistently higher than the corrosion rates for the non-welded coupons, as shown in Tables 3 and 4. The difference between the two decreased as the solution aggressiveness decreased. In these tests, solution aggressiveness corresponded with the fluoride concentration, which is discussed below.

The corrosion rates for each type of coupon decreased as the aluminum concentration increased. As shown in Tables 3 and 4, the fluoride concentration decreased with aluminum concentration due to aluminum complexing of fluoride. This effect was independent of the aluminum source. The aluminum source, however, did affect the difference between welded and non-welded coupons. By comparing the rates in the tables, dissolved aluminum solutions were always more aggressive to the welded coupons than aluminum nitrate solutions. This difference is especially important for assessing the effect on dissolver life since dissolved aluminum from the cladding and fuel matrix will occur during the Mark 42 campaign and the solutions will be exposed to welded joints.

Different exposure times were evaluated to determine if extended exposures affected the corrosion rate. One-day and one-week rates were calculated. As can be seen from Tables 3 and 4, the one-week rates were not consistently higher or lower than the one-day rates, although lower rates typically occurred for dissolved aluminum solutions. However, lower one-week rates usually occurred with a significant drop in fluoride concentration.

The analysis of the corrosion rate data has shown that a complex relationship occurs among the test variables, i.e. coupon type, fluoride concentration, aluminum concentration and source and exposure time. For most variables, the affect on corrosion rate is manifested through its affect on the "effective" free fluoride concentration.

4.2 Effective Free Fluoride Effect

The effect of fluoride concentration is shown graphically in Figures 1-4, where the one-week corrosion rate increases with fluoride concentration. For the welded coupons, Figures 1 and 2 show the corrosion rate as a function of total and "effective" free fluoride concentrations, respectively. Figures 3 and 4 show a similar relationship for the non-welded coupons. The total fluoride graphs, Figures 2 and 4, delineate an effect on corrosion rate from the concentration of aluminum. However, when the corrosion rate is plotted against effective free fluoride concentration a singular relationship is observed, which indicates that the fluoride concentration is the controlling variable. The anomalous behavior of the 0.4M dissolved aluminum solution (as seen in Figure 1 and 3) is believed to be from variability in the aluminum weights dissolved in the solution and is not considered to have a significant effect on the corrosion rate of the 304 coupons.

4.3 ***Solution Analysis***

Solution analyses were performed by SRTC/ADS to verify target solution chemistries, especially the fluoride and aluminum concentrations, and to measure a corrosion rate based on soluble Fe, Cr and Ni concentrations. The ICPES results are shown in Table 5. In general, the aluminum concentrations were in good agreement to the target values, although, the ADS results obtained for the metallic aluminum solutions were slightly higher. Corrosion rate calculations were based on the total weight of Fe, Ni, and Cr measured in the solutions. Pre-test quantities measured by ADS were subtracted from the post-test quantities to obtain the adjusted concentrations. These adjusted quantities were summed and used as the weight loss shown in Equation 1. For these corrosion rate calculations the surface area was the combined surface area for the welded and non-welded coupons. The average corrosion rate calculated from the coupon weight loss agrees relatively well with the solution analysis corrosion rate and hence is validated.

4.4 Coupons

Visual observation of both groups of coupons tested, Figure 5, showed general corrosion on the non-welded coupons, similar to previous corrosion tests done for the Rocky Flats Sand Slag (RFSS) and crucible campaign [6]. Metallographic examination of a non-welded coupon for this program was not done because of its similarity to the corrosion observed for the RFSS campaign. However, noticeable corrosion of the welded coupons was observed. As a result, two welded coupons tested in the 0.2M Al with 0.3M F- solution, one with dissolved Al and the other with $Al(NO_3)_3$, were evaluated on a microscopic scale using standard metallographic techniques. These welded coupons were sectioned transversely to the length, mounted in an epoxy resin, ground, and polished. Prior to observation, the coupons were electrolytically etched with a 10 wt% oxalic acid solution.

Figure 6 shows a representative photograph of the welded coupons. The welds are clearly evident indicating corrosion resulting from the dissolver solution.

Metallographic examination of the coupons shows the ffect of corrosion on the surface of each sample. Figures 7 and 8 show a transverse cross section of coupons tested in 8M nitric, 0.2M aluminum, and 0.3M fluoride. The difference between the coupons is the source of aluminum; coupon # 186 was tested using dissolved aluminum while coupon # 195 was tested using aluminum nitrate. The weld region appears to exhibit a general corrosion affect on the outside surface and does not indicate the presence of severe corrosion in the weld itself. The parent metal adjacent to the weld, however, shows the presence of intergranular corrosion from the testing solution. In addition, precipitates are seen dispersed throughout the parent metal matrix. Intergranular corrosion is caused by impurities at the grain boundaries causing the grain boundary area to be more reactive than the matrix. This type of attack is generally associated with welding induced sensitization in stainless steel where chromium carbides form at the grain boundaries and, as a result, deplete the surrounding area of chromium. This chromium depleted zone provides a region adjacent to the weld that does not contain sufficient corrosion resistance to resist attack in many corrosive environments. Sensitization occurs when Type 304 stainless steel is heated into a temperature range of 950°C to 1450°C. Because of the welding process, these coupons likely saw temperatures in this region. However, because sensitization does not occur in 304L stainless steel, the material of construction for the dissolver vessel, intergranular corrosion will not be a factor in the dissolver vessel. Hence, the intergranular corrosion attack seen in the 304 welded coupons should not occur and cause a premature failure in the dissolver vessel.

5 Conclusions

Unirradiated Mark 42 fuel tubes are to be dissolved in an upcoming campaign in F-Canyon. SRTC/MTS developed a corrosion program to assess the impact of new flow sheets on dissolver corrosion. Corrosion rates of both 304 non-welded and 304 welded coupons were calculated using weight losses and soluble Fe, Cr and Ni concentrations. The corrosion rates were calculated for both one day and one week weight losses. The values ranged from 2.7 to 32.5 mpy, indicating a low degradation potential for the dissolver vessel. The welded coupons had a larger corrosion rate than the non-welded coupon. The difference in corrosion rate between the welded and the non-welded coupons decreased as the solution aggressiveness decreased. In these tests, solution aggressiveness corresponded with the fluoride concentration.

The average corrosion rate calculated from the soluble Fe, Cr and Ni concentrations agrees well with the coupon weight loss corrosion rates. Since the coupons used in the study were 304 stainless steel as opposed to 304L stainless steel, the materials of construction for the dissolver vessel, the corrosion rates obtained are conservative with respect to the expected corrosion of the dissolver vessel.

6 References

[1] "Flow Sheet Development for the Dissolution of Unirradiated Mark 42 Fuel Tubes in F-Canyon – Part II", Alice M. Murray, William J. Crooks III, WSRC-TR-99-00196, June 28, 1999

[2] "Corrosion Test Plan: Mark 42 Dissolution", K. A. Dunn and J. I. Mickalonis, SRT-MTS-99-2026, June 10, 1999.

[3] "Conduct of Research & Development – Savannah River Technology Center (U)", WSRC-IM-97-00024, Rev. 1, November 30, 1998

[4] "Standard Practice for Laboratory Immersion Corrosion Testing of Metals", American Society For Testing & Materials, Designation G31-72, Reapproved 1995

[5] "NMSS Laboratory notebook", WSRC-NB-97-00510, October 27, 1997 (active notebook)

[6] "Corrosion Testing In Support Of F-Canyon: Rocky Flats Sand Slag And Crucible Campaign (U)", WSRC-TR-99-00296, (To be published)

Table 1. Mark 42 Corrosion Test Matrix

Nitric Acid (M)	Fluoride (M)	Aluminum (M)	Boron (g/L)
8	0.2, 0.3, 0.4	0.2, 0.3, 0.5	1.8

Table 2. Test Solutions For Mark-42 Corrosion Tests

Group[1]	Solution	F^- (M)	Batch	Al^{+3} (M)
I	1	0.2	A	0.2
			B	0.3
			C	0.5
	2	0.3	A	0.2
			B	0.3
			C	0.5
	3	0.4	A	0.2
			B	0.3
			C	0.5
II	1	0.2	A	0.2
			B	0.3
			C	0.5
	2	0.3	A	0.2
			B	0.3
			C	0.5
	3	0.4	A	0.2
			B	0.3
			C	0.5

1. Group I – metallic aluminum (Type 6063)
   Group II – aluminum nitrate

Table 3. Corrosion Rates For 304 Welded Coupons In Mark 42 Solution At 90°C

Nitric (M)	Al (M)	Total Fluoride (M)	Free Fluoride (ppm)		Corrosion Rate (mpy)	
			Initial	Final	1 Day	1 Week
8	0.2*	0.2	71.07335	60.95516	16.68365	12.2964
8	0.2*	0.3	60.70246	78.13112	26.14842	19.71329
8	0.2*	0.4	113.3768	66.58586	32.50745	28.81597
8	0.2#	0.2	60.31777	59.6926	12.1149	12.87391
8	0.2#	0.3	84.99312	75.38551	15.9778	19.07895
8	0.2#	0.4	106.8924	76.82723	22.8566	27.8837
8	0.3*	0.2	56.27312	40.44415	9.875438	8.274908
8	0.3*	0.3	48.56693	65.19975	17.06866	12.71166
8	0.3*	0.4	95.81543	67.14853	27.05318	20.75098
8	0.3#	0.2	47.95862	43.81035	5.120598	5.638524
8	0.3#	0.3	70.03396	58.57502	11.67214	12.81983
8	0.3#	0.4	84.63328	61.08393	15.61205	19.84071
8	0.5*	0.2	34.18081	24.30873	4.575171	4.475252
8	0.5*	0.3	29.74902	43.262	8.861586	6.483707
8	0.5*	0.4	70.18191	50.76046	16.77349	10.60879
8	0.5#	0.2	29.87445	24.72129	3.869324	4.258915
8	0.5#	0.3	45.21452	31.28927	6.904465	6.568042
8	0.5#	0.4	61.72941	44.36643	10.85079	9.712269

Table 4. Corrosion Rates For Non-welded 304 Coupons In Mark 42 Solution At 90°C

Nitric (M)	Al (M)	Molar Fluoride (M)	Free Fluoride (ppm)		Corrosion Rate (mpy)	
			initial	Final	1 Day	1 Week
8	0.2*	0.2	71.07335	60.95516	9.518704	9.722305
8	0.2*	0.3	60.70246	78.13112	15.85931	16.375
8	0.2*	0.4	113.3768	66.58586	24.2753	23.0366
8	0.2#	0.2	60.31777	59.6926	8.696871	11.21513
8	0.2#	0.3	84.99312	75.38551	15.54722	16.76585
8	0.2#	0.4	106.8924	76.82723	20.01008	23.21345
8	0.3*	0.2	56.27312	40.44415	4.946605	5.821197
8	0.3*	0.3	48.56693	65.19975	10.88149	10.84508
8	0.3*	0.4	95.81543	67.14853	17.79426	16.86468
8	0.3#	0.2	47.95862	43.81035	3.464184	4.740032
8	0.3#	0.3	70.03396	58.57502	10.96992	11.43285
8	0.3#	0.4	84.63328	61.08393	14.81381	18.05804
8	0.5*	0.2	34.18081	24.30873	2.67356	2.657212
8	0.5*	0.3	29.74902	43.262	6.012908	4.78313
8	0.5*	0.4	70.18191	50.76046	12.36911	8.478409
8	0.5#	0.2	29.87445	24.72129	4.041548	3.681903
8	0.5#	0.3	45.21452	31.28927	4.166384	5.396905
8	0.5#	0.4	61.72941	44.36643	7.516135	8.395185

NOTE: * is Dissolved Aluminum, # is $Al(NO_3)_3$

Table 5. Post Test Solution Analyses For Mark 42 Test Solutions

Nominal Chemistry			ICPES Results (ppm)					Adjusted Values (ppm)[1]			Total Wt.[2]	Corr. Rate
Al Metal	**Al Nitrate**	**F^- (M)**	**Al**	**B**	**Cr**	**Ni**	**Fe**	**Cr**	**Ni**	**Fe**	**(g)**	**(ppm)**
0.2		0.2	3040	2333	127	53	503	104	52	455	0.256	10.970
0.5		0.2	8325	2527	85	18	249	62	17	201	0.106	4.548
0.2		0.4	4225	3193	422	176	1550	399	175	1502	0.622	26.624
0.5		0.4	8200	2513	141	49	519	118	48	471	0.242	10.348
	0.2	0.2	2825	2243	127	59	528	127	59	525	0.287	12.310
	0.5	0.2	7700	2447	59	21	211	59	21	208	0.097	4.186
	0.2	0.4	3075	2413	320	140	1205	320	140	1202	0.631	26.999
	0.5	0.4	7325	2163	119	46	420	119	46	417	0.224	9.578

1. The adjusted values were calculated by subtracting the pre-test measurement from the post-test measurement.
2. The total weight was calculated by summing the adjusted values, where ppm is equivalent to mg/L.

Figure 1. Corrosion Rate As A Function Of Free F Concentration
Welded 304 Coupons - 1 Week

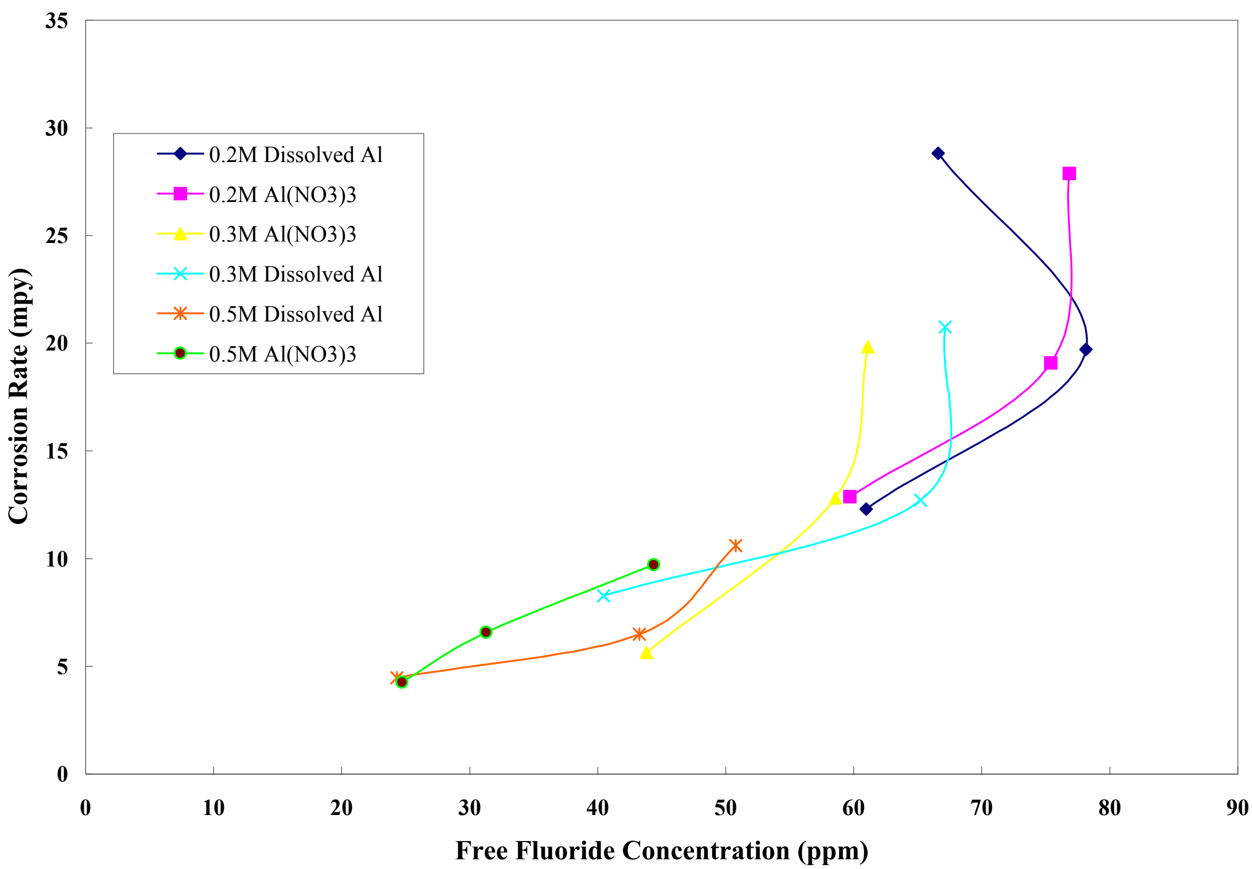


Figure 2. Corrosion Rate As A Function Of Molar F Concentration
Welded 304 Coupons - 1 Week

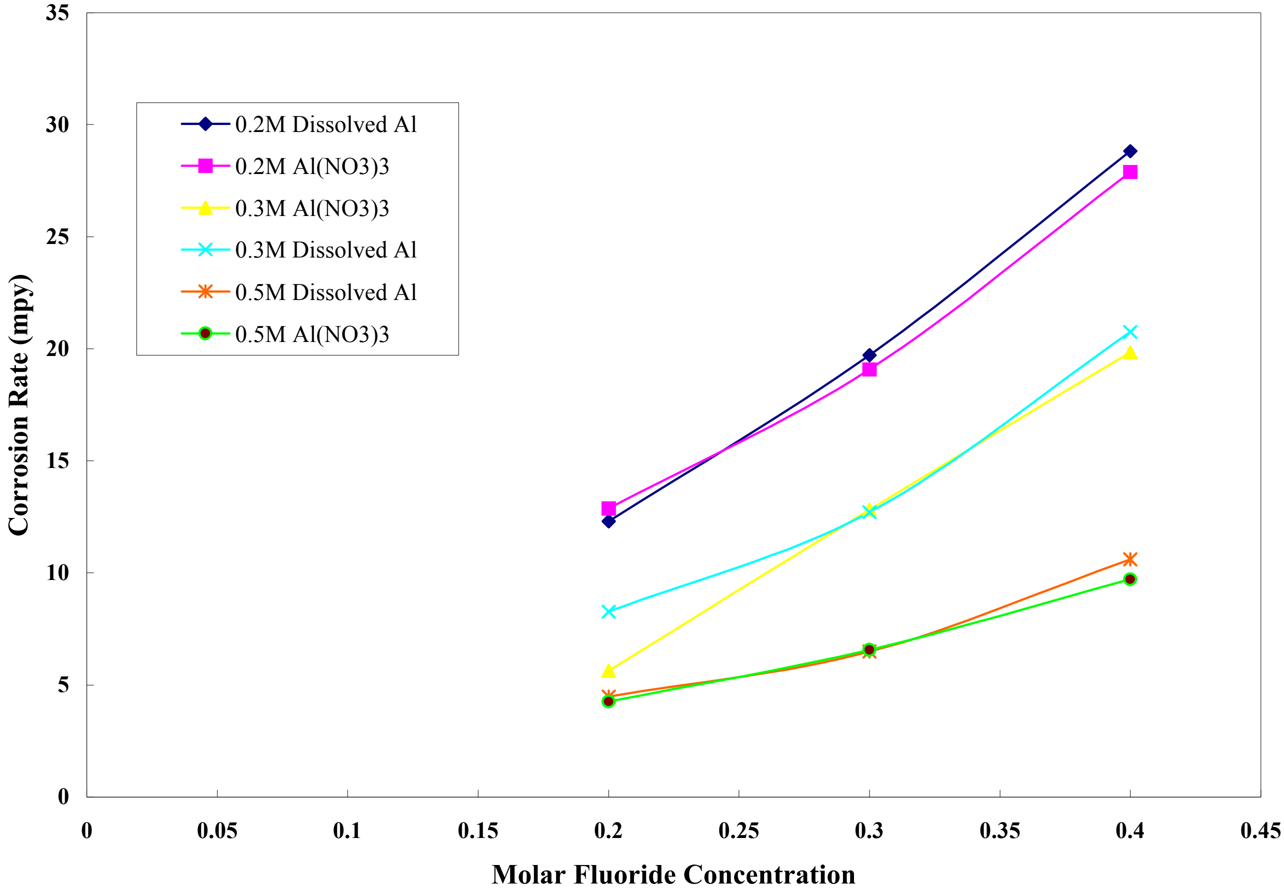


Figure 3. Corrosion Rate As A Function Of Free F Concentration
Unwelded 304 Coupons - 1 Week

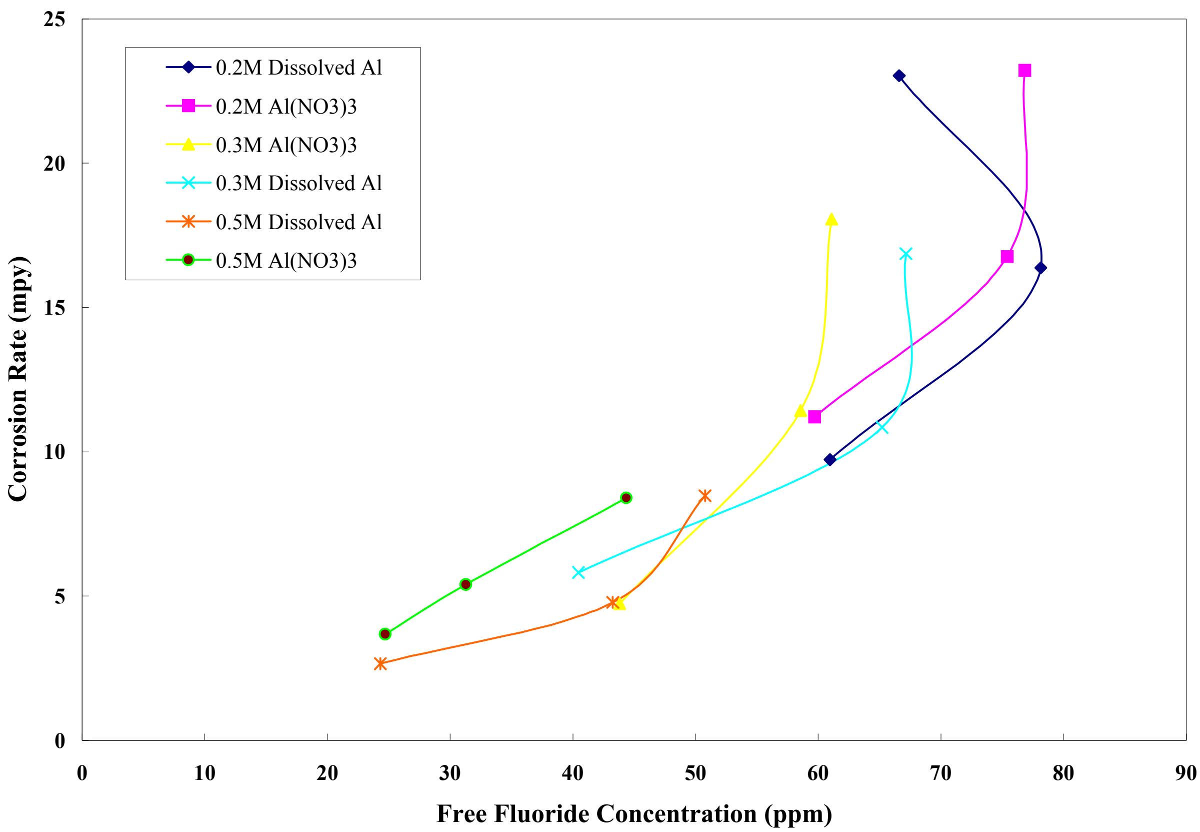
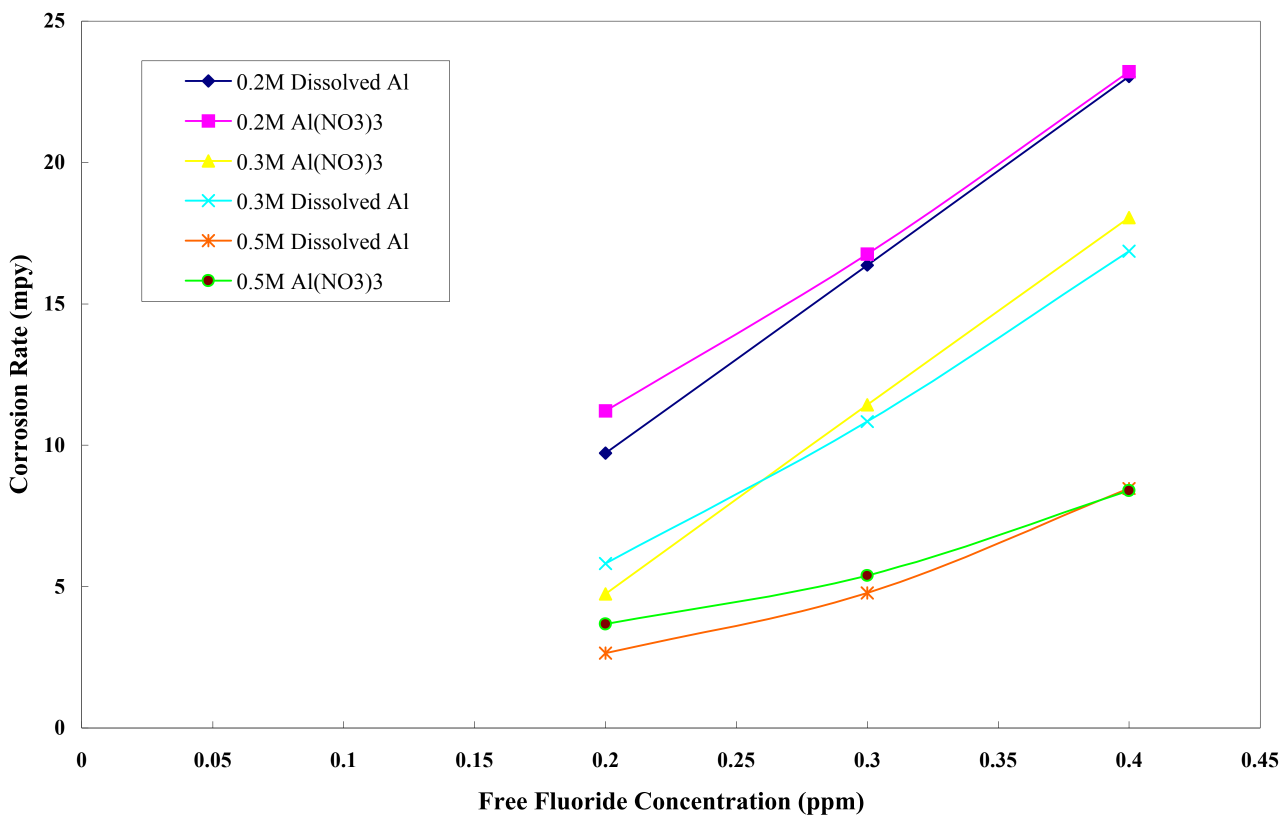
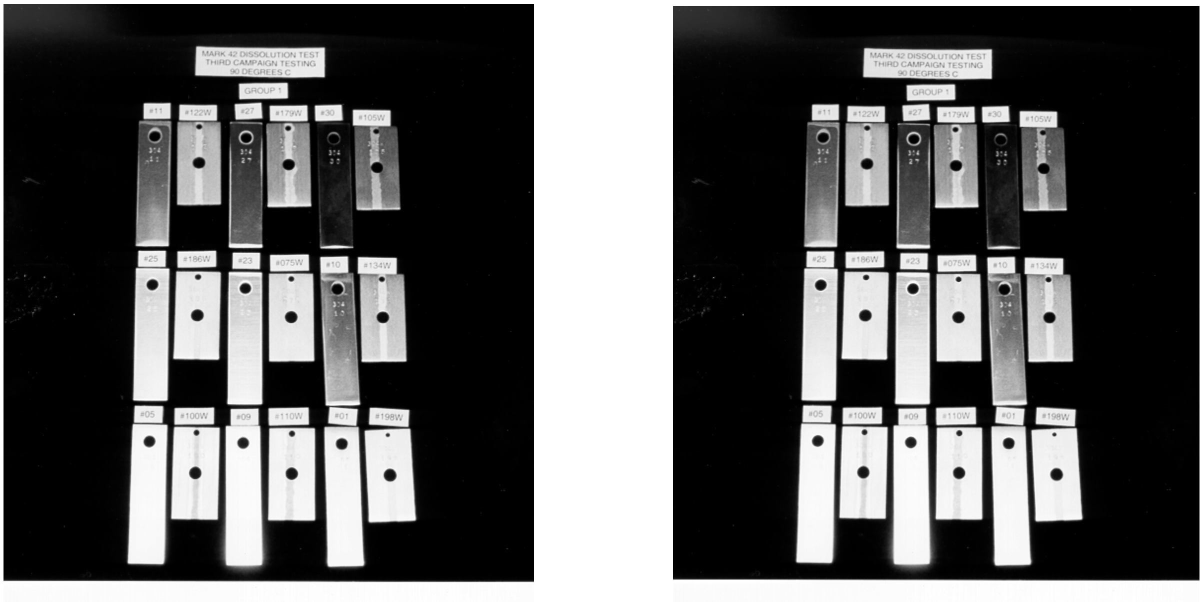


**Figure 4. Corrosion Rate As A Function Of Molar F Concentration
Unwelded 304 Coupons - 1 Week**

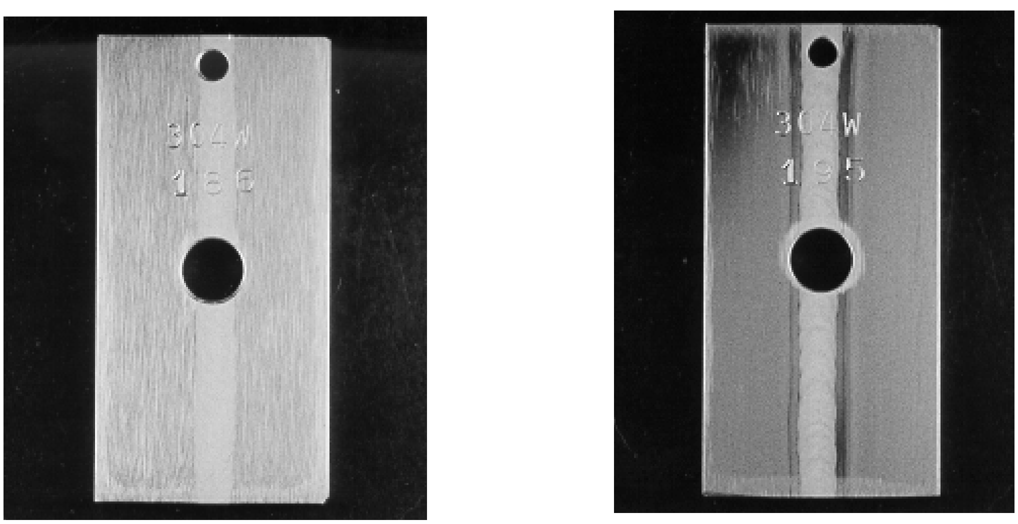




Group I
Dissolved Al

Group II
$Al(NO_3)_3$

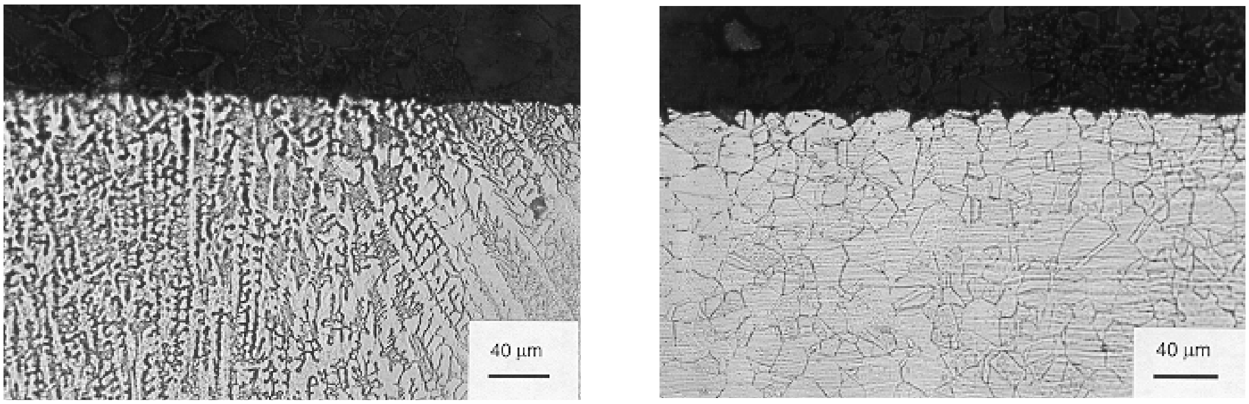
Figure 5. Photograph of 304 welded and 304 non-welded test coupons



Coupon # 186
Dissolved Al

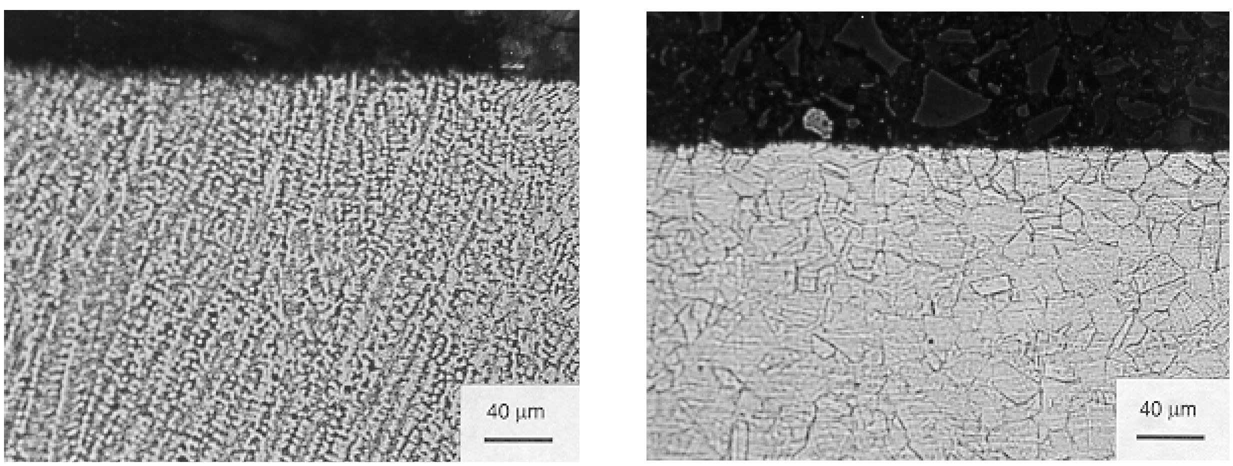
Coupon # 195
$Al(NO_3)_3$

Figure 6. Photograph of welded test coupons.
Dissolver Solution: 8M Nitric, 0.2M Aluminum, and 0.3M Fluoride.



Weld Parent Metal

Figure 7. Transverse cross section of weld and parent metal from welded 304 stainless steel test coupon # 186.



Weld Parent Metal

Figure 8. Transverse cross section of weld and parent metal from welded 304 stainless steel test coupon # 195.

Distribution:

N. E. Barnett, 707-F
H. Branham, Jr., 703-F
G. Chandler, 773-A
W. H. Clifton, Jr., 703-F
W. J. Crooks, III, 773-A
K. A. Dunn, 773-41A
J. Greggi, Jr., 707-F
N. C. Iyer, 773-41A
A. N. Jwayyed, 221-14F
W. L. Melton, III, 772-F
J. I. Mickalonis, 773-A
A. M. Murray, 773-A
A. L. Williams, 773-A
G. J. Winkler, 703-F
Document Control, 773-52A, (Attn: J. Dozier)