OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL COVER SHEET
Complete Only Applicable Items

1. QA: QA

2. ☐ Analysis	☐ Engineering ☐ Performance Assessment ☐ Scientific	3. ☒ Model	☐ Conceptual Model Documentation ☒ Model Documentation ☐ Model Validation Documentation

4. Title:

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5. Document Identifier (including Rev. No. and Change No., if applicable):

ANL-EBS-MD-000003 REV 00

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II. Inventory of Metal Samples with Traceability - 128

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12. Remarks

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OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL REVISION RECORD

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ABBREVIATIONS AND ACRONYMS

AFM	atomic force microscope or microscopy
AMR	analyses and models report
APC	aqueous phase corrosion
ASTM	American Society for Testing and Materials
BSW	basic saturated water
CD	compact disc
CLST	container life and source term
CP	cyclic polarization
CRWMS	Civilian Radioactive Waste Management System
DOE	Department of Energy
DOX	dry oxidation
DS	drip shield
DTN	data tracking number
DWA	prefix for qualified Alloy 22 weight loss samples used in LTCTF
EBS	engineered barrier system
GC	general corrosion
HAC	humid air corrosion
IRSR	issue resolution status report
KTI	key technical issue
LC	localized corrosion
LLNL	Lawrence Livermore National Laboratory
LTCTF	Long Term Corrosion Test Facility
M&O	Management and Operating Contractor
MIC	microbial influenced corrosion
NRC	Nuclear Regulatory Commission
OCRWM	Office of Civilian Radioactive Waste Management
PMR	process model report
QA	quality assurance

ABBREVIATIONS AND ACRONYMS (Continued)

ROM	read only memory
RH	relative humidity
SAW	simulated acidic concentrated water
SCC	stress corrosion cracking
SCE	saturated calomel electrode
SCW	simulated concentrated water
SDW	simulated dilute water
SIP	scientific investigation plan
SN	scientific notebook
SSW	simulated saturated water
TDP	technical development plan
WAPDEG	waste package degradation code
WP	waste package
WPOB	waste package outer barrier
wt%	weight percent
YMP	Yucca Mountain Project

1. PURPOSE

1.1 ANALYSES AND MODELS REPORT

As described in the License Application Design Selection Report, the recommended waste package design is Engineering Design Alternative II (CRWMS M&O 1999a). This design includes a double-wall waste package (WP) underneath a protective drip shield (DS). The purpose and scope of the process-level model is to account for both general and localized corrosion of the waste package outer barrier (WPOB), which is assumed to be Alloy 22 (UNS N06022-21Cr-13Mo-4Fe-3W-2C-Ni [American Society for Testing and Materials (ASTM) 1997a]). This model will include several sub-models, which will account for dry oxidation (DOX), humid air corrosion (HAC), general corrosion (GC) in the aqueous phase, and localized corrosion (LC) in the aqueous phase. This analyses and models report (AMR) serves as a feed to the waste package degradation code (WAPDEG) analyses. It also serves as a basis for the WP process model report (PMR) and model abstraction for WAPDEG (CRWMS M&O 1999b). Lists of Data Tracking Numbers (DTNs) and their Q-status is included in the Document Input Reference System database and are also included in the Technical Data Management System database and are not in this document.

1.2 BACKGROUND ON ALLOY 22

Alloy 22 (UNS N06022) is now being considered for construction of the outer barrier of the WP. This alloy consists of 20.0-22.5% Cr, 12.5-14.5% Mo, 2.0-6.0% Fe, 2.5-3.5% W, 2.5% (max.) Co, and balance Ni (ASTM 1997a). Other impurity elements include P, Si, S, Mn, Cb, and V (CRWMS M&O 1999e; Treseder et al. 1991). Alloy 22 is less susceptible to LC in environments that contain Cl^- than Alloys 825 and 625, materials of choice in earlier designs. The unusual LC resistance of Alloy 22 is apparently due to the additions of Mo and W, both of which are believed to stabilize the passive film at very low pH (Hack 1983). The oxides of these elements are very insoluble at low pH. Consequently, Alloy 22 exhibits relatively high thresholds for localized attack. Very high repassivation potentials have been observed by some (Gruss et al. 1998), while others have found very low corrosion rates in simulated crevice solutions containing 10 wt% $FeCl_3$ (Gdowski 1991; Haynes 1987, 1988). Furthermore, no significant localized attack of Alloy 22 has been seen in crevices exposed to water compositions representative of those expected in the repository. Such tests have been conducted in the Yucca Mountain Project's (YMP's) Long Term Corrosion Test Facility (LTCTF) (Estill 1998). Test media used in this facility include simulated acidic concentrated water (SAW), which is about one-thousand times more concentrated than the ground water at Yucca Mountain (J-13 well water) and which has been acidified with H_2SO_4 (Gdowski 1997c). The measured pH of SAW is approximately 2.7.

1.3 ENVIRONMENT

The WP will experience a wide range of conditions during its service life. Initially, the high-level waste containers will be hot and dry due to the heat generated by radioactive decay. However, the temperature will eventually drop to levels where both HAC and aqueous phase corrosion (APC) will be possible. Crevices will be formed between the WP and supports;

beneath mineral precipitates, corrosion products, dust, rocks, cement, and biofilms; and between layers of the containers. There has been concern that the crevice environment may be more severe than the near field environment. The hydrolysis of dissolved metal can lead to the accumulation of H^+ and a corresponding decrease in pH. Electromigration of Cl^- (and other anions) into the crevice must occur to balance cationic charge associated with H^+ ions (Gartland 1997; Walton et al. 1996). These exacerbated conditions can set the stage for subsequent attack of the corrosion resistant material by passive corrosion, pitting (initiation and propagation), stress corrosion cracking (SCC), or other mechanisms.

1.4 RELATIONSHIP TO PRINCIPAL FACTORS

Degradation of the WP is key to understanding one of the most important principal factors in repository performance. This principal factor is the amount of water transmitted into and the rate of release of radionuclides out of the WP. Once water contacts (touches) the surface of the WP, its fate becomes intertwined with that of the WP. The models and supporting experimental data to account for WP degradation, as well as the evolution of water involved in the various degradation processes, have been sponsored by the YMP. These models and supporting experimental data are reported in two companion PMRs, one for the WP and another for the waste form. This AMR addresses the development of the models to account for the degradation of the outer barrier of the WP, based upon data generated by the YMP, and an integral part of the WP PMR.

1.5 ACTIVITY PLANS

Approved activity plans and technical development plans were used in the performance of the work described in this document. Any necessary deviations from these activity plans are documented in the corresponding scientific notebooks (SNs). These procedures are compliant to the Office of Civilian Radioactive Waste Management (OCRWM) quality assurance (QA) requirements.

1.6 SUMMARY OF MODEL

The model for the GC and LC of Alloy 22 is summarized in Figure 1. The threshold relative humidity (RH) is first used to determine whether or not DOX will take place. If DOX is determined to occur, the parabolic growth law represented by Equations 11 and 13 is then used to calculate the corrosion rate as a function of temperature. If the threshold RH is exceeded, HAC will occur in the absence of dripping water, and APC will occur in the presence of dripping water. If APC is assumed to occur, the corrosion and critical potentials are used to determine whether the mode of attack is general or localized. The correlation represented by Equation 17 and Table 5 can be used as the basis for estimating these potentials at the 50th percentile. Since the material specifications will be based partly on the measured corrosion and critical potentials, it is assumed that these potentials will be uniformly distributed about the 50th percentile values determined from the correlation. For example, the 0th and 100th percentile values of E_{corr} are assumed to be at E_{corr} (50th percentile) ± 75 mV. This acceptable margin was determined by splitting the differences shown in Table 6. Acceptability is defined as a condition where no LC occurs. Similarly, the 0th and 100th percentile values of $E_{critical}$ are assumed to be at $E_{critical}$ (50th percentile) ± 75 mV. Material falling outside of these specified ranges will not be accepted. If the comparison of E_{corr} to $E_{critical}$ indicates GC, the distribution of rates determined from the LTCTF will be used as the basis of the GC rate. If the comparison indicates LC, the distribution of rates presented in Table 22 will be used. This model does not yet account for the effects of aging on corrosion rates. However, such enhancements of the corrosion rate will be accounted for in the future. Other correlations of E_{corr} and $E_{critical}$ data given here may also be used, if deemed appropriate.

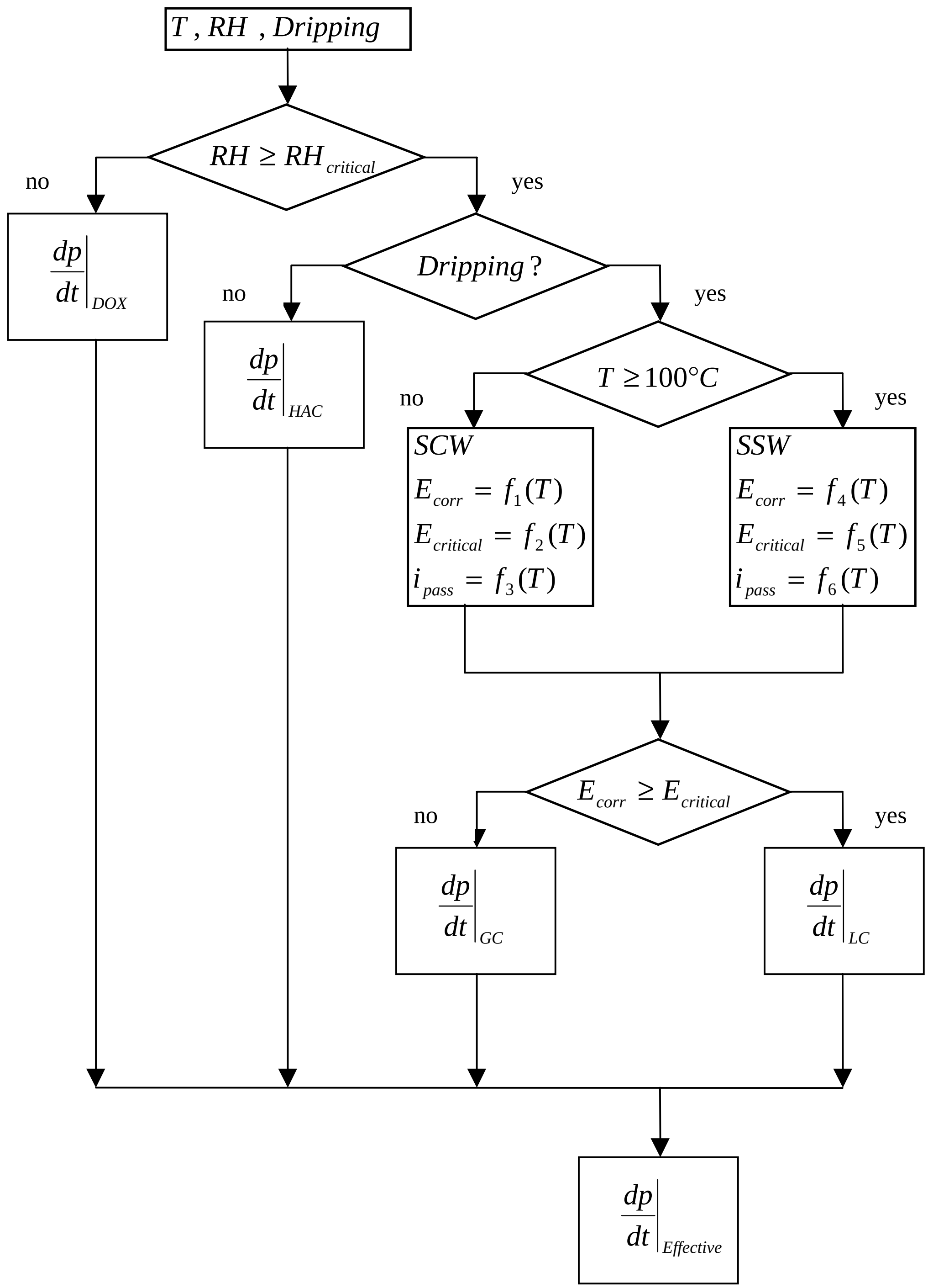

Figure 1. Schematic Representation of Corrosion Model for Alloy 22 Outer Barrier

1.7 UNCERTAINTY AND VARIABILITY

The primary uncertainty in the threshold RH for HAC and APC is due to the presence of nitrate. Values of the equilibrium RH as a function of temperature for a saturated solution of $NaNO_3$ are given in Table 9 and Figure 8 of the AMR on WP surface environment (CRWMS M&O 2000a). Despite significant experimental work at Lawrence Livermore National Laboratory (LLNL), there continues to be significant uncertainty in the threshold RH for HAC and APC.

In an ideal case, the crevice corrosion temperature can be estimated from the intersection of the lines representing the corrosion and threshold potentials at elevated temperature. To force crevice corrosion to occur in the model, E_{corr} and $E_{critical}$ can simply be equated over temperature ranges of uncertainty (90-120°C). It is assumed that the crevice corrosion temperature is uniformly distributed over this range of uncertainty. Additional data is needed to fill this void.

From experimental measurements presented in Section 6.5.2, the maximum uncertainty in the GC rate is estimated to be approximately 6 to 20 nm y^{-1} in the case of samples with the generic crevice geometry and 11 to 38 nm in the case of samples with the generic weight-loss geometry. These estimates of error are believed to correspond to about one standard deviation (1σ). From the formal error analysis given in Section 6.5.3, it is concluded that the typical uncertainty observed in weight loss and dimensional measurements prevent determination of GC rates less than 38 nm y^{-1} (~40 nm y^{-1}). Therefore, any measured corrosion rate greater than 160 nm y^{-1} (4σ) should be easily distinguishable from measurement error. Any rate less than 160 nm y^{-1} guarantees that the WP outer barrier (wall thickness of 2 cm) will not fail by GC.

It is assumed that no scale formation occurs, so all negative rates are eliminated and the entire distribution is assumed to be due to uncertainty. As shown in Section 6.5.2, the rate at the 50^{th} percentile is approximately 50 nm y^{-1}, the rate at the 90^{th} percentile is approximately 100 nm y^{-1}, and the maximum rate is 731 nm y^{-1}. About 10% of the values fall between 100 and 750 nm y^{-1}.

1.8 MODEL VALIDATION

The validation process is discussed in Attachment 1, Item 6, of the OCRWM Procedure, AP-3.10Q. Model validation is accomplished in part by comparing experimental measurements of key model parameters to corroborative data that has been published in the open scientific literature. For example, GC rates, corrosion potentials, threshold potentials, and assumed crevice pH values are compared to those published for Alloy 22 and similar alloys in somewhat similar environments (NaCl solutions, sea water, etc.). Validation of the overall model will require extensive review of calculations performed with the abstracted model based upon this process-level model. That abstracted model is addressed in a companion AMR. Calculated corrosion rates will be compared to experimental measurements to make sure that those rates are reasonable. Absolute validation of a model intended for the prediction of a service life of 10,000 years may not be possible. These models are based upon the best knowledge and insight into these materials and systems available at the present time. As our state of understanding improves, predictions will inevitably be updated to reflect such advancement. Through the implementation of probabilistic calculations that embody the integrated corrosion models provided here, an attempt is made to compensate for our uncertainty as human beings.

1.9 RESOLUTION OF COMMENTS IN ISSUE RESOLUTION STATUS REPORT

The Issue Resolution Status Report (IRSR) recently issued by the Nuclear Regulatory Commission (NRC) provides guidance for the development of process-level models (NRC 1999). The primary consideration in the key technical issues (KTIs) is the container life and source term (CLST). There must be a high degree of confidence in the adequacy of the engineered barrier system (EBS) design, thereby providing assurance that containers will be adequately long-lived, and radionuclide release from the EBS will be sufficiently controlled. The container design and the packaging of spent nuclear fuel and high-level waste glass are expected to make a significant contribution to the overall repository performance. The IRSR defines the physical boundary of the EBS by the walls of the WP emplacement drifts. The IRSR deems six sub-issues to be important to the resolution of the relevant KTI. The first sub-issue is specifically relevant to this AMR, the effects of corrosion processes on the lifetime of the containers.

The following are the acceptance criteria for the first sub-issue:

1. The Department of Energy (DOE) has identified and considered likely modes of corrosion for container materials including dry-air oxidation, humid-air corrosion, and aqueous corrosion processes, such as GC, LC, microbial influenced corrosion, SCC, and hydrogen embrittlement as well as the effect of galvanic coupling.

   Response: This AMR includes process-level models for dry-air oxidation, humid-air corrosion, and aqueous corrosion processes, such as GC, LC, and microbial influenced corrosion. Galvanic coupling effects have been minimized to the extent possible and will be accounted for in greater detail in future revisions. Both SCC and hydrogen embrittlement are dealt with in companion AMRs.

2. DOE has identified the broad range of environmental conditions within the WP emplacement drifts that may promote the corrosion processes listed previously, taking into account the possibility of irregular wet and dry cycles that may enhance the rate of container degradation.

   Response: This AMR includes environmental thresholds that can be used to switch between dominant modes of corrosion. For example, as the WP temperature drops and the RH increases, the mode of attack changes from dry-air oxidation to humid-air or aqueous-phase corrosion. A comparison of the corrosion and threshold potentials is used to determine whether or not localized corrosion will occur.

3. DOE has demonstrated that the numerical corrosion models used are adequate representations, taking into consideration associated uncertainties of the expected long-term behaviors and are not likely to underestimate the actual degradation of the containers as a result of corrosion in the repository environment.

   Response: Uncertainties are accounted for in corrosion rates. As shown in Section 6.5.2, the rate at the 50th percentile is approximately 50 nm y^{-1}, the rate at the 90th percentile is approximately 100 nm y^{-1}, and the maximum rate is 731 nm y^{-1}. About 10% of the values fall between 100 and 750 nm y^{-1}. The effects of thermal aging over extended periods of time

(10,000 years) is being accounted for in the overall corrosion model for the WPOB. This is discussed in detail in Section 6.7 entitled "The Effect of Aging and Phase Instability on Corrosion."

4. DOE has considered the compatibility of container materials, the range of material conditions, and the variability in container fabrication processes, including welding, in assessing the performance expected in the containers intended waste isolation.

   Response: The effects of welding and thermal aging on the corrosion resistance of the WP materials will be accounted for as discussed in Sections 5.9 and 6.7 entitled "The Effect of Aging and Phase Instability on Corrosion." A fully aged sample of Alloy 22 appears to exhibit a less noble corrosion potential, shifted in the cathodic direction by approximately 63 mV in the case of SAW at 90°C, 109 mV in the case of simulated concentrated water (SCW) at 90°C, and by more than 100 mV in the case of basic saturated water (BSW) at 100°C. It is assumed that E_{corr} is corrected to account for fully aged material by subtracting approximately 100 mV from values calculated for the base metal. The shift in $E_{critical}$ (threshold potential 1) also appears to be approximately 100 mV in most cases. Thus, the difference $E_{critical}$-E_{corr} appears to be virtually unchanged. The effect of thermal aging on the corrosion rate is accounted for in the enhancement factor, G_{aged}, and is based upon a ratio of the non-equilibrium current densities for base metal and aged material. The value of G_{aged} for base metal is approximately one ($G_{aged} \sim 1$), whereas the value of G_{aged} for fully aged material is larger ($G_{aged} \sim 2.5$). Material with less precipitation than the fully aged material would have an intermediate value of G_{aged} ($1 \leq G_{aged} \leq 2.5$).

5. DOE has justified the use of data collected in corrosion tests not specifically designed or performed for the Yucca Mountain repository program for the environmental conditions expected to prevail at the Yucca Mountain site.

   Response: The threshold RH used to determine whether vapor phase attack is by DOX or HAC is based upon the deliquescence point of salt deposits that could form on the WP surface due to aerosol transport. Measurements of GC rates in the vapor and aqueous phases, electrochemical potentials, and other relevant performance data were in test media that can be directly related to water chemistry expected on the WP surface during the service life of Alloy 22. These water chemistries are based upon evaporative concentrations of the standard J-13 well-water chemistry. Crevice chemistry is being measured in situ, with and without the presence of buffer ions. In the aqueous phase, a range of temperature extending from room temperature to 120°C is being investigated. The high-temperature limit is based upon the boiling point of a near-saturation water chemistry without buffer. The expected boiling point of the aqueous phase on the WP surface is expected to be lower.

6. DOE has conducted a consistent, sufficient, and suitable corrosion testing program at the time of the License Application submittal. In addition, DOE has identified specific plans for further testing to reduce any significant area(s) of uncertainty as part of the performance confirmation program.

Response: The DOE has established a corrosion test program that addresses all anticipated modes of corrosive attack of the WP. Studies include exposure of over 18,000 samples of candidate WP material in the LTCTF. A large number of pre- and post-exposure measurements of dimension and weight allow establishment of distribution functions for representation of the GC rate. Microscopic examination of samples from the LTCTF and other corrosion tests is done with AFM, scanning electron microscopy, X-ray diffraction, X-ray photoelectron spectroscopy, secondary ion mass spectrometry, and other state-of-the-art surface analytical techniques. Potentiodynamic and potentiostatic electrochemical tests are conducted with base metal, thermally aged material, and simulated welds. Thermally aged material is fully characterized with the transmission electron microscope (CRWMS M&O 2000b).

7. DOE has established a defensible program of corrosion monitoring and testing of the engineered subsystems components during the performance confirmation period to assure they are functioning as intended and anticipated.

   Response: The DOE has established a corrosion test program that addresses all anticipated modes of corrosive attack of the WP. There is a clear linkage between the experimental data being collected and modules in the predictive WAPDEG code that serves as the heart of the Total System Performance Assessment. Data and modules have been developed for each key element of the Engineered Design Alternative II design: the WPOB (Alloy 22), the inner structural support (stainless steel 316NG), and the protective DS (Ti Gr 7). Companion AMRs provide data and modules for the stainless steel 316NG and the Ti Gr 7 alloy.

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2. QUALITY ASSURANCE

2.1 PROCEDURE FOR ANALYSES AND MODELS (AP-3.10Q)

The QA program applies to this analysis. All types of waste packages were classified (per QAP-2-3 REV 10) as Quality Level-1 in *Classification of the MGR Uncanistered Spent Nuclear Fuel Disposal Container System* (CRWMS M&O 1999c, p. 7). This analysis applies to all of the waste package designs included in the MGR Classification Analyses. Reference CRWMS M&O (1999c) is cited as an example. The development of this analysis is conducted under activity evaluation *Long Term Materials Testing and Modeling* (CRWMS M&O 1999d) which was prepared per QAP-2-0 REV 5. The results of that evaluation were that the activity is subject to the *Quality Assurance Requirements and Description* (DOE 1998) requirements.

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3. COMPUTER SOFTWARE AND MODEL USAGE

3.1 SOFTWARE APPROVED FOR QUALITY ASSURANCE WORK

As per AP-E-20-81, raw data for determining the local environment within WP crevices was obtained with a data acquisition system operating with a macro created with LabView Full Development System for Windows 95/NT/3.1 (Serial Number # G10X71724). LabView is considered “industry standard software” and is, therefore, exempt from the OCRWM procedure entitled *Software Configuration Management* (AP-SI.1Q, Revision 2, ICN 0). The specific application was written and documented by Mr. Richard Green of LLNL in accordance with the first version of the relevant OCRWM procedure (AP-SI.1Q, Revision 0, ICN 0) and is consistent with the later revision of that procedure (AP-SI.1Q, Revision 2, ICN 0). That document is also included in the list of references (Green 1999).

Data acquisition software was checked by measuring known quantities. For example, in the case of analog-to-digital converters, known voltage waveforms were measured. Software used with potentiostats to collect CP data was used to measure the voltage-current characteristics across known resistances. Validation was accomplished by ensuring that the application of a given voltage across a known resistance caused a current flow consistent with Ohm’s law.

3.2 SOFTWARE ROUTINES

The electronic notebook discussed in AP-E-20-81 was kept with Microsoft Excel 97. Calculations used to manipulate raw data were performed electronically in spreadsheets created with Microsoft Excel 97. The Microsoft Excel 97 that was used was bundled with Microsoft Office 97 Professional Edition for Windows 95/NT or Workstation 4.0 (Serial Number # 269-056-174). Excel is considered “industry standard software” and is, therefore, exempt from the OCRWM procedure entitled *Software Configuration Management* (AP-SI.1Q, Revision 2, ICN 0). All spreadsheets have been assigned DTNs, which are listed in the data inventory sheet. Electronic copies of the data inventory sheet and the supporting data are found on the compact disc (CD) read only memory (ROM) and discussed in Section 10.

The correlation equations presented in this document were created within Excel spreadsheets. Those correlation equations were checked by hand calculation, using a Hewlett-Packard 20S scientific calculator. All correlation equations were found to be reasonable predictors of the represented data. Many of the tabulated calculations were also checked by hand calculation. For example, the junction potential corrections given in Tables 7 through 11 were checked in this manner and revised as necessary to reflect changes in assumed water chemistry. The error analyses represented by Tables 16 through 20 were also checked by hand calculation. No other significant computational routines are involved in the process level model described here.

3.3 INTEGRITY OF TRANSFER OF DATA

The integrity of electronic data transfer has been verified as required by OCRWM Procedure YAP-SV.1Q. The comparison method was used to ensure the accuracy of the transferred data. A sampling of ~5% of the data in the source file was visually compared to the corresponding data in the transferred file. The data selected was at the reviewer's discretion. Reviewers included the originator, as well as the document editor and QA staff.

4. INPUTS

4.1 DATA AND PARAMETERS

4.1.1 Definition of Parameters

a	dimension of weight loss sample
b	dimension of weight loss sample
c	dimension of weight loss sample
b_0	coefficient in regression equation
b_1	coefficient in regression equation
b_2	coefficient in regression equation
$f(y)$	probability density function
i_{corr}	corrosion current density
i_{pass}	passive current density
k	parabolic rate constant in DOX model
p	wall penetration due to corrosive attack
t	exposure time during weight loss measurement
t	time in DOX model
u_i	mobility of the i^{th} ion
w	measured weight loss
w_{oxide}	formula weight of oxide formed during DOX
x	independent variable in regression equation
x	oxide thickness in DOX model
x_i	measured parameter in sensitivity (error) analysis
x_o	initial oxide thickness in DOX model
y	dependent variable in regression equation
y	computed value in sensitivity (error) analysis
z_i	valence (charge) of the i^{th} ion
$C_i(\alpha)$	molar concentration of the i^{th} ion in alpha phase
$C_i(\beta)$	molar concentration of the i^{th} ion in the beta phase
D_{oxide}	diffusivity of reacting species through protective oxide
E_{corr}	corrosion potential
$E_{critical}$	critical potential – threshold for localized attack
E_j	junction potential – correction for reference electrode junction
F	Faraday's constant
G_{aged}	enhancement factor for corrosion rate to account for thermal aging of Alloy 22
G_{MIC}	enhancement factor for corrosion rate to account for microbial influenced corrosion
J_{oxide}	flux of reacting species through protective oxide
R	universal gas constant
R^2	regression coefficient
RH	RH
$RH_{critical}$	threshold RH for HAC
T	temperature

σ	standard deviation
μ	mean
ρ	density of Alloy 22
ρ_{oxide}	density of oxide formed during DOX
ζ_{oxide}	stoichiometric coefficient for DOX reaction

4.1.2 Determination of Input Parameters

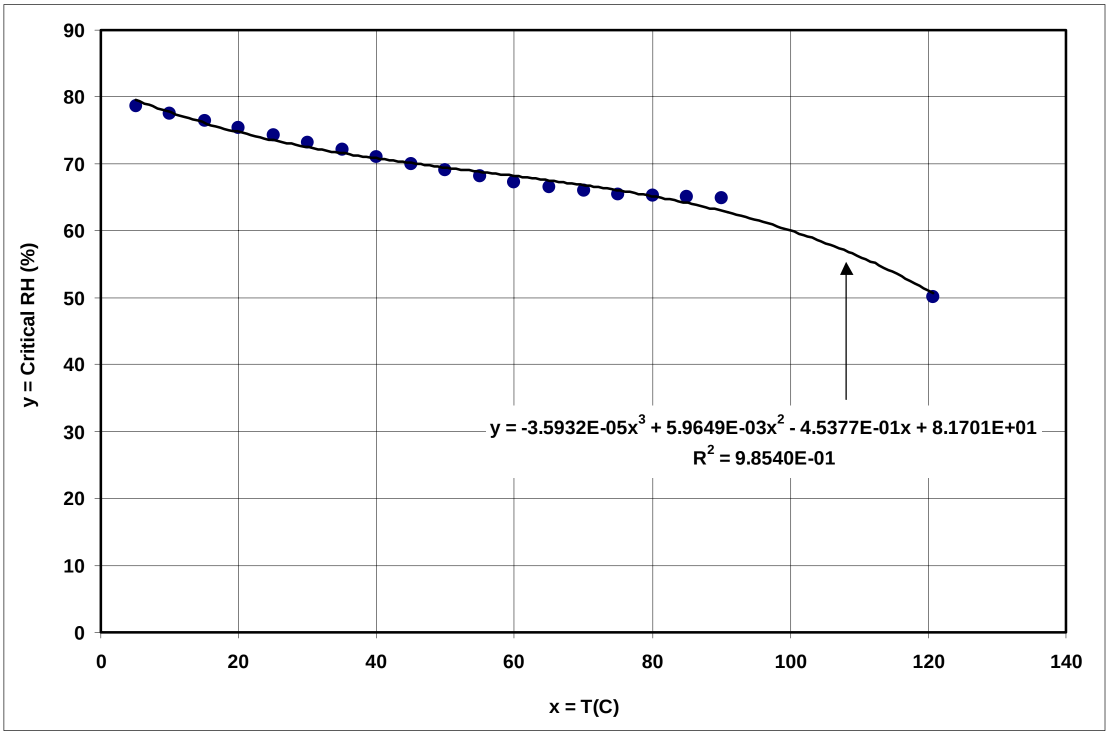
Input for this AMR includes bounding conditions for the local environment on the WP surface, which include temperature, RH, presence of liquid-phase water, liquid-phase electrolyte concentration (chloride, buffer, and pH), and oxidant level. The detailed evolution of the environment on the WP and DS surface is defined by a companion AMR entitled *Environment on the Surface of Drip Shield and Waste Package Outer Barrier* (CRWMS M&O 2000a). This work has been used to define the threshold RH for HAC and APC, as well as a medium for testing WP materials under what is now believed to be a worst-case scenario. This test medium is presented here as simulated saturated water (SSW) and has a boiling point of approximately 120°C.

As discussed in the AMR on WP and DS surface environment (CRWMS M&O 2000a), hygroscopic salts may be deposited by aerosols and dust introduced with the backfill and ventilation air. They will be contained in seepage water that enters the drifts and the episodic water that flows through the drifts. Such hygroscopic salts enable aqueous solutions to exist as thin surface films at relative humidities below 100%. The threshold RH ($RH_{critical}$) at which an aqueous solution can exist is defined as the deliquescence point (CRWMS M&O 2000a). This threshold defines the condition necessary for aqueous electrochemical corrosion processes of a metal with salt deposits to occur at a given temperature. The deliquescence point of NaCl is relatively constant with temperature and varies from 72-75%. In contrast, the deliquescence point of $NaNO_3$ has a strong dependence on temperature, ranging from an RH of 75.36% at 20°C to 65% at 90°C. The implied equilibrium RH is 50.1% at 120.6°C, the boiling point of a saturated $NaNO_3$ solution at sea level. The primary uncertainty in the threshold RH for HAC and APC is due to the presence of nitrate. Values of the equilibrium RH as a function of temperature for a saturated solution of $NaNO_3$ are given in the AMR on WP and DS surface environment (CRWMS M&O 2000a). It is expected that any other salts with lower deliquescence points ($RH_{critical}$) are precipitated in surrounding rock before they reach the WP surface. This threshold obeys the following polynomial in temperature, which is a fit of the data deliquescence point data for $NaNO_3$:

$$RH_{critical} = -3.5932\times10^{-5}\times T(°C)^3 + 5.9649\times10^{-3} \times T(°C)^2 - 0.45377 \times T(°C) + 81.701 \quad \text{(Eq. 1)}$$

$R^2 = 0.9854$,

where R^2 is the coefficient of determination and where R is the coefficient of correlation. This correlation is compared to the data in Figure 2.



DTN: LL991208205924.096

Figure 2. Deliquescence Point for Sodium Nitrate Solutions

As discussed in the AMR on WP and DS surface environment (CRWMS M&O 2000a), the evaporative concentration of J-13 well water results in the concentration of Na^+, K^+, Cl^-, and NO_3^-. J-13 well water has a typical water chemistry for saturated zone and perched waters at Yucca Mountain and a mean composition that was reported by Harrar et al. (1990). During evaporative concentration HCO_3^-, Ca^{2+}, and Mg^{2+} are removed from solution due to carbonate precipitation. The concentration of HCO_3^- reaches a constant level, while the concentrations of F^- and SO_4^{2-} initially increase but eventually fall due to precipitation. Ultimately, the F^- reaches a low steady state value. The SSW used for testing is an abstract embodiment of this observation. The SSW formulation is based upon the assumption that evaporation of J-13 eventually leads to a sodium-potassium-chloride-nitrate solution. The absence of sulfate and carbonate in this test medium is believed to be conservative, in that carbonate would help buffer pH in any occluded geometry such as a crevice. It is well known that polyprotic acids serve as buffers.

Experimental data from the scientific and technical literature, the LTCTF and CP measurements, and crevice corrosion experiments at LLNL are used as a basis for this process-level model. The rationale for the test media in the LTCTF is discussed in Section 6.4.2 and by Gdowski (1997a, 1997b, 1997c). Determination of many of the listed parameters is not found specifically in this section but is discussed in detail in Section 6.0, "Analysis/Model." Specific input parameters from the LTCTF are GC rates from the various test media. CP measurements provide corrosion and threshold potentials necessary for switching from one corrosion mode to another (GC to LC). The crevice corrosion experiments enable the crevice pH to be reasonably bounded.

Inputs are handled as per OCRWM procedures AP-3.10Q and AP-3.15Q. Data is submitted to the Technical Data Management System and is listed in the associated Data Input Reference Sheet.

4.2 CRITERIA

The following criterion applies to general corrosion and localized corrosion of the WPOB of all WP designs (CRWMS M&O 1999f).

The disposal container/WP shall be designed, in conjunction with the Emplacement Drift System and the natural barrier, such that the expected annual dose to the average member of the critical group shall not exceed 25 mrem total effective dose equivalent at any time during the first 10,000 years after permanent closure, as a result of radioactive materials released from the geologic repository (CRWMS M&O 1999f) (Section 1.2.1.3).

4.3 CODES AND STANDARDS

4.3.1 Standard Test Media

G. E. Gdowski, *Formulation and Make-up of Simulated Dilute Water (SDW), Low Ionic Content Aqueous Solution*, Yucca Mountain Project, Lawrence Livermore National Laboratory, Livermore, CA, TIP-CM-06, Revision CN TIP-CM-06-0-2, April 4, 1997, Table 1, p. 3. (Gdowski 1997a)

G. E. Gdowski, *Formulation and Make-up of Simulated Concentrated Water (SCW), High Ionic Content Aqueous Solution*, Yucca Mountain Project, Lawrence Livermore National Laboratory, Livermore, CA, TIP-CM-07, Revision CN TIP-CM-07-0-2, April 4, 1997, Table 1, pp. 3-4. (Gdowski 1997b)

G. E. Gdowski, *Formulation and Make-up of Simulated Acidic Concentrated Water (SAW), High Ionic Content Aqueous Solution*, Yucca Mountain Project, Lawrence Livermore National Laboratory, Livermore, CA, TIP-CM-08, Revision CN TIP-CM-08-0-2, April 4, 1997, Table 1, p. 3. (Gdowski 1997c)

4.3.2 Cyclic Polarization Measurements

Standard Reference Test Method for Making Potentiostatic and Potentiodynamic Anodic Polarization Measurements, Designation G 5-94, 1997 Annual Book of ASTM Standards, Section 3, Vol. 3.02, pp. 54-57. (ASTM 1997d)

Standard Reference Test Method for Making Potentiostatic and Potentiodynamic Anodic Polarization Measurements, Designation G 5-87, 1989 Annual Book of ASTM Standards, Section 3, Vol. 3.02, pp. 79-85. (ASTM 1989)

4.3.3 General Corrosion Measurements

Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens, Designation G 1-90, 1997 Annual Book of American Society for Testing and Materials (ASTM) Standards, Section 3, Vol. 3.02, pp. 15-21. (ASTM 1997e)

Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens, Designation G 1-81, 1987 Annual Book of ASTM Standards, Section 3, Vol. 3.02, pp. 89-94, Subsection 8 - Calculation of Corrosion Rate, Appendix X1 – Densities for a Variety of Metals and Alloys. (ASTM 1987)

4.3.4 Comparative Density of Alloy 22

Standard Specification for Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Chromium-Molybdenum-Copper, and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Plate, Sheet, and Strip, Designation B 575-97, 1997. (ASTM 1997a)

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5. ASSUMPTIONS

5.1 DRY OXIDATION

DOX occurs at any RH below the threshold for HAC:

$$RH < RH_{critical} \qquad \text{(Eq. 2)}$$

This threshold RH for HAC ($RH_{critical}$) is assumed to obey Equation 1, which is based upon the AMR entitled *Environment on the Surface of Drip Shield and Waste Package Outer* (CRWMS M&O 2000a). This process is assumed to result in the formation of an adherent, protective oxide film of uniform thickness. The rate of DOX will be limited by mass transport through the growing metal oxide film. Consequently, the oxide thickness is assumed to obey a parabolic growth law (film thickness proportional to the square root of time). Reasonable values of the parabolic rate constant are assumed as discussed in Section 6.1. DOX is assumed to occur uniformly over each WAPDEG patch, which is comparable in size to that of a LTCTF sample with generic weight-loss geometry. Welding is assumed to have no significant effect on the DOX threshold and rate. Backfill is also assumed to have no significant effect on the DOX threshold and rate. These assumptions are relevant to the analysis presented in Section 6.1.

As pointed out in CRWMS M&O (2000a), the deliquescence point can cover a broad range. For example, the deliquescence point of NaOH is 1.63% at 75°C. The deliquescence point of K_2SO_4 is 97.59% at 20°C. It is assumed that the uncertainty in $RH_{critical}$ can be represented by a triangular distribution (Section 6.5.4). The value at the 50th percentile is represented by Equation 1. Values at the 0th and 100th percentiles are assumed to be 1.63 and 97.59%, respectively. The specified bounds represent possible binary combinations of anions and cations in J-13 well water. This range addresses concerns regarding a possible lack of conservatism raised during auditing of this AMR.

5.2 HUMID AIR CORROSION

HAC occurs at any RH above the threshold:

$$RH \geq RH_{critical} \qquad \text{(Eq. 3)}$$

This threshold RH for HAC ($RH_{critical}$) is assumed to obey Equation 1, which is based upon the AMR entitled *Environment on the Surface of Drip Shield and Waste Package Outer Barrier* (CRWMS M&O 2000a). The measured distributions of general corrosion rates for HAC and APC are indistinguishable. Actual rates were below the level of detection. Therefore, the combined distributions presented here are based upon the combined data for the vapor and aqueous phases and are assumed to represent HAC and APC equally well. It is also assumed that the corrosion rate is constant and does not decay with time. Less conservative corrosion models assume that the rate decays with time. HAC is assumed to occur uniformly over each WAPDEG patch, which is comparable in size to that of a LTCTF sample with generic weight-loss geometry. Welding is assumed to have no significant effect on the HAC threshold and rate.

Backfill is also assumed to have no significant effect on the HAC threshold and rate. These assumptions are relevant to the analysis presented in Section 6.2.

5.3 AQUEOUS PHASE CORROSION

At a given surface temperature, the existence of liquid-phase water on the WP depends upon the presence of a salt and mineral deposit. In the presence of such a deposit, a liquid-phase can be established at a higher temperature and lower RH than otherwise possible. In the model discussed here, two conditions must be met for APC, (1) dripping water and (2) RH above the deliquescence point of the deposit at the temperature of the WP surface. While dripping can occur without this condition being met, it is assumed that both conditions are necessary for APC. Without this level of RH, it is assumed that no aqueous phase could be sustained on the surface.

$$RH \geq RH_{critical} \quad \text{(Eq. 4)}$$

This threshold RH for APC ($RH_{critical}$) is assumed to obey Equation 1, which is based upon the AMR entitled *Environment on the Surface of Drip Shield and Waste Package Outer Barrier* (CRWMS M&O 2000a). For the time being, the composition of the electrolyte formed on the WP surface is assumed to be that of SCW below 100°C and that of SSW above 100°C. It is assumed that the corrosion rate is constant and does not decay with time. Less conservative corrosion models assume that the rate decays with time. General APC is assumed to occur uniformly over each WAPDEG patch, which is comparable in size to that of a LTCTF sample with generic weight-loss geometry. Welding is assumed to have no significant effect on the APC threshold and rate. Backfill is also assumed to have no significant effect on the APC threshold and rate. These assumptions are relevant to the analysis presented in Section 6.3.

5.4 DRIPPING CONDENSATE FROM INNER SURFACE OF THE DRIP SHIELD

Once the temperature of the DS drops below the dew point, condensation can occur on the inner surface. This condensate can then form droplets that fall through the intervening vapor space and impinge the underlying WP surface, provided that the droplets are sufficiently large so that they can fall through the temperature gradient towards the WP without complete evaporation. After impingement, instantaneous thermodynamic equilibrium is assumed to exist between the condensate and surface deposit. The assumption of instantaneous equilibrium is based on a conservative approach. While much additional work is needed to determine the actual electrolyte composition in this scenario, SCW is assumed below 100°C, while SSW is assumed above 100°C. This assumption is based on the data from CRWMS M&O (2000a), which shows an increase in boiling point as the concentration increases from SCW to SSW. It is assumed that the corrosion rate is constant and does not decay with time. Less conservative corrosion models assume that the rate decays with time. This assumption is relevant to the analysis presented in Section 6.3.

5.5 FLOW THROUGH OPENINGS BETWEEN DRIP SHIELD

Section 5.5 is included in this report to show the relationship between water penetrating the protective DS and the water actually contacting the WPOB. Potential ground movement due to seismic activity may cause displacement of adjacent DSs along the drift axis, thereby opening pathways that enable dripping water to reach the WP. For a given mass flow of water contacting the outer surface of the DS, the fraction passing through an opening to the WP is assumed to be proportional to the following multiplication factor (Θ_{shield}):

$$\Theta_{shield} = \frac{A_{opening}}{A_{shield}} \qquad \text{(Eq. 5)}$$

where $A_{opening}$ is the projected area of the opening on the floor of the drift and A_{shield} is the projected area of the DS on the floor of the drift. If the DS fails due to SCC, a multiplication factor of one is assumed. This assumption is relevant to the analysis presented in Section 6.3.

5.6 THRESHOLD FOR LOCALIZED CORROSION

If the open circuit corrosion potential (E_{corr}) is less than the threshold potential for localized corrosion ($E_{critical}$), no localized corrosion occurs:

$$E_{corr} < E_{critical} \qquad \text{(Eq. 6)}$$

Threshold values have been determined for various representative environments, as discussed in Section 6.4. This assumption is relevant to the analysis presented in Section 6.4.

As an example, in an ideal case the crevice corrosion temperature can be estimated from the intersection of the lines representing the corrosion and threshold potentials at an elevated temperature. To force crevice corrosion to occur in the model, E_{corr} and $E_{critical}$ can simply be equated over temperature ranges of uncertainty (90-120°C). It is assumed that the crevice corrosion temperature is uniformly distributed over this range of uncertainty. This assumption is relevant to the analysis presented in Section 6.4.3 and is based on a conservative approach for crevice corrosion temperature.

5.7 EFFECT OF GAMMA RADIOLYSIS ON CORROSION POTENTIAL

Effects of oxidant can be accounted for through the open circuit corrosion potential (E_{corr}). Based upon published data described in Section 6.5.2, as well as new experimental data shown in this AMR, it is believed that the shift in corrosion potential due to gamma radiolysis will be much less than 200 mV. It is believed that this shift is insufficient to cause LC. This assumption is relevant to the analyses presented in Section 6.4 and 6.5.2.

5.8 EFFECT OF MICROBIAL GROWTH ON CORROSION POTENTIAL

The effect of microbial growth on E_{corr} and GC rates for Alloy 22 have been studied by Lian et al. (1999) and Horn et al. (1998). End-point measurements of E_{corr} in both inoculated and sterile media indicate that microbial growth does not have any large impact on this parameter. The GC rate appears to be doubled in the presence of microbes. More work is needed to help resolve this issue in the future. This assumption is relevant to the analyses presented in Sections 6.4, 6.5, and 6.8 and will be further developed in the future.

5.9 EFFECT OF AGING AND PHASE INSTABILITY ON CORROSION

The WP surface temperature will always be below 350°C, a limit determined by the spent nuclear fuel cladding. By further constraining the WP surface temperature, making sure that it is always below 300°C, the effects of aging and phase instability on the corrosion performance of Alloy 22 can be assumed to be insignificant. An extrapolation of the curves given in the companion AMR on aging and phase stability does not indicate that the phase stability of Alloy 22 *base metal* will be a problem at less than about 300°C (CRWMS M&O 2000b). However, it must be emphasized that such estimates are preliminary and uncertain. Much additional work is needed in this area. Rebak et al. have investigated the effects of high-temperature aging on the corrosion resistance of Alloy 22 in concentrated hydrochloric acid. However, due to the temperature used to age the samples (922-1033 K) and the extreme test media used (boiling 2.5% HCl and 1 M HCl at 339 K), these data are not considered relevant to performance assessment for the repository. This data will soon be published by R. B. Rebak, N. E. Koon, and P. Crook in an article entitled "Effect of High Temperature Aging on the Electrochemical Behavior of C-22 Alloy." This paper will appear in the Proceedings of the 50^{th} Meeting of the International Society of Electrochemistry, which documents a conference held in Pavia, Italy, in September 1999. This assumption is relevant to Section 6.4 and 6.5 and will be further developed in the future.

5.10 FLOW THROUGH COINCIDENT PENETRATION IN WASTE PACKAGE

It is assumed that the entire mass flow of water passing through the opening in the DS is distributed uniformly on the underlying WP. The fraction of this water that enters a failed WP is assumed to be proportional to the following multiplication factor ($\Theta_{package}$):

$$\Theta_{package} = \frac{A_{failed}}{A_{package}} \qquad \text{(Eq. 7)}$$

where A_{failed} is the projected area of all failed (completely corroded) WAPDEG patches on the floor of the drift and $A_{package}$ is projected area of the WP on the floor of the drift. This assumption is used throughout the analysis. This assumption is based on a conservative approach to allow for maximum water flow.

5.11 ASSUMPTIONS PERTAINING TO INNER BARRIER

Section 5.11 is included in this report to emphasize that all corrosion performance is allocated to the WPOB even though the WP is a double-wall container. It is assumed that the stainless steel 316NG inner barrier of the WP provides structural integrity for the WP until the outer barrier fails. No credit is claimed for the corrosion resistance of this stainless steel layer. This assumption is used throughout the analysis and is based on a conservative approach even though the inner barrier is expected to be a barrier for water ingress and radionuclide release.

After penetration of the WPOB, the formation of a crevice between the Alloy 22 and 316NG is possible. The formation of a low-pH crevice environment in this interfacial region is possible as discussed in Section 6.6.5. Crevice corrosion of the Alloy 22 due to the local chemistry established through hydrolysis of dissolved metal from the 316NG could be severe. While such inside-out attack is not accounted for in the present model, it may be desirable to account for it in the future, especially in crevice regions with welds that might be susceptible to SCC. This assumption is used throughout the analysis.

5.12 QUALIFICATION STATUS OF ASSUMPTIONS

The validity of assumptions, and hence the qualification, will be determined through future confirmatory tests. This document and its conclusions may be affected by technical product input information that requires confirmation. Any changes to the document or its conclusions that may occur as a result of completing the confirmation activities will be reflected in subsequent revisions. The status of the input information quality may be confirmed by review of the Document Input Reference System database.

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6. ANALYSIS

6.1 DRY OXIDATION

DOX of Alloy 22 is assumed to occur at any $RH < RH_{\text{critical}}$, thereby forming an adherent, protective oxide film of uniform thickness. It is assumed that the protective oxide film is primarily Cr_2O_3. The oxidation reaction is given as (Welsch et al. 1996):

$$4/3\,Cr + O_2 \longrightarrow 2/3\,Cr_2O_3 \quad \text{(Eq. 8)}$$

The rate of DOX is assumed to be limited by mass transport through this growing metal oxide film. Fick's first law is applied, assuming a linear concentration gradient across the oxide film of thickness x:

$$J_{oxide} = -D_{oxide}\frac{\partial C}{\partial x} \approx -D_{oxde}\frac{\Delta C}{x} \quad \text{(Eq. 9)}$$

where J_{oxide} is the molar flux of the reacting species in the oxide, D_{oxide} is the diffusivity of the reacting species in the oxide, ΔC is the corresponding differential molar concentration. Oxide growth is related to the flux by:

$$\frac{dx}{dt} = \frac{\zeta_{oxide} \times w_{oxide} \times J_{oxide}}{\rho_{oxide}} \quad \text{(Eq. 10)}$$

where ζ_{oxide} is the stoichiometric coefficient (moles of oxide per mole of diffusing species), w_{oxide} is the formula weight of the oxide, and ρ_{oxide} is the density of the oxide. Integration shows that the oxide thickness should obey the following parabolic growth law (Wagner's Law [Welsch et al. 1996]), where the film thickness is proportional to the square root of time. This is represented by Equation 11.

$$x = \sqrt{x_0^2 + k \times t} \quad \text{(Eq. 11)}$$

where x_0 is the initial oxide thickness, x is the oxide thickness at time t, and k is a temperature-dependent parabolic rate constant. More specifically, k is defined as follows:

$$k = \frac{2 \times \zeta_{oxide} \times w_{oxide} \times D_{oxide} \times \Delta C}{\rho_{oxide}} \quad \text{(Eq. 12)}$$

To facilitate an approximate calculation, published values of k can be used (Welsch et al. 1996). From Figure 18 of this reference, it is concluded that all observed values of k fall below a line defined by:

$$\log\left[k\left(m^2 s^{-1}\right)\right] = -12.5\left(\frac{10^3}{T(K)}\right) - 3.5 \quad \text{(Eq. 13)}$$

where T is defined as the absolute temperature. The highest temperature is expected to be approximately 350°C (623 K), which corresponds to the limit for the fuel cladding. The value of k corresponding to this upper limit is 2.73×10^{-24} m^2 s^{-1} (8.61×10^{-5} square µm per year). After one year, this corresponds to a growth of 0.0093 µm (about 9.3 nm y^{-1}). As will be seen in a subsequent discussion (Section 6.5.3), this estimated rate is comparable to that expected for APC at lower temperatures. It is, therefore, assumed that DOX of the Alloy 22 can be accounted for through application of the parabolic law. The above expression represents a conservative upper bound, based upon the published literature.

As discussed in the AMR for corrosion of the titanium DS (CRWMS M&O 2000c), logarithmic growth laws may be more appropriate at relatively lower temperature than parabolic laws. However, such logarithmic expressions predict that the oxide thickness (penetration) asymptotically approaches a small maximum level. In contrast, the parabolic law predicts continuous growth of the oxide, which is much more conservative. Since such conservative estimates of the rate of DOX do not appear to be life limiting and since reliable data for determining the maximum oxide thickness for Alloy 22 do not appear to be available, the parabolic growth law will be used for the WPOB.

The DOX model presented here assumes uniform oxidation of the WPOB surface. In the future, the possibility of preferential DOX along grain boundaries in the Alloy 22 should be considered. Such preferential attack would ultimately be diffusion controlled, with the diffusion path being equivalent to the length of oxidized grain boundary.

6.2 HUMID AIR CORROSION

HAC is assumed to occur above a threshold RH, provided that there are no impinging drips.

$$RH \geq RH_{critical} \qquad \text{(Eq. 14)}$$

This threshold RH for HAC ($RH_{critical}$) is assumed to obey Equation 1. The existence of this threshold is due to the dependence of water adsorption on RH.

Despite significant experimental work at LLNL, there continues to be significant uncertainty in the threshold RH for HAC and APC. Furthermore, data published by Leygraf (1995) indicates that it may be reasonable to consider HAC at a RH below that predicted with Equation 1 at 20°C. The approximate number of water monolayers on typical metal surfaces as a function of RH is given by Leygraf (1995) and repeated in Table 1.

Table 1. Coverage of Metal Surfaces by Water

Relative Humidity (%)	Number of Water Monolayers
20	1
40	1.5-2
60	2-5
80	5-10

Based upon this data, it might be reasonable to consider the possibility of HAC at only 40% RH. This is the point at which it may be possible for two monolayers of water to exist on the WP surface. However, under these conditions there are no electrolytes to facilitate the electrochemical corrosion.

As pointed out in CRWMS M&O (2000a), observed deliquescence points cover a very broad range of RH. The deliquescence point of NaOH is 1.63% RH at 75°C, while that of K_2SO_4 is 97.59% RH at 20°C. It is assumed that the uncertainty in $RH_{critical}$ can be represented by a triangular distribution. The triangular distribution is described in Section 6.5.4. The value at the 50^{th} percentile is represented by Equation 1. Values at the 0^{th} and 100^{th} percentiles are assumed to be 1.63 and 97.59%, respectively. The specified bounds represent possible binary combinations of anions and cations in J-13 well water.

It is assumed that HAC can be treated as uniform GC. The measured distributions of general corrosion rates for HAC and APC are indistinguishable. Actual rates were below the level of detection. Therefore, the combined distributions presented here are based upon the combined data for the vapor and aqueous phases and are assumed to represent HAC and APC equally well. It is also assumed that the corrosion rate is constant and does not decay with time.

6.3 AQUEOUS PHASE CORROSION

At a given surface temperature, the existence of liquid-phase water on the WP depends upon the presence of a salt deposit. In the presence of such a deposit, a thin-film liquid phase can be established at a higher temperature and lower RH than otherwise possible. In the model discussed here, it is assumed that two conditions must be met for APC—RH above the deliquescence point of the deposit at the temperature of the WP surface and impinging drips:

$$RH \geq RH_{critical} \qquad \text{(Eq. 15)}$$

This threshold RH for APC ($RH_{critical}$) is assumed to obey Equation 1, which is based upon the AMR entitled *Environment on the Surface of Drip Shield and Waste Package Outer Barrier* (CRWMS M&O 2000a). Drips may be due to liquid-phase ground water that flows through openings in the DS or condensate on the underside of the DS. For the time being, the composition of the electrolyte formed on the WP surface is assumed to be that of SCW below 100°C and that of SSW above 100°C. It is assumed that the corrosion rate is constant and does not decay with time. Less conservative corrosion models assume that the rate decays with time.

6.4 LOCALIZED CORROSION

6.4.1 Threshold Potential of Alloy 22

The localized corrosion model for Alloy 22 assumes that localized attack occurs if the open circuit corrosion potential (E_{corr}) exceeds the threshold potential for breakdown of the passive film ($E_{critical}$):

$$E_{corr} \geq E_{critical} \qquad \text{(Eq. 16)}$$

The repassivation potential is the level at which a failed passive film repassivates, or heals, thereby protecting the surface. Compared to materials proposed for use in earlier WP designs, Alloy 22 has superior resistance to localized corrosion. Gruss et al. (1998) have shown that the repassivation potential of Alloy C-22 is far greater than that of Alloy 625, which substantiates this claim (Table 2):

Table 2. Repassivation Potentials of Alloys 625 and C-22

Specimen No.	Chloride (M)	Temperature (°C)	Repassivation Potential (V vs. SCE)
625-1	4	95	-0.183
625-2	4	60	-0.167
625-3	1	95	-0.367
625-4	1	95	-0.166
625-5	1	95	-0.153
625-6	1	60	1.001
625-7	0.028	60	0.857
625-8	0.028	60	0.873
C22-1	4	95	0.916
C22-2	4	95	0.911
C22-3	4	95	0.900
C22-4	4	60	0.911
C22-5	1	95	0.829
C22-6	1	60	0.986
C22-7	0.028	95	0.854

NOTE: Gruss et al. (1998)

6.4.2 Cyclic Polarization in Synthetic Concentrated J-13 Well Waters

The YMP has used CP to determine threshold potentials for Alloy 22 in test media relevant to the environment expected in the repository. Relevant test environments are assumed to include simulated dilute water (SDW), SCW, and SAW at 30, 60, and 90°C as well as SSW at 100 and 120°C. The compositions of all of the environments are given in Table 3. The compositions of these test media are based upon the work of Gdowski (1997a, 1997b, 1997c). The SSW composition has been recently developed and is being documented in a revision of a companion AMR on the subject of WP and DS surface environment (CRWMS M&O 2000a). The revision is in preparation. In general, anions such as chloride promote LC, whereas other anions such as nitrate tend to act as corrosion inhibitors. Thus, there is a very complex synergism of corrosion effects in the test media.

CP measurements have been based on a procedure similar to ASTM G 5-87 (ASTM 1989). Necessary deviations have been noted in the corresponding controlled SNs. Copies of these SNs are maintained by the Management and Operating Contractor (M&O) in Las Vegas. For example, ASTM G 5-87 calls for an electrolyte of 1N H_2SO_4, whereas SDW, SCW, SAW, and SSW are used here. Furthermore, aerated solutions were used here, unlike the procedure that calls for de-aerated solutions. Representative CP curves are shown in Figures 3 through 9. The shape of these CP curves is categorized as type 1, 2, or 3.

Table 3. Composition of Standard Test Media Based upon J-13 Well Water

Ion	SDW (mg/L^{-1})	SCW (mg/L^{-1})	SAW (mg/L^{-1})	SSW (mg/L^{-1})
K^{+1}	3.400E+01	3.400E+03	3.400E+03	1.416E+05
Na^{+1}	4.090E+02	4.090E+04	4.090E+04	4.870E+04
Mg^{+2}	1.000E+00	1.000E+00	1.000E+03	0.000E+00
Ca^{+2}	5.000E-01	1.000E+00	1.000E+03	0.000E+00
F^{-1}	1.400E+01	1.400E+03	0.000E+00	0.000E+00
Cl^{-1}	6.700E+01	6.700E+03	6.700E+03	1.284E+05
NO_3^{-1}	6.400E+01	6.400E+03	6.400E+03	1.310E+06
SO_4^{-2}	1.670E+02	1.670E+04	1.670E+04	0.000E+00
HCO_3^{-1}	9.470E+02	7.000E+04	0.000E+00	0.000E+00
Si	27 (60°C), 49 (90°C)	27 (60°C), 49 (90°C)	27 (60°C), 49 (90°C)	0.000E+00
pH	8.100E+00	8.100E+00	2.700E+00	7.000E+00

NOTE: CRWMS M&O (2000a)

A generic type 1 curve exhibits complete passivity (no passive film breakdown) between the corrosion potential and the point defined as threshold potential 1. This interpretation was verified by visual inspection of samples after potential scans and photographic documentation of some of those samples (all samples are held in the archives at LLNL). Threshold potential 1 is in the range where the onset of oxygen evolution is expected and is defined by a large excursion in anodic current. This particular definition of threshold potential 1 is specific to type 1 curves. Type 1 behavior has only been observed with Alloy 22 and is illustrated by Figures 3 and 4. The interpretation of type 1 curves as exhibiting no passive film breakdown is consistent with the ASTM G 61-86.

A generic type 2 curve exhibits a well-defined oxidation peak at the point defined as threshold potential 1. Threshold potential 2 is in the range where the onset of oxygen evolution is expected and is defined by a large increase in anodic current. These particular definitions of the threshold potentials are specific to type 2. Repassivation potentials 1 and 2 are defined as the points where the hysteresis loop passes through current levels of $4.27x10^{-6}$ and 10^{-5} amps, respectively (not shown). Repassivation potential 3 is determined from the first intersection of the hysteresis loop (reverse scan) with the forward scan. Type 2 is observed with both Alloy 22 and 316L and is illustrated by Figures 5 through 7. Definitions of the threshold and repassivation potentials are somewhat subjective and may vary from investigator to investigator. Scully et al. (1999) define the threshold potential for crevice corrosion of Alloy 22 as the point during the scan of electrochemical potential in the forward direction where the current density increases to a level of 10^{-6} to 10^{-5} A cm^{-2}. Gruss et al. (1998) define the repassivation potential as the point where the current density drops to 10^{-6} to 10^{-7} A cm^{-2}, which is comparable to the definition of repassivation potential 3.

A generic type 3 curve exhibits a complete breakdown of the passive film and active pitting at potentials relatively close to the Corrosion Potential (E_{corr}). In this case, threshold potential 1 corresponds to the critical pitting potential. Type 3 behavior has only been observed with 316L and is illustrated by Figure 8.

A representative curve for platinum in SCW at 90°C is shown in Figure 9. CP measurements of Pt were made to serve as a basis of comparison for similar measurements with Alloy 22 and other materials of interest. From such comparisons, it is concluded that the anodic oxidation peak observed in type 2 curves (between 200 and 600 mV) is due to an anodic reaction of the Alloy 22 passive film. No anodic oxidation peak is observed in the measurement of Pt.

SSW is a saturated sodium-potassium-chloride-nitrate electrolyte, formulated to represent the type of concentrated electrolyte that might evolve on a hot WP surface. This formulation has a boiling point of approximately 120°C at ambient pressure. It is evident in Figure 3 that Alloy 22 maintains passivity at potentials up to the reversal potential (1200 mV versus Ag/AgCl), even under these relatively hostile conditions.

In regard to type 2 polarization curves for Alloy 22 in SCW, the electrochemical process leading to the anodic oxidation peak (leading edge at approximately 200 mV versus Ag/AgCl) cannot be determined from the CP data alone. This peak is probably due to some change in the oxidation state of the passive film and probably has very little to do with any loss of passivity. To augment these potentiodynamic measurements, potentiostatic polarization tests have been performed. Figure 10 shows the observed transient current when an Alloy 22 sample is polarized at 200 mV versus Ag/AgCl in SCW at 90°C, close to the potential where the leading edge of the anodic oxidation peak is located. The current initially increases to a maximum of approximately 25 microamps per square centimeter (the sample size is approximately 0.96 cm^2) at 9 hours. This corresponds to a typical non-equilibrium passive current density measured for Alloy 22 at this potential in the absence of the anodic oxidation peak. For example, see a type 1 polarization curve for Alloy 22 in SAW. Therefore, in regard to type 2 polarization curves, the anodic oxidation peak does not define any localized corrosion or loss in passivity. Furthermore, threshold potential 1 (leading edge of the anodic oxidation peak at approximately 200 mV versus Ag/AgCl) should not be used as the basis for switching on localized corrosion of Alloy 22. Here, it is also assumed that threshold potential 2 represents the lower bound for breakdown of the passive film.

A composite of the CP data is shown in Figure 11. The initial portions of these curves show that passivity is maintained at potentials at least as high as 400 mV versus Ag/AgCl in all cases. The lowest potential at which any electrochemical reactivity of the passive film is observed at approximately 200 mV versus Ag/AgCl. Based upon data presented here, it is concluded that a pitting attack of Alloy 22 should not occur under conditions expected in the repository. To further substantiate this conclusion, it is noted that no pitting of Alloy 22 has yet been observed in samples removed from LTCTF. These data include one-year exposures to SDW, SCW, and SAW at 60 and 90°C. DTNs are associated with Figures 24 through 26.

The CP data given in this AMR are for test media believed to be representative of the expected repository environment. In such test media and at plausible electrochemical potentials, it does not appear that there will be significant localized breakdown of the passive film. Furthermore, relatively wide crevices (110 to 540 microns) formed from passive Alloy 22 do not appear to undergo significant increases in hydrogen ion concentration (pH suppression) at reasonable electrochemical potentials. These potentials are generally below the thresholds determined by CP. Finally, Alloy 22 crevices exposed in the LTCTF do not indicate significant crevice corrosion.

However, it should be noted that the University of Virginia has very recently generated some CP data with very tight crevices and concentrated electrolytes consisting of 5 M LiCl, 0.24 to 0.024 M $NaNO_3$, 0.026 to 0.26 M Na_2SO_4, and HCl (Scully et al. 1999). Testing was conducted at two temperature levels, 80 and 95°C. The crevices were formed with a multiple crevice former, PTFE tape, and an applied torque of 70 inch pounds. Under these circumstances, some electrochemical activity indicative of crevice corrosion was observed at potentials ranging from 71 to 397 mV versus Ag/AgCl, depending upon the composition of the electrolyte. Using a current density criterion for repassivation of 10^{-5} A cm^{-2}, repassivation potentials were determined to be slightly above, but relatively close to, the open-circuit corrosion potential.

While these concentrated lithium-chloride based electrolytes are not believed to be directly relevant to those conditions anticipated in the repository, the University of Virginia data point out that no attitude of complacency should be adopted in regard to conducting further research in the area of localized corrosion of Alloy 22. Unlike compositions based upon J-13 well water, these electrolytes have no buffer ions *per se*. Clearly, additional work is needed to better understand the passivity and resistance to localized attack of all WP materials. In the future, similar measurements with test media believed to be relevant to the repository should be conducted. Specifically, testing with the tight-crevice geometry used by the University of Virginia and standard electrolytes such as SDW, SCW, SAW, and SSW should be conducted. As more data become available, the correlations for the corrosion and threshold potentials should be updated, expressing these quantities in terms of temperature, pH, and the concentrations of various ions. The effect of welding and aging should also be accounted for. This AMR should be viewed as works in progress, with each new version reflecting an evolving level of understanding.

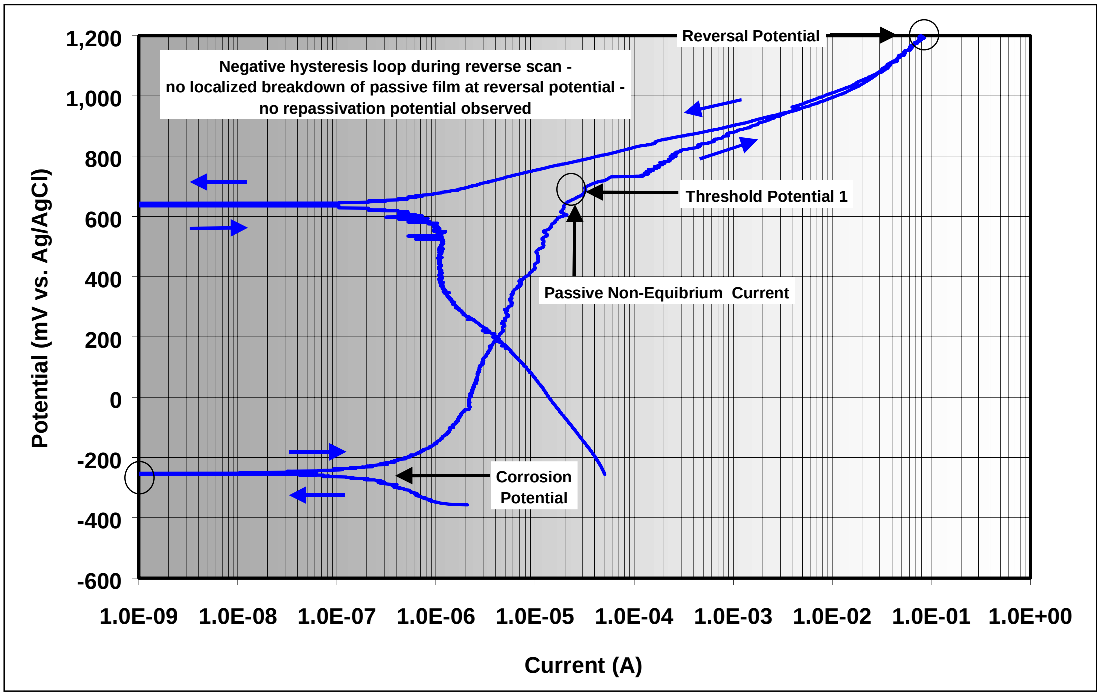

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Figure 3. Type 1 – Alloy 22 in SSW at 120°C (DEA033)

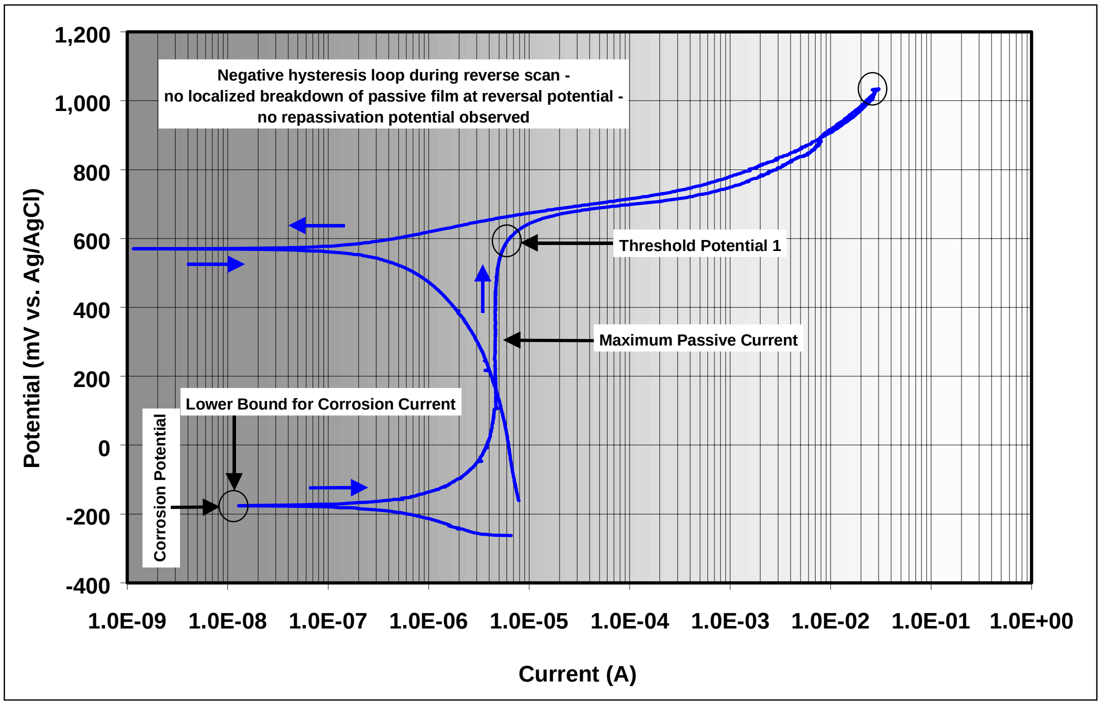

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Figure 4. Type 1 – Alloy 22 in SAW at 90°C (DEA002)

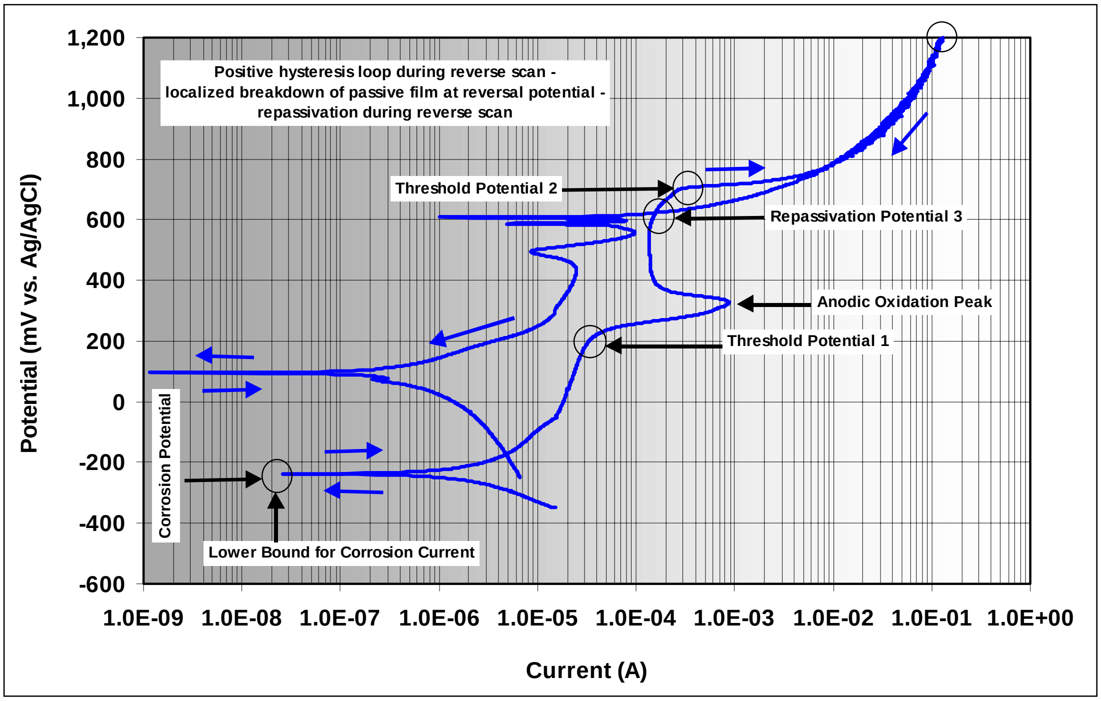

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Figure 5. Type 2 – Alloy 22 in SCW at 90°C (DEA016)

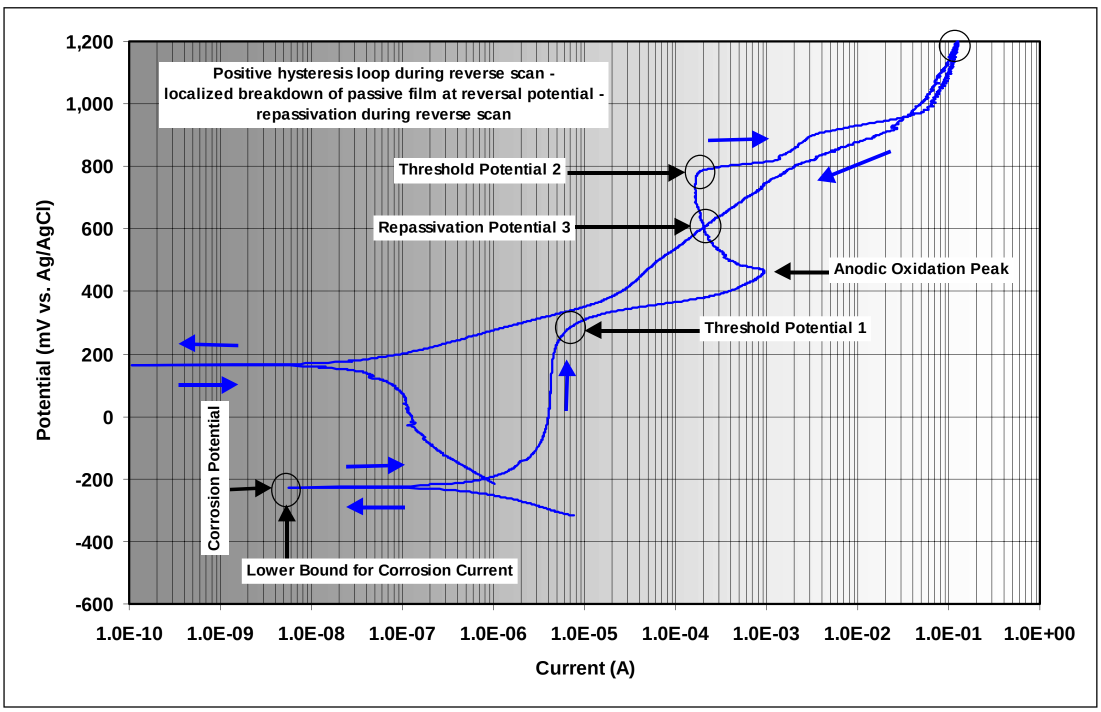

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Figure 6. Type 2 – Alloy 22 in SCW at 60°C (DEA017)

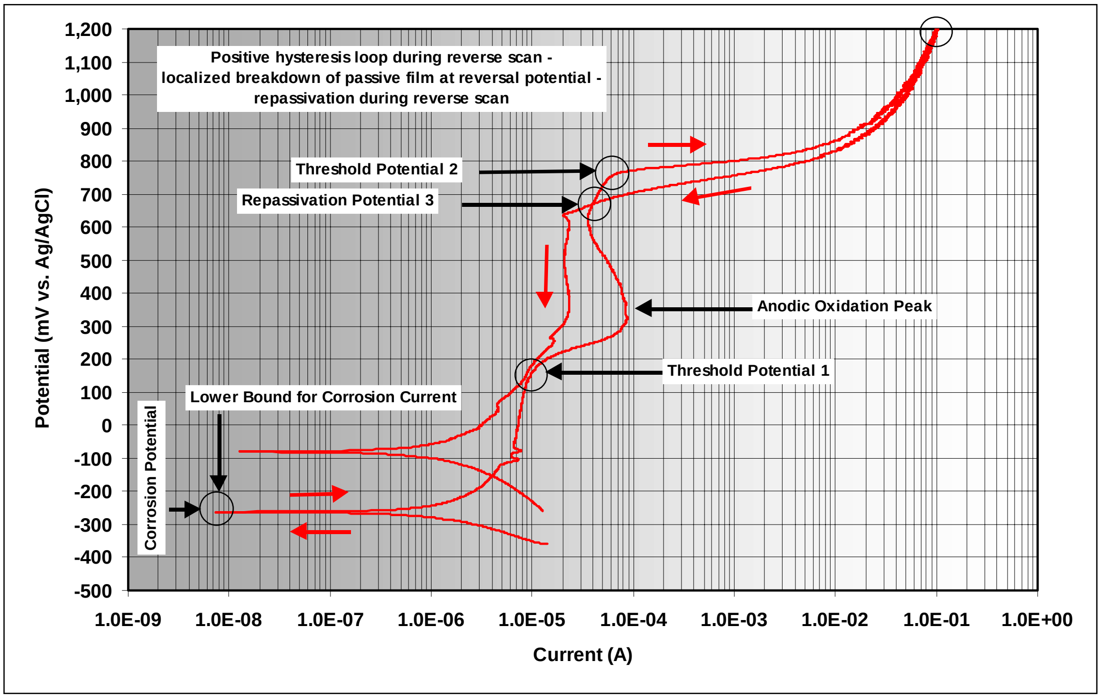

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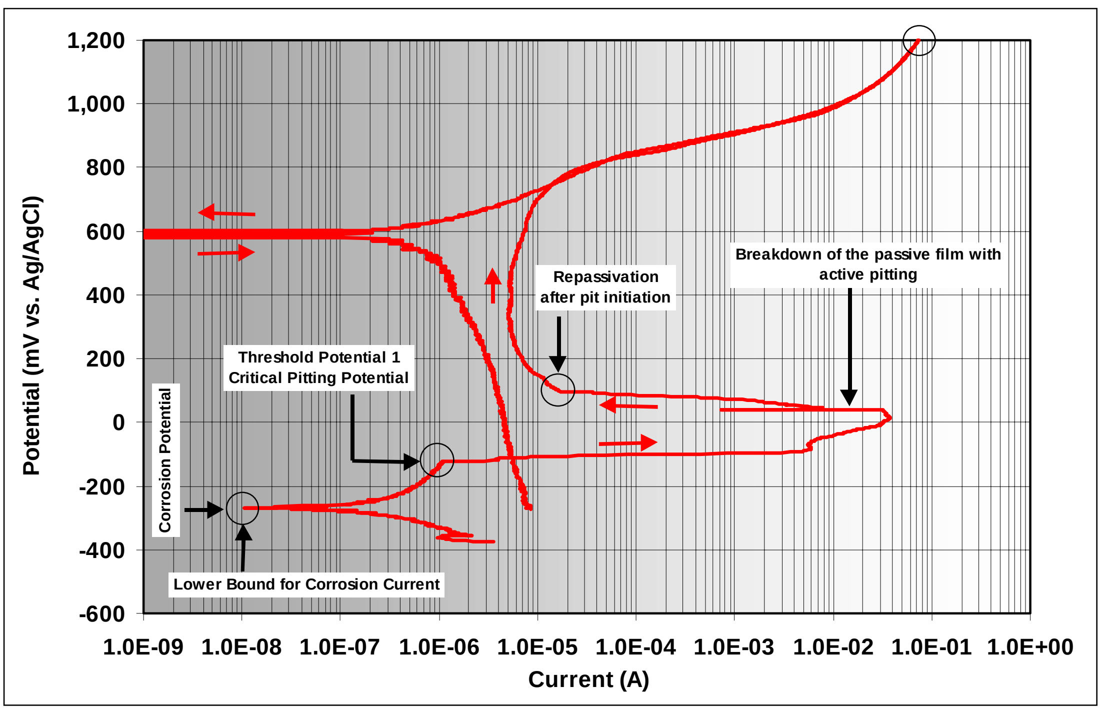
Figure 7. Type 2 – 316L in SCW at 90°C (PEA002)



DTN: LL990610105924.074

Figure 8. Type 3 – 316L in SSW at 100°C (PEA016)

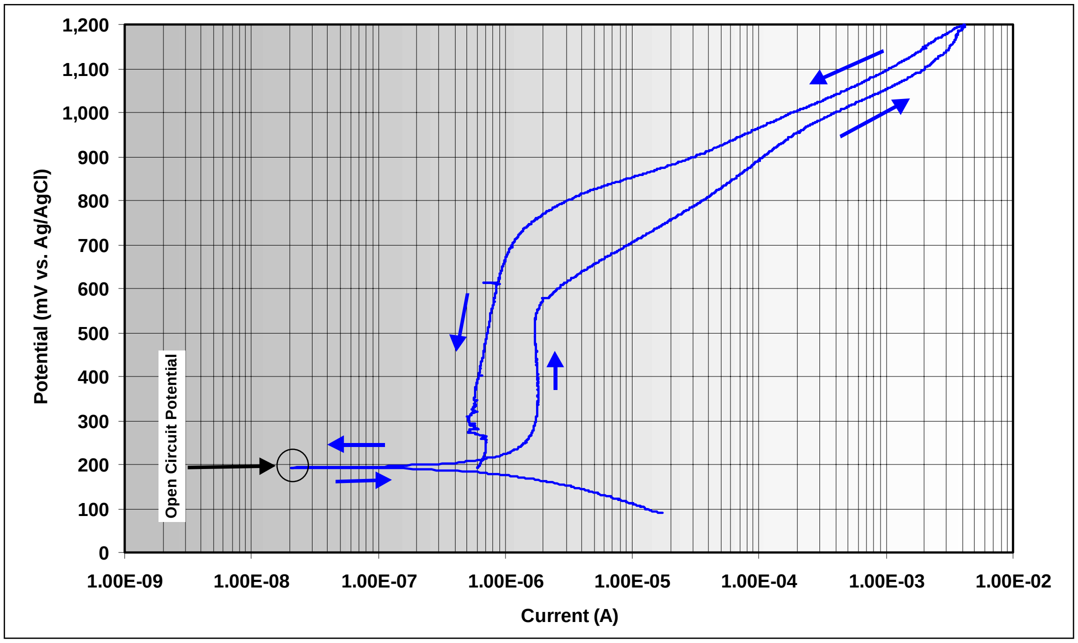


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Figure 9. Baseline – Pt in SCW at 90°C (PT001)

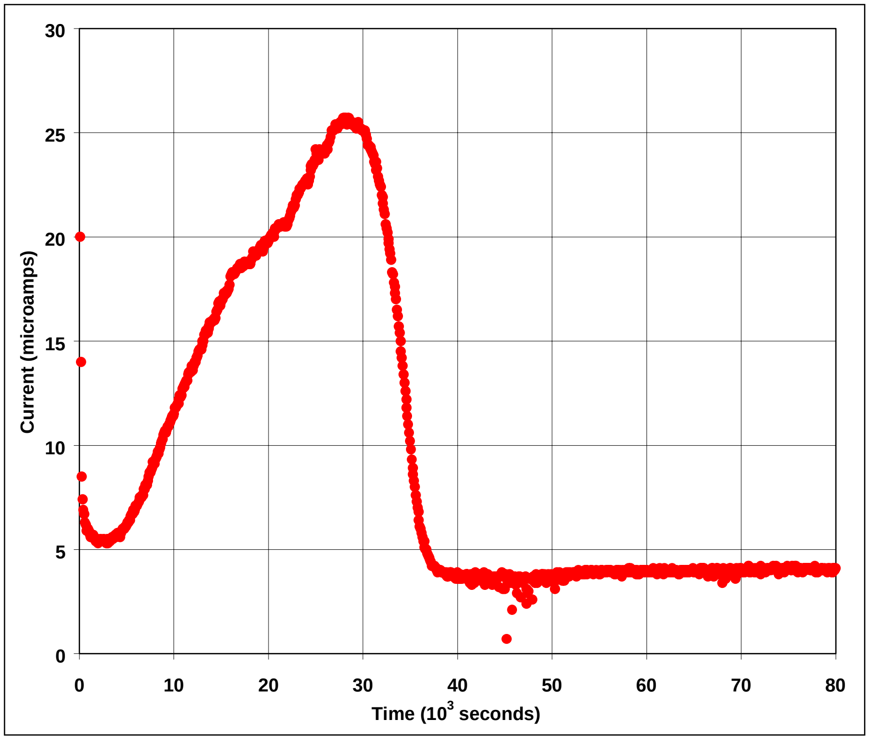

Figure 10. Potentiostatic Polarization of Alloy 22 in SCW at 90°C and 200mV Versus Ag/AgCl

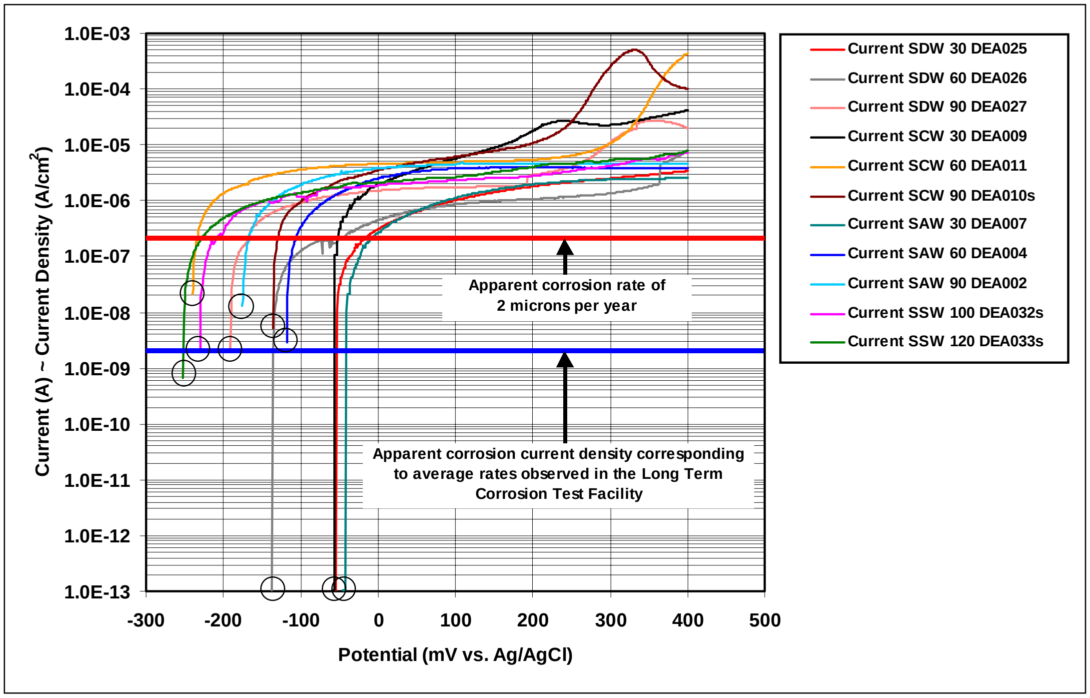

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Figure 11. Alloy 22 in Various Repository Media – Comparison of CP Data

6.4.3 Correlation of Potential Versus Temperature Data for Various Test Media

Values of corrosion and threshold potentials are shown in Table 4 and have been correlated as a function of temperature for the conditions of interest. These correlated data are shown in Figures 12 through 15. In general, it has been found that these potential verses temperature data can be represented by the following simple regression equation:

$$y = b_0 + b_1 x \qquad \text{(Eq. 17)}$$

where y is either the corrosion or threshold potential (mV versus Ag/AgCl), and x is the temperature (°C). The linear curves were derived from regression analysis. All correlations are summarized in Table 5, with the correlation for E_{corr} and the most conservative correlation for $E_{critical}$ labeled. While calculated values of y are believed to have only three significant figures, coefficients in those regression equations used to calculate values of y are given with more figures. By carrying the extra figures during the calculation, round-off error in the final values can be minimized. In the case of type 2 CP curves, the selected threshold potential 1 is determined by the position of the observed anodic oxidation peak and may not result in any actual loss of passivity and localized corrosion.

The specifications for the WP material must include allowable values for E_{corr} and $E_{critical}$. Acceptance of a material requires that (1) the measured value of E_{corr} in a particular environment cannot exceed the value calculated with the corresponding correlation in Table 5 by more than 75 mV, and (2) the measured value of $E_{critical}$ in a particular environment cannot be less than the value calculated with the corresponding correlation in Table 5 by more than 75 mV.

The correlations given in Table 5 were used to calculate the values at 10°C intervals of E_{corr} and $E_{critical}$ shown in Table 6 for SDW, SCW, and SAW. The correlation for $E_{critical}$ in SSW was not used since it is based upon relatively few data points and indicates that the threshold increases with temperature, which is counter intuitive. A constant bounding value of 150 mV is assumed in this case. Table 6 shows the difference between $E_{critical}$ and E_{corr} (column heading *Diff.*) and is never less than 150 mV between 20 and 150°C. Therefore, implementation of the potential-based specification will prevent the use of heats of material that would be prone to passive film instability or localized corrosion. The cost of such performance would be associated with the quantity of rejected material (assumed to be approximately 20%). The specification can be changed to allow more material to be accepted but with greater risk of localized corrosion.

There are precedents for using electrochemical measurements as the basis of water chemistry and materials specifications in the nuclear industry. For example, measurements of corrosion potential are indicative of dissolved oxygen and can be used to assure adequate de-aeration in various regions of the steam cycle. The role of electrochemical potential on SCC has been well documented by Andresen (1987).

The critical potentials are specified as threshold potential 1 or 2. However, it must be emphasized that localized corrosion may not occur, even if these potential levels are reached. It is doubtful that localized corrosion will occur in any of these solutions, at any potential above E_{corr} and below the thermodynamic limit of water. Long-term potential control experiments should be performed to determine actual values of $E_{critical}$ for Alloy 22. Clearly, more work needs to be done.

In an ideal case, the crevice corrosion temperature can be estimated from the intersection of the lines representing the corrosion and threshold potentials at elevated temperature. Better correlations of E_{corr} and $E_{critical}$ with material history, water chemistry, and temperature may ultimately allow precise prediction of the crevice corrosion temperature. Improved correlations would provide rigorous statistical estimates of uncertainty and variability in E_{corr} and $E_{critical}$. The precise determination of uncertainty and variability in E_{corr} and $E_{critical}$ would enable designers to determine the impact of accepting 100% of the supplied WP material on repository performance. In the mean time, crevice corrosion can be forced to occur in the model by equating E_{corr} and $E_{critical}$ over temperature ranges of uncertainty (90-120°C). This assumption would provide a conservative estimate of the crevice corrosion temperature. Improved LC models with accurate temperature dependence will allow a precise sensitivity study, assessing the impact of various WP design changes on the radiological dose at the site boundary. Additional work and data is needed to fill this void.

Table 4. Compilation of Electrochemical Potentials Determined from CP Curves

Sample ID	Medium	Temp.	Reversal Potential	Corrosion Potential	Threshold Potential 1	Threshold Potential 2	Repass-ivation Potential 1	Repass-ivation Potential 2	Repass-ivation Potential 3	CP Curve Type
		°C	mV	mV	mV	mV	mV	mV	mV	
DEA025	SDW	30	1200	-55	466	688	524	577	619	Type 1-2
DEA026	SDW	60	1200	-137	317	874	438	495	506	Type 2
DEA027	SDW	90	1200	-191	192	757	283	338	387	Type 2
DEA023	SDW	30	1200	-65	436	900	511	555	564	Type 2
DEA022	SDW	60	1200	-174	282	800	464	508	501	Type 2
DEA024	SDW	90	1190	-162	185	739	270	308	422	Type 2
DEA019	SDW	30	1190	-93	420	900	516	556	579	Type 2
DEA021	SDW	60	1190	-161	290	809	445	491	509	Type 2
DEA020	SDW	90	1200	-158	169	724	268	335	390392	Type 2
DEA009	SCW	30	795	-57	169	421	none	none	none	Type 2
DEA011	SCW	60	797	-240	234	777	292	319	680	Type 2
DEA010	SCW	90	798	-136	206	719	16	46	663	Type 2
DEA012	SCW	30	1200	-173	338	910	490	530	699	Type 2
DEA014	SCW	60	1190	-231	226	771	319	344	572	Type 2
DEA013	SCW	90	1190	-173	336	910	490	532	699	Type 2
DEA015	SCW	30	1190	-188	341	907	538	572	742	Type 2
DEA017	SCW	60	1200	-226	238	789	323	353	595	Type 2
DEA016	SCW	90	1190	-237	199	704	609	609	622	Type 2

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Table 4. Compilation of Electrochemical Potentials Determined from CP Curves (Continued)

Sample ID	Medium	Temp.	Reversal Potential	Corrosion Potential	Threshold Potential 1	Threshold Potential 2	Repass-ivation Potential 1	Repass-ivation Potential 2	Repass-ivation Potential 3	CP Curve Type
		°C	mV	mV	mV	mV	mV	mV	mV	
DEA007	SAW	30	1020	-42	663	750	none	none	none	Type 1
DEA004	SAW	60	1050	-118	575	774	none	none	none	Type 1
DEA002	SAW	90	1040	-176	555	642	none	none	none	Type 1
DEA003	SAW	30	1100	-66	650	775	none	none	none	Type 1
DEA006	SAW	60	1040	-115	613	783	none	none	none	Type 1
DEA029	SAW	90	1200	-171	595	652	646	671	849	Type 1
DEA005	SAW	30	1820	-84	664	867	none	none	none	Type 1
DEA008	SAW	60	1070	-102	605	708	none	none	none	Type 1
DEA031	SAW	90	1200	-150	600	650	none	none	none	Type 1
DEA032	SSW	100	1200	-234	234	768	none	none	none	Type 2
DEA033	SSW	120	1200	-253	664	715	none	none	none	Type 1
DEA035	SSW	100	1200		216	526	none	none	none	Type 1
DEA034	SSW	120	1200	-320	171	471	none	none	none	Type 2

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Note: The term “none” indicates no detected breakdown in passive film up to the specified reversal potential; no determination of repassivation potential was possible. All potentials were measured with an Ag/AgCl reference electrode. One should subtract 197 mV from measured values to convert to the Normal Hydrogen Electrode potential scale.

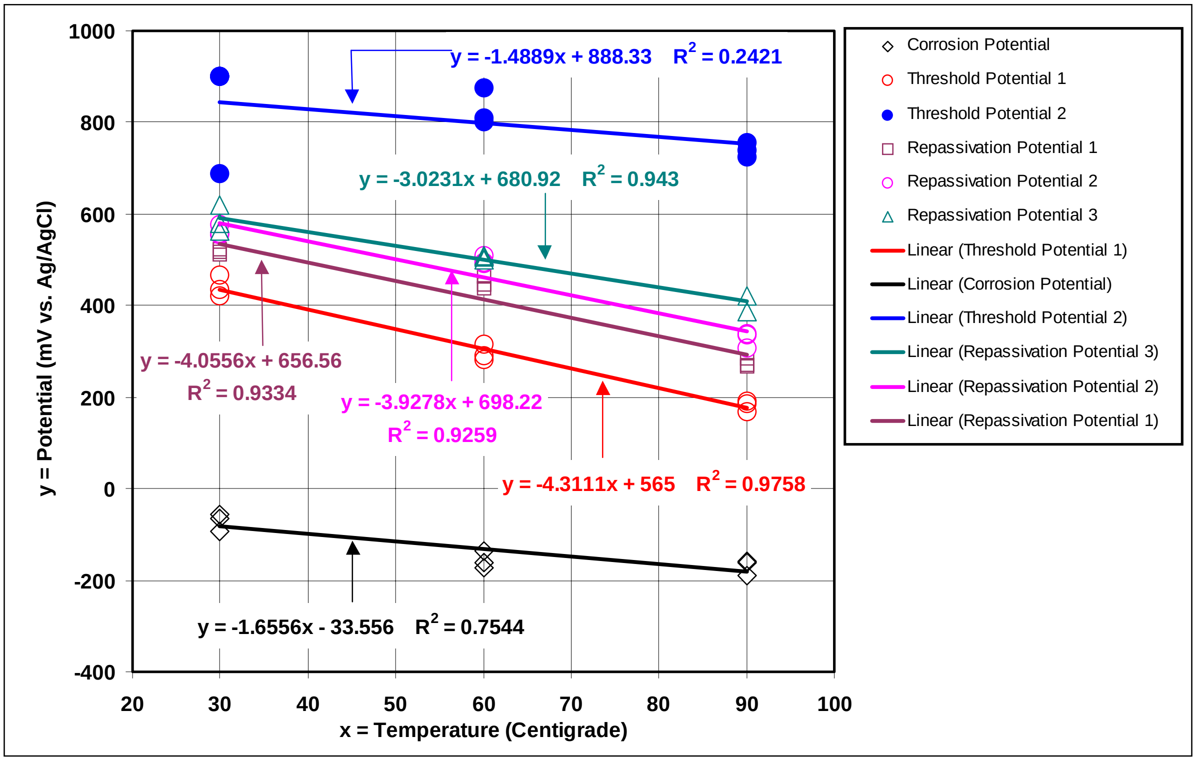

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Figure 12. Potentials Versus Temperature: Alloy 22 in SDW

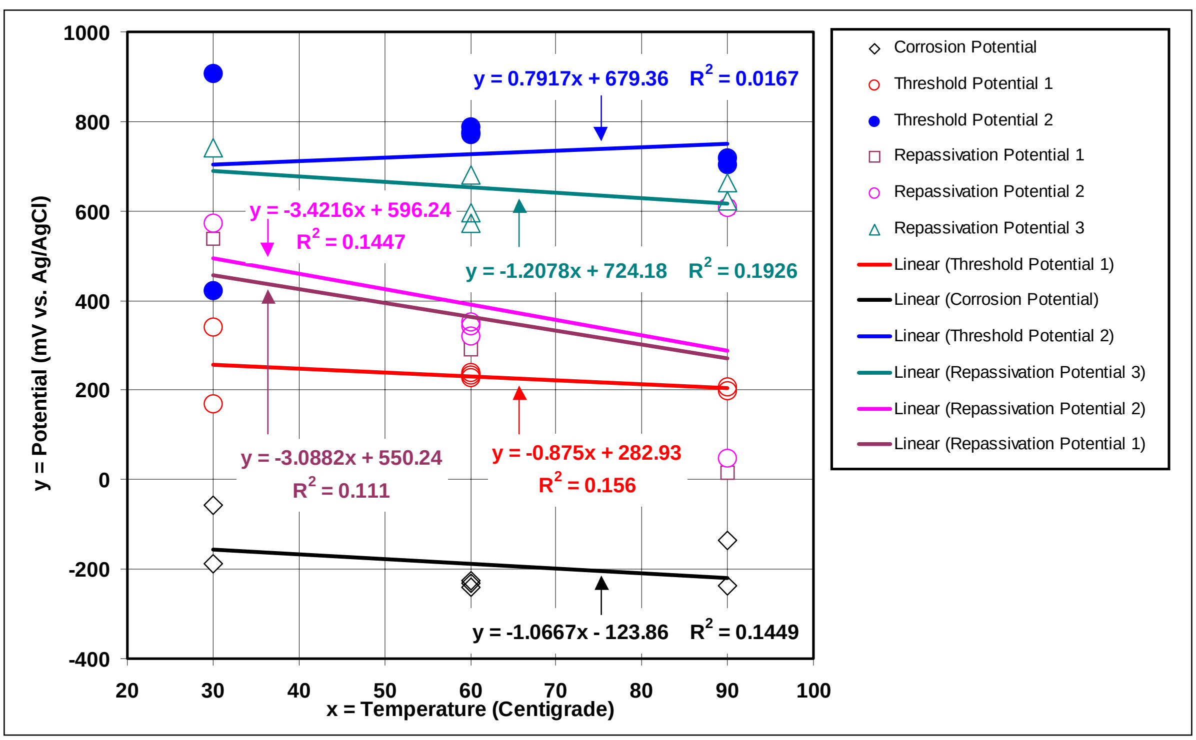

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Figure 13. Potentials Versus Temperature: Alloy 22 in SCW

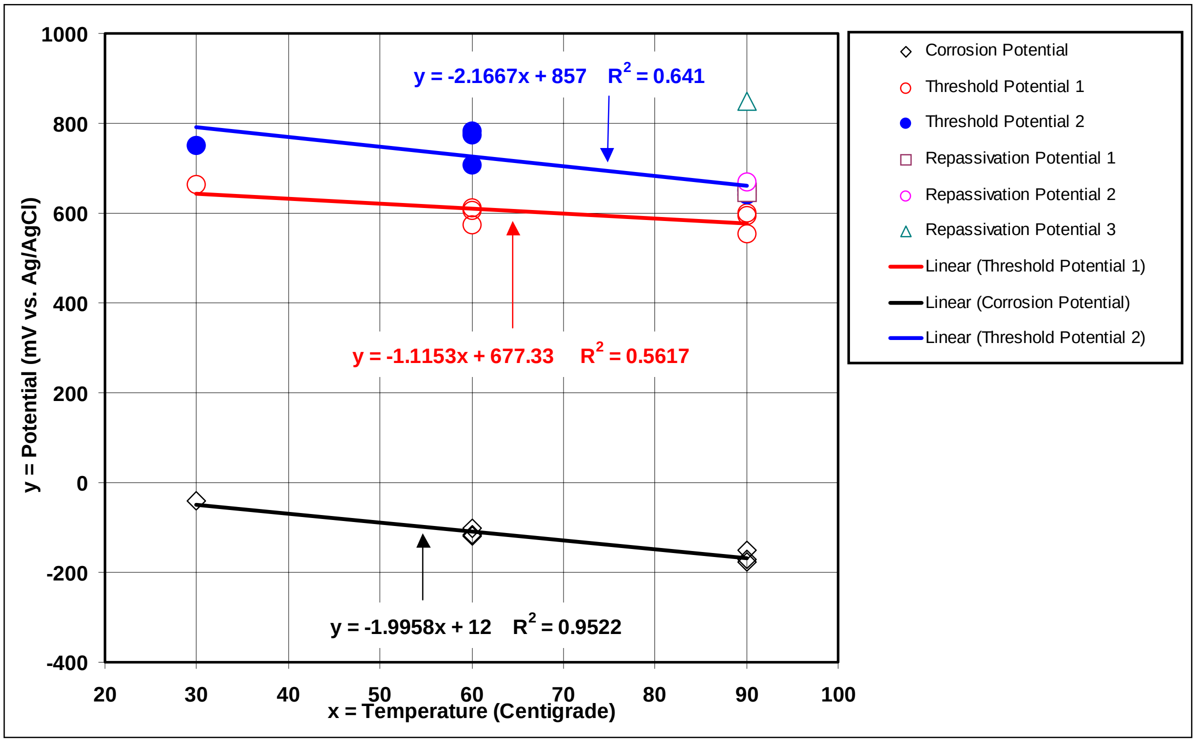

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Figure 14. Potentials Versus Temperature: Alloy 22 in SAW

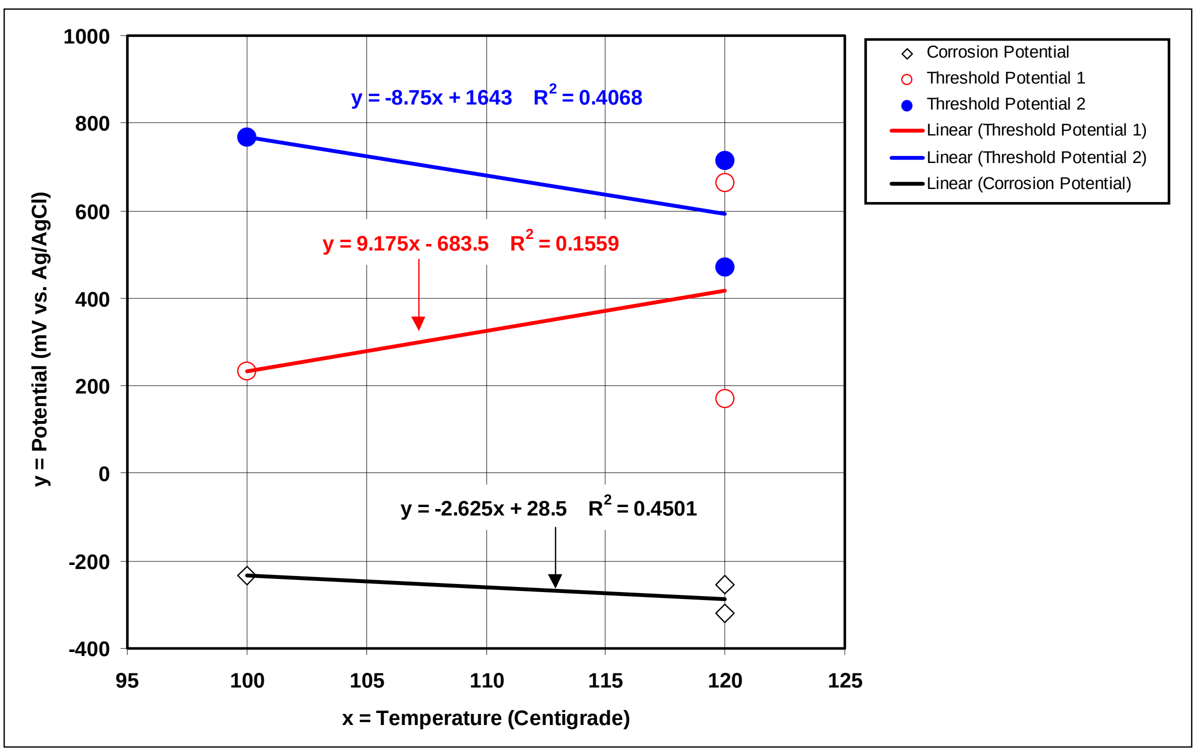

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Figure 15. Potentials Versus Temperature: Alloy 22 in SSW

Table 5. Summary of Correlated Corrosion and Threshold Potential Data, Alloy 22

Figure	Medium	Curve	Potential	Parameter	b_0	b_1	R^2
12	SDW	Type 2	Corrosion	E_{corr}	-33.556	-1.6556	0.7544
12	SDW	Type 2	Threshold 1		565	-4.3111	0.9758
12	SDW	Type 2	Threshold 2	$E_{critical}$	888.33	-1.4889	0.2421
12	SDW	Type 2	Repassivation 1		656.56	-4.0556	0.9334
12	SDW	Type 2	Repassivation 2		698.22	-3.9278	0.9259
12	SDW	Type 2	Repassivation 3		680.92	-3.0231	0.943
13	SCW	Type 2	Corrosion	E_{corr}	-123.86	-1.0667	0.1449
13	SCW	Type 2	Threshold 1		282.93	-0.875	0.156
13	SCW	Type 2	Threshold 2	$E_{critical}$	679.36	0.7917	0.0167
13	SCW	Type 2	Repassivation 1		550.24	-3.0882	0.111
13	SCW	Type 2	Repassivation 2		596.24	-3.4216	0.1447
13	SCW	Type 2	Repassivation 3		724.18	-1.2078	0.1926
14	SAW	Type 1	Corrosion	E_{corr}	12	-1.9958	0.9522
14	SAW	Type 1	Threshold 1a	$E_{critical}$	677.33	-1.1153	0.5617
14	SAW	Type 1	Threshold 1b		857	-2.1667	0.641
15	SSW	Type 1	Corrosion	E_{corr}	28.5	-2.625	0.4501
15	SSW	Type 1	Threshold 1a	$E_{critical}$	-683.5	9.175	0.1559
15	SSW	Type 1	Threshold 1b		1643	-8.75	0.4068

NOTE: R^2 is the regression coefficient.

Table 6. Values of E_{corr} and $E_{critical}$ Based on Correlated CP Data, Alloy 22

T (°C)	SDW E_{corr} (mV)	SDW $E_{critical}$ (mV)	SDW *Diff.* (mV)	SCW E_{corr} (mV)	SCW $E_{critical}$ (mV)	SCW *Diff.* (mV)	SAW E_{corr} (mV)	SAW $E_{critical}$ (mV)	SAW *Diff.* (mV)	SSW E_{corr} (mV)	SSW $E_{critical}$ (mV)	SSW Diff. (mV)
20	-67	479	545	-145	265	411	-28	655	683	-24	150	174
30	-83	436	519	-156	257	413	-48	644	692	-50	150	200
40	-100	393	492	-167	248	414	-68	633	701	-77	150	227
50	-116	349	466	-177	239	416	-88	622	709	-103	150	253
60	-133	306	439	-188	230	418	-108	610	718	-129	150	279
70	-149	263	413	-199	222	420	-128	599	727	-155	150	305
80	-166	220	386	-209	213	422	-148	588	736	-182	150	332
90	-183	177	360	-220	204	424	-168	577	745	-208	150	358
100	-199	134	333	-231	195	426	-188	566	753	-234	150	384
110	-216	91	306	-241	187	428	-208	555	762	-260	150	410
120	-232	48	280	-252	178	430	-227	543	771	-287	150	437
130	-249	5	253	-263	169	432	-247	532	780	-313	150	463
140	-265	-39	227	-273	160	434	-267	521	789	-339	150	489
150	-282	-82	200	-284	152	436	-287	510	797	-365	150	515

6.4.4 Effect of Gamma Radiolysis on Corrosion Potential

Anodic shifts in the open circuit corrosion potential of stainless steel have been experimentally observed (Glass et al. 1986; Kim 1987, 1988, 1999a, 1999b). Glass et al. (1986) performed ambient-temperature CP of 316L samples in 0.018 M NaCl solution during exposure to 3.5 Mrad h^{-1} gamma radiation. He found that the corrosion current shifted in the anodic direction by approximately 200 mV. From inspection of the graphical data in this article, it is concluded that there is very little increase in the corresponding corrosion current density. However, the separation between the corrosion potential and the threshold for localized attack decreased slightly. This shift in corrosion potential was shown to be due to the formation of hydrogen peroxide. This finding was subsequently confirmed by Kim (1988). In this case, ambient-temperature CP of 316 stainless steel in acidic (pH~2) 1.5 M NaCl during exposure to 0.15 Mrad h^{-1} gamma radiation showed a 100 mV anodic shift in the corrosion potential, with very little effect on the corrosion current. Note that Glass et al. (1986) and Kim (1988) worked on stainless steels, not Alloy 22.

Additional studies of the corrosion and threshold potentials of Alloy 22 in the presence of gamma radiation, as done by Glass et al. in the early 1980's, is beyond the YMP's current work scope. To determine the maximum impact that gamma radiolysis could have on the corrosion potential, hydrogen peroxide was added to electrolytes used for testing Alloy 22. Experiments at 25°C are illustrated by Figures 16 and 17. As the concentration of hydrogen peroxide in SAW approaches 72 ppm (calculated from number of added drops of H_2O_2), the corrosion potential asymptotically approaches 150 mV versus Ag/AgCl, well below any threshold where localized attach would be expected in SAW. Similarly, as the concentration of hydrogen peroxide in SCW approaches 72 ppm, the corrosion potential asymptotically approaches -25 mV versus Ag/AgCl, well below any threshold where localized attach would be expected in SCW. This change in corrosion potential is also below any level where a change in oxidation state would be expected. Since extremely high radiation levels would be required to achieve such shifts in corrosion potential and since even the maximum shifts in potential would be less than those required for breakdown of the passive film, it seems unlikely that gamma radiolysis will lead to catastrophic failure of Alloy 22 due to LC. However, as more resources become available, actual tests with a gamma source should be performed.

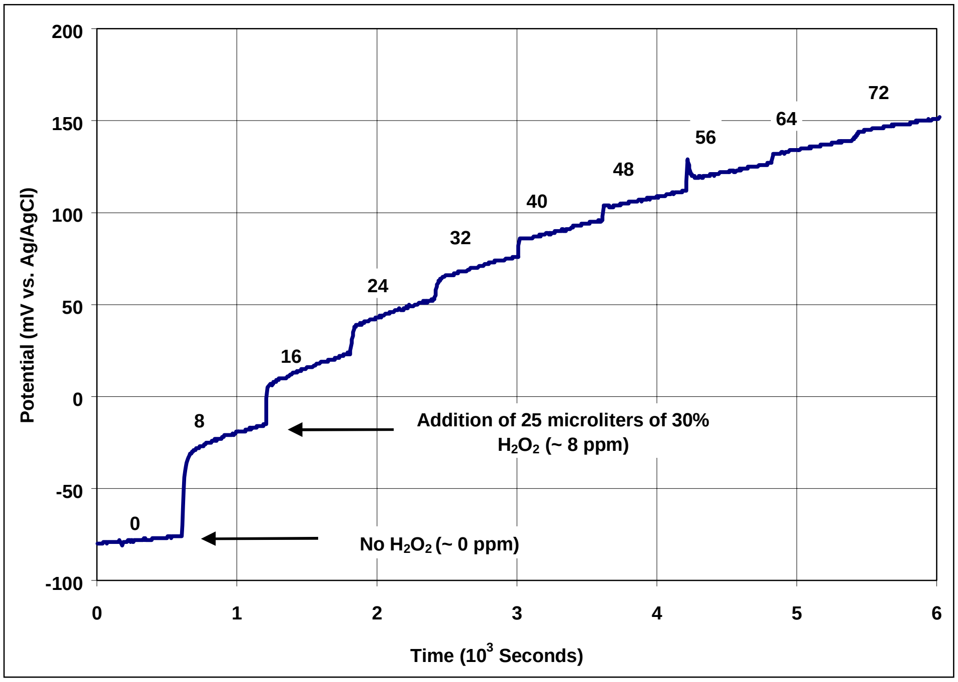


Figure 16. Effect of Hydrogen Peroxide on Corrosion Potential of Alloy 22 in SAW at 25°C

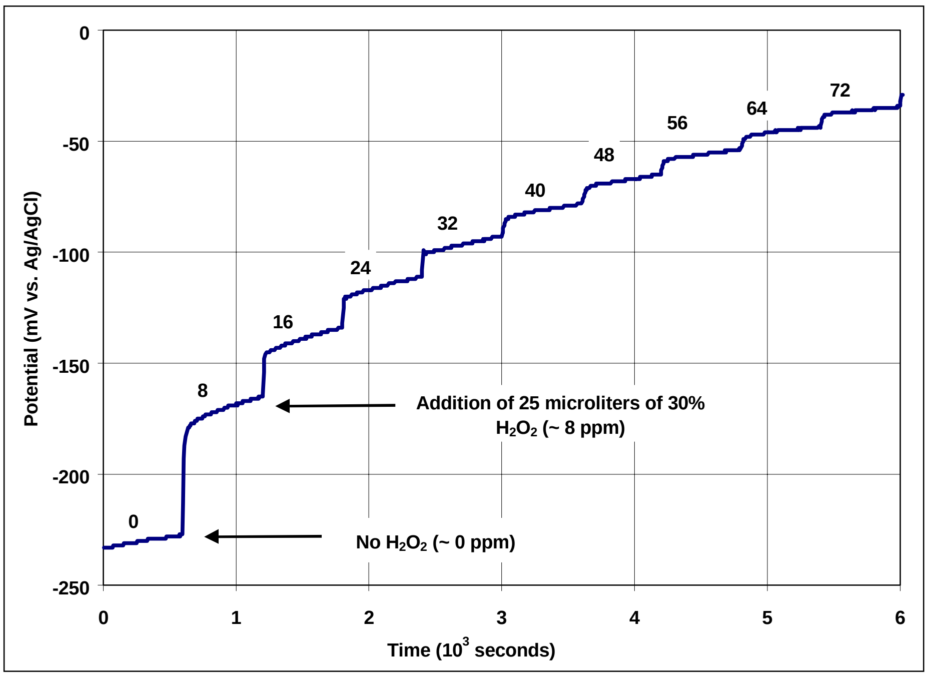


Figure 17. Effect of Hydrogen Peroxide on Corrosion Potential of Alloy 22 in SCW at 25°C

6.4.5 Correction of Measured Potential for Junction Potential

It is important to understand the magnitude of the error in the potential measurements due to the junction potential. A correction has been performed based upon the Henderson Equation (Bard and Faulkner 1980).

$$E_j = \frac{\sum_i \frac{|z_i| u_i}{z_i}[C_i(\beta) - C_i(\alpha)]}{\sum_i |z_i| u_i [C_i(\beta) - C_i(\alpha)]} \frac{RT}{F} \ln \frac{\sum_i |z_i| u_i C_i(\alpha)}{\sum_i |z_i| u_i C_i(\beta)} \qquad \text{(Eq. 18)}$$

where E_j is the potential across the junction connecting the α and β phases, z_i is the valence of the i^{th} ion, u_i is the mobility of the i^{th} ion, $C_i(\alpha)$is the concentration of the i^{th} ion in the α phase, $C_i(\beta)$ is the concentration of the i^{th} ion in the β phase, R is the universal gas constant, T is the absolute temperature, and F is Faraday's constant. Calculated values of E_j for the isothermal junction are summarized in Table 7 and required the summation of various products such as $|z_i| u_i C_i(\alpha)$, $|z_i| u_i C_i(\beta)$, $|z_i| u_i [C_i(\beta) - C_i(\alpha)]$ and $|z_i| u_i [C_i(\beta) - C_i(\alpha)]/z_i$.

Table 7. Summary of Junction Potential Corrections for CP (volts)

T (°C)	SDW	SCW	SAW	SSW
30	2.716E-03	1.188E-03	6.019E-03	-7.649E-03
60	2.984E-03	1.306E-03	6.615E-03	-8.406E-03
90	3.253E-03	1.423E-03	7.210E-03	-9.164E-03

A positive value indicates that the electrochemical potential on the KCl side of the junction (β phase) is greater than the electrochemical potential in the test medium (α phase), in close proximity to the Luggin probe. The potential in the test medium can be calculated from the measured value by subtracting E_j.

The calculated junction potentials in Table 7 are supported by the data in Tables 8 through 11. Ionic properties used in the calculation were taken from Bard and Faulkner (1980). These corrections are not very large, with the largest being less than 9 mV. This value corresponds to the junction potential for SSW at 90°C. It is concluded that insignificant error results from neglecting to correct for the junction potential.

Table 8. Junction Potential Correction for CP with SDW

	FW_i	$C_i(\alpha)$ **(mol/L^{-1})**	z_i	$\lvert z_i \rvert$	u_i **(cm^2 sec^{-1} V^{-1})**	$\lvert z_i \rvert u_i C_i(\alpha)$ **(mol cm^{-1} s^{-1} V^{-1})**	$\lvert z_i \rvert u_i C_i(\beta)$ **(mol cm^{-1} s^{-1} V^{-1})**	$\lvert z_i \rvert u_i [C_i(\beta) - C_i(\alpha)]$ **(mol cm^{-1} s^{-1} V^{-1})**	$\lvert z_i \rvert u_i [C_i(\beta) - C_i(\alpha)]/z_i$ **(mol cm^{-1} s^{-1} V^{-1})**
K^{+1}	39.0983	8.696E-04	1	1	7.62E-04	6.626E-07	3.048E-03	3.047E-03	3.047E-03
Na^{+1}	22.9898	1.779E-02	1	1	5.19E-04	9.239E-06	0	-9.239E-06	-9.239E-06
Mg^{+2}	24.3050	4.114E-05	2	2	5.00E-04	4.114E-08	0	-4.114E-08	-2.057E-08
Ca^{+2}	40.0780	1.248E-05	2	2	6.17E-04	1.538E-08	0	-1.538E-08	-7.692E-09
F^{-1}	18.9984	7.369E-04	-1	1	5.00E-04	3.685E-07	0	-3.685E-07	3.685E-07
Cl^{-1}	35.4527	1.890E-03	-1	1	7.91E-04	1.495E-06	3.165E-03	3.163E-03	-3.163E-03
NO_3^{-1}	62.0049	1.032E-03	-1	1	7.40E-04	7.642E-07	0	-7.642E-07	7.642E-07
SO_4^{-2}	96.0636	1.738E-03	-2	2	8.27E-04	2.875E-06	0	-2.875E-06	1.438E-06
HCO_3^{-1}	61.0171	1.552E-02	-1	1	4.61E-04	7.155E-06	0	-7.155E-06	7.155E-06
SiO_3^{-2}	76.0837	9.614E-04	-2	2	5.00E-04	9.614E-07	0	-9.614E-07	4.807E-07
H^{+1}	1.0079	7.943E-09	1	1	3.63E-03	2.879E-11	0	-2.879E-11	-2.879E-11
pH		8.100E+00			Summation	2.358E-05	6.212E-03	6.189E-03	-1.154E-04
					E_j	2.716E-03	Volts	at 30°C	Beta - Alpha
					E_j	2.984E-03	Volts	at 60°C	Beta - Alpha
					E_j	3.253E-03	Volts	at 90°C	Beta - Alpha

Table 9. Junction Potential Correction for CP with SCW

	FW_i	$C_i(\alpha)$ mol/L^{-1}	z_i	$\lvert z_i \rvert$	u_i (cm^2 sec^{-1} V^{-1})	$\lvert z_i \rvert u_i C_i(\alpha)$ (mol cm^{-1} s^{-1} V^{-1})	$\lvert z_i \rvert u_i C_i(\beta)$ (mol cm^{-1} s^{-1} V^{-1})	$\lvert z_i \rvert u_i [C_i(\beta)-C_i(\alpha)]$ (mol cm^{-1} s^{-1} V^{-1})	$\lvert z_i \rvert u_i [C_i(\beta)-C_i(\alpha)]/z_i$ (mol cm^{-1} s^{-1} V^{-1})
K^{+1}	39.0983	8.696E-02	1	1	7.62E-04	6.626E-05	3.048E-03	2.981E-03	2.981E-03
Na^{+1}	22.9898	1.779E+00	1	1	5.19E-04	9.239E-04	0	-9.239E-04	-9.239E-04
Mg^{+2}	24.3050	4.114E-05	2	2	5.00E-04	4.114E-08	0	-4.114E-08	-2.057E-08
Ca^{+2}	40.0780	2.495E-05	2	2	6.17E-04	3.077E-08	0	-3.077E-08	-1.538E-08
F^{-1}	18.9984	7.369E-02	-1	1	5.00E-04	3.685E-05	0	-3.685E-05	3.685E-05
Cl^{-1}	35.4527	1.890E-01	-1	1	7.91E-04	1.495E-04	3.165E-03	3.015E-03	-3.015E-03
NO_3^{-1}	62.0049	1.032E-01	-1	1	7.40E-04	7.642E-05	0	-7.642E-05	7.642E-05
SO_4^{-2}	96.0636	1.738E-01	-2	2	8.27E-04	2.875E-04	0	-2.875E-04	1.438E-04
HCO_3^{-1}	61.0171	1.147E+00	-1	1	4.61E-04	5.289E-04	0	-5.289E-04	5.289E-04
SiO_3^{-2}	76.0837	9.614E-04	-2	2	5.00E-04	9.614E-07	0	-9.614E-07	4.807E-07
H^{+1}	1.0079	7.943E-09	1	1	3.63E-03	2.879E-11	0	-2.879E-11	-2.879E-11
pH		8.100E+00			Summation	2.070E-03	6.212E-03	4.142E-03	-1.714E-04
					E_j	1.188E-03	Volts	at 30°C	Beta - Alpha
					E_j	1.306E-03	Volts	at 60°C	Beta - Alpha
					E_j	1.423E-03	Volts	at 90°C	Beta - Alpha

Table 10. Junction Potential Correction for CP with SAW

	FW_i	$C_i(\alpha)$ mol L^{-1}	z_i	$\lvert z_i \rvert$	u_i (cm^2 sec^{-1} V^{-1})	$\lvert z_i \rvert u_i C_i(\alpha)$ (mol cm^{-1} s^{-1} V^{-1})	$\lvert z_i \rvert u_i C_i(\beta)$ (mol cm^{-1} s^{-1} V^{-1})	$\lvert z_i \rvert u_i [C_i(\beta) - C_i(\alpha)]$ (mol cm^{-1} s^{-1} V^{-1})	$\lvert z_i \rvert u_i [C_i(\beta) - C_i(\alpha)]/z_i$ (mol cm^{-1} s^{-1} V^{-1})
K^{+1}	39.0983	8.696E-02	1	1	7.62E-04	6.626E-05	3.048E-03	2.981E-03	2.981E-03
Na^{+1}	22.9898	1.779E+00	1	1	5.19E-04	9.239E-04	0	-9.239E-04	-9.239E-04
Mg^{+2}	24.3050	4.114E-02	2	2	5.00E-04	4.114E-05	0	-4.114E-05	-2.057E-05
Ca^{+2}	40.0780	2.495E-02	2	2	6.17E-04	3.077E-05	0	-3.077E-05	-1.538E-05
F^{-1}	18.9984	0.000E+00	-1	1	5.00E-04	0.000E+00	0	0.000E+00	0.000E+00
Cl^{-1}	35.4527	1.890E-01	-1	1	7.91E-04	1.495E-04	3.165E-03	3.015E-03	-3.015E-03
NO_3^{-1}	62.0049	1.032E-01	-1	1	7.40E-04	7.642E-05	0	-7.642E-05	7.642E-05
SO_4^{-2}	96.0636	1.738E-01	-2	2	8.27E-04	2.875E-04	0	-2.875E-04	1.438E-04
HCO_3^{-1}	61.0171	0.000E+00	-1	1	4.61E-04	0.000E+00	0	0.000E+00	0.000E+00
SiO_3^{-2}	76.0837	9.614E-04	-2	2	5.00E-04	9.614E-07	0	-9.614E-07	4.807E-07
H^{+1}	1.0079	1.995E-03	1	1	3.63E-03	7.233E-06	0	-7.233E-06	-7.233E-06
pH		2.700E+00			Summation	1.584E-03	6.212E-03	4.629E-03	-7.803E-04
					E_j	6.019E-03	Volts	at 30°C	Beta - Alpha
					E_j	6.615E-03	Volts	at 60°C	Beta - Alpha
					E_j	7.210E-03	Volts	at 90°C	Beta - Alpha

Table 11. Junction Potential Correction for CP with SSW

	FW_i	$C_i(\alpha)$ mol L^{-1}	z_i	$\|z_i\|$	u_i (cm^2 sec^{-1} V^{-1})	$\|z_i\| u_i C_i(\alpha)$ (mol cm^{-1} s^{-1} V^{-1})	$\|z_i\| u_i C_i(\beta)$ (mol cm^{-1} s^{-1} V^{-1})	$\|z_i\| u_i [C_i(\beta) - C_i(\alpha)]$ (mol cm^{-1} s^{-1} V^{-1})	$\|z_i\| u_i [C_i(\beta) - C_i(\alpha)]/z_i$ (mol cm^{-1} s^{-1} V^{-1})
K^{+1}	39.0983	3.622E+00	1	1	7.62E-04	2.759E-03	3.048E-03	2.882E-04	2.882E-04
Na^{+1}	22.9898	2.118E+01	1	1	5.19E-04	1.100E-02	0	-1.100E-02	-1.100E-02
Mg^{+2}	24.3050	0.000E+00	2	2	5.00E-04	0.000E+00	0	0.000E+00	0.000E+00
Ca^{+2}	40.0780	0.000E+00	2	2	6.17E-04	0.000E+00	0	0.000E+00	0.000E+00
F^{-1}	18.9984	0.000E+00	-1	1	5.00E-04	0.000E+00	0	0.000E+00	0.000E+00
Cl^{-1}	35.4527	3.622E+00	-1	1	7.91E-04	2.865E-03	3.165E-03	2.993E-04	-2.993E-04
NO_3^{-1}	62.0049	2.113E+01	-1	1	7.40E-04	1.564E-02	0	-1.564E-02	1.564E-02
SO_4^{-2}	96.0636	0.000E+00	-2	2	8.27E-04	0.000E+00	0	0.000E+00	0.000E+00
HCO_3^{-1}	61.0171	0.000E+00	-1	1	4.61E-04	0.000E+00	0	0.000E+00	0.000E+00
SiO_3^{-2}	76.0837	0.000E+00	-2	2	5.00E-04	0.000E+00	0	0.000E+00	0.000E+00
H^{+1}	1.0079	1.000E-07	1	1	3.63E-03	3.625E-10	0	-3.625E-10	-3.625E-10
pH		7.000E+00			Summation	3.227E-02	6.212E-03	-2.606E-02	4.631E-03
					E_j	-7.649E-03	Volts	at 30°C	Beta - Alpha
					E_j	-8.406E-03	Volts	at 60°C	Beta - Alpha
					E_j	-9.164E-03	Volts	at 90°C	Beta - Alpha

6.5 RATES OF GENERAL AQUEOUS-PHASE CORROSION

GC rates are assumed if the threshold potential ($E_{critical}$) is not exceeded. GC rates have been estimated with weight-loss data from the LTCTF (Estill 1998). LC rates and failure mode characteristics (e.g., number failure sites and opening size) will have to be estimated from other published data. Only estimates of LC rates are given in this report. Since pitting has not been observed in LTCF experiments at LLNL, it is assumed that the primary mode of LC is crevice corrosion. This aqueous phase general and localized corrosion model will be applied to each element (patch) in the WAPDEG simulation. To the extent possible, uncertainty will be estimated from available data.

6.5.1 Corrosion Rates Based Upon Electrochemical Measurements

The corrosion (or penetration) rate of an alloy can be calculated from the corrosion current density with the following formula derived from Jones (1996):

$$\frac{dp}{dt} = \frac{i_{corr}}{\rho_{alloy} n_{alloy} F} \quad \text{(Eq. 19)}$$

where p is the penetration depth, t is time, i_{corr} is the corrosion current density, ρ_{alloy} is the density of the alloy, assumed to be approximately 8.69 g cm^{-3} for Alloy 22, n_{alloy}, is the number of gram equivalents per gram of alloy, and F is Faraday's constant. The value of n_{alloy} can be calculated with the following formula:

$$n_{alloy} = \sum_j \left(\frac{f_j n_j}{a_j} \right) \quad \text{(Eq. 20)}$$

where f_j is the mass fraction of the jth alloying element in the material, n_j is the number of electrons involved in the anodic dissolution process, which is assumed to be congruent, and a_j is the atomic weight of the jth alloying element. Congruent dissolution means that the dissolution rate of a given alloy element is proportional to its concentration in the bulk alloy. These equations have been used to calculate the penetration rate for Alloy 22 as a function of corrosion current density. The results of these calculations are shown in Tables 12 and 13. Values of $(f_j n_j/a_j)/100$ must be summed to calculate dp/dt. While calculated values of dp/dt are believed to have only three significant figures, values of $(f_j n_j/a_j)/100$ are given with more figures. By carrying the extra figures during calculation (and checking), round-off errors in final results can be minimized. In subsequent versions of the AMR, fewer significant figures will be reported. The penetration rate for Alloy 22 is linearly proportional to current density and is estimated to be between 9.39 and 9.73 µm per year at 1 µA cm^{-2}.

Usually, the corrosion current density, i_{corr}, is determined from the intersection of the anodic and cathodic Tafel lines at E_{corr} (Jones 1996; Bard and Faulkner 1980). However, this assumes that Butler-Volmer kinetics apply at the interface. Since the Alloy 22 surface is passivated with a protective oxide film, this may not be true. In fact, the cathodic curves from E_{corr} have limited Tafel linearity in Figures 3 through 9. Nevertheless, approximate Tafel extrapolations generally yield i_{corr} values around 1×10^{-6} A cm^{-2}, which are about one hundred times higher than the equivalent i_{corr} from LTCTF weight loss data. Tafel extrapolations should give much lower i_{corr} when the specimen electrodes are pre-exposed for times much greater than the one hour specified by ASTM G 5-87 (ASTM 1989) because the passive corrosion rate decreases logarithmically with time. Given these non-idealities, the local minima in current observed at E_{corr} (circled in Figure 11) has been interpreted as a lower bound for the corrosion current density, i_{corr}, not as the corrosion current density per se. The non-equilibrium passive current density, i_{pass}, serves as the upper bound of the corrosion current density. It is believed that the local minima (circled) are relatively close to the corrosion current density, the point at which the anodic and cathodic processes are balanced. Note that current (A) and current density (A cm^{-2}) are practically the same since the exposed area of the sample is about one square centimeter (0.96 cm^2).

In principle, electrochemically determined rates should be consistent with those observed in the LTCTF. To a first order approximation, such consistency appears to exist between most of the circled current densities (lower bound of the corrosion current densities) and the LTCTF results. GC rates from the LTCTF appear to be normally distributed around a mean value. The median GC rate based upon all Alloy 22 weight loss samples is approximately 16.51 nm y^{-1} (0.01651 µm per year). See Section 6.5.3. Assuming a penetration rate of 9.73 µm y^{-1} at a corrosion current density of 1 µA cm^{-2}, the median corrosion rate in the LTCTF corresponds to an apparent corrosion current density of approximately 1.70×10^{-9} A cm^{-2}. As can be seen in Figure 11, this value lies within the range of observed lower bounds of the density, which covers a range extending from 6×10^{-10} to 2×10^{-8} A cm^{-2}. Since the instrument appeared to have difficulty measuring extremely low current levels, values of 10^{-13} A cm^{-2} are ignored.

The lower bounds of the corrosion currents and the non-equilibrium passive currents from CP measurements in SDW, SCW, SAW, and SSW are summarized in Figures 18 through 21. In general, it has been found that the current verses temperature data can be represented by the following linear regression equation:

$$\ln y = \ln b_0 + b_1 \ln x \qquad \text{(Eq. 21)}$$

where y is the current (A) and x is the temperature (°C). This can be rewritten as follows:

$$y = b_0 \times (x)^{b_1} \qquad \text{(Eq. 22)}$$

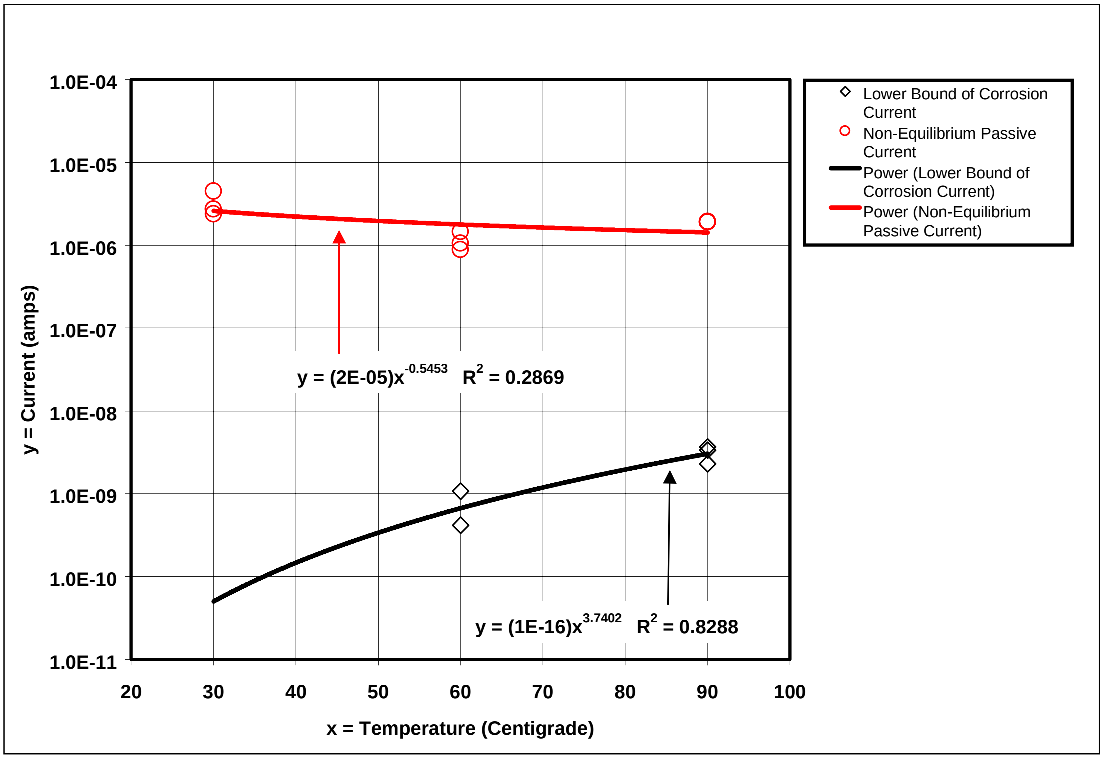
Since the exposed area in these measurements is approximately 0.96 cm^2, the current density is approximately equal to the current. The coefficients based upon the correlation of data for SDW, SCW, SAW, and SSW are summarized in Table 14. These coefficients were used to calculate the bounding values given in Table 15. The ranges of current density are converted to ranges of corrosion rate based upon the information in Tables 12 and 13.

Table 12. Conversion of Current Density to Corrosion (Penetration) Rate – Result

	Units	Value at Low f_i	Value at High f_i
Faraday Constant	C equiv-1	9.648460E+04	9.648460E+04
Assumed Current Density	A cm^{-2}	1.000000E-06	1.000000E-06
Assumed Mass Density	g cm^{-3}	8.690000E+00	8.690000E+00
Total $(f_j n_j / a_j)/100$		3.864793E-02	4.005512E-02
dp/dt	cm sec^{-1}	3.086000E-11	2.977585E-11
dp/dt	µm per year	9.732010E+00	9.390113E+00

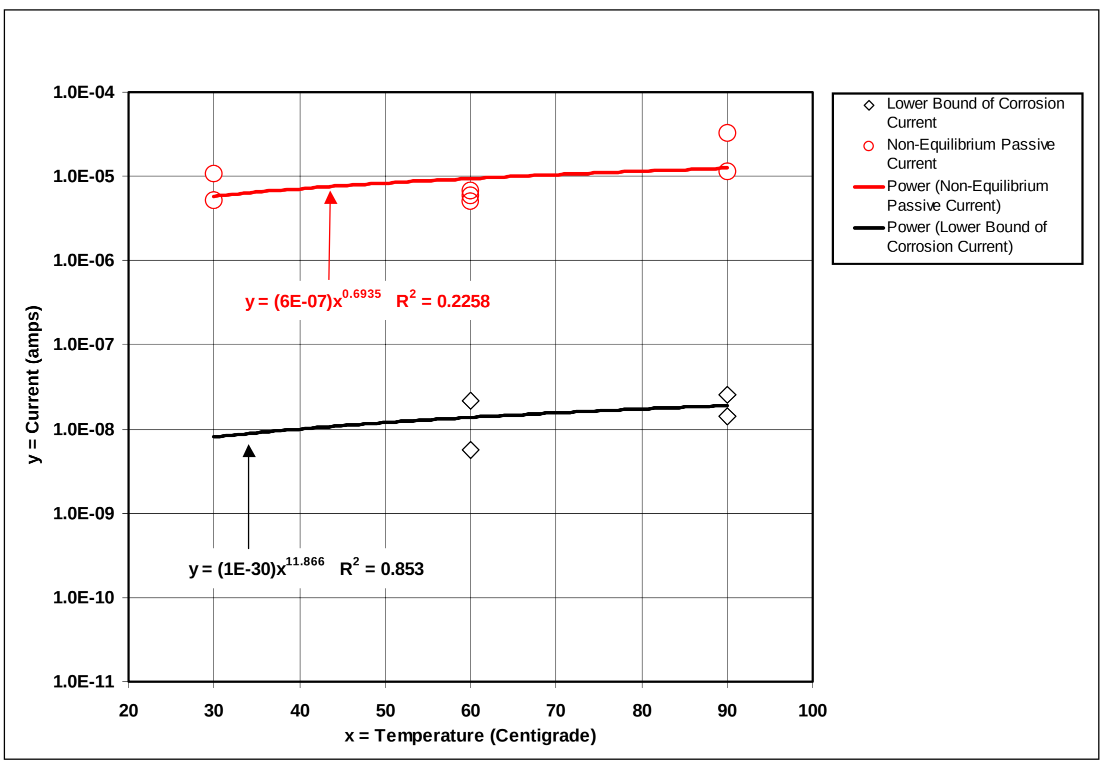
Table 13. Conversion of Current Density to Corrosion (Penetration) Rate – Calculation

	a_j	n_j	n_j	n_j	f_j wt%	f_j wt%	$(f_j n_j / a_j)/100$	$(f_j n_j / a_j)/100$
		Low	**High**	**Calc.**	**Low**	**High**	**Low**	**High**
C	12.011	2	4	4	0.015	0.015	4.995421E-05	4.995421E-05
Ni	58.69	2	3	2	62.365	49.535	2.125234E-02	1.688022E-02
Cr	51.9969	3	6	3	20.000	22.500	1.153915E-02	1.298154E-02
Mo	95.94	3	6	3	12.500	14.500	3.908693E-03	4.534084E-03
Fe	55.847	2	3	2	2.000	6.000	7.162426E-04	2.148728E-03
Cu	63.546	1	2	2	0.000	0.000	0.000000E+00	0.000000E+00
P	30.973762	3	5	5	0.020	0.020	3.228539E-05	3.228539E-05
Si	28.0855	4	4	4	0.080	0.080	1.139378E-04	1.139378E-04
S	32.066	2	6	6	0.020	0.500	3.742282E-05	9.355704E-04
Mn	54.93805	2	2	2	0.500	0.500	1.820232E-04	1.820232E-04
W	183.85	2	6	6	2.500	3.500	8.158825E-04	1.142236E-03
Co	58.9332	2	3	2	0.000	2.500	0.000000E+00	8.484182E-04
V	50.9415	2	3	3	0.000	0.350	0.000000E+00	2.061188E-04
Ti	47.88	2	3	3	0.000	0.000	0.000000E+00	0.000000E+00
Pd	105.42	2	2	2	0.000	0.000	0.000000E+00	0.000000E+00
Other	1	0	0	0	0.000	0.000	0.000000E+00	0.000000E+00
Total					100.000	100.000	3.864793E-02	4.005512E-02



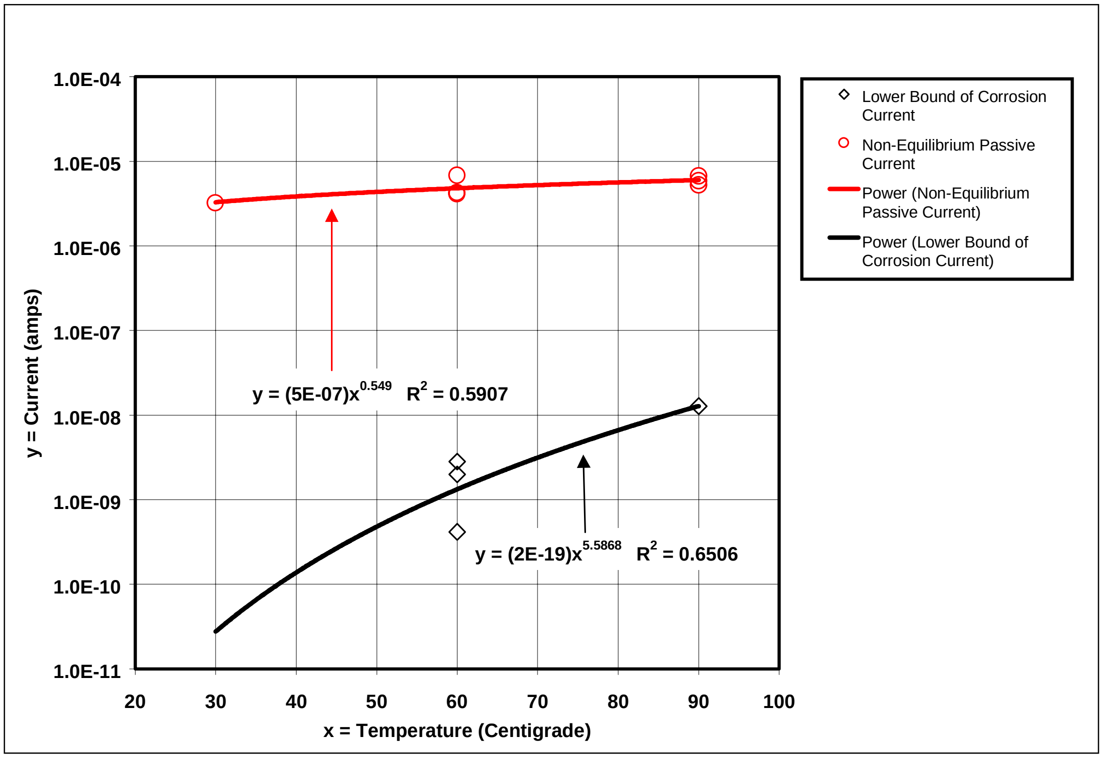
DTN: LL990610205924.075

Figure 18. Bounding Currents Versus Temperature, Alloy 22 in SDW



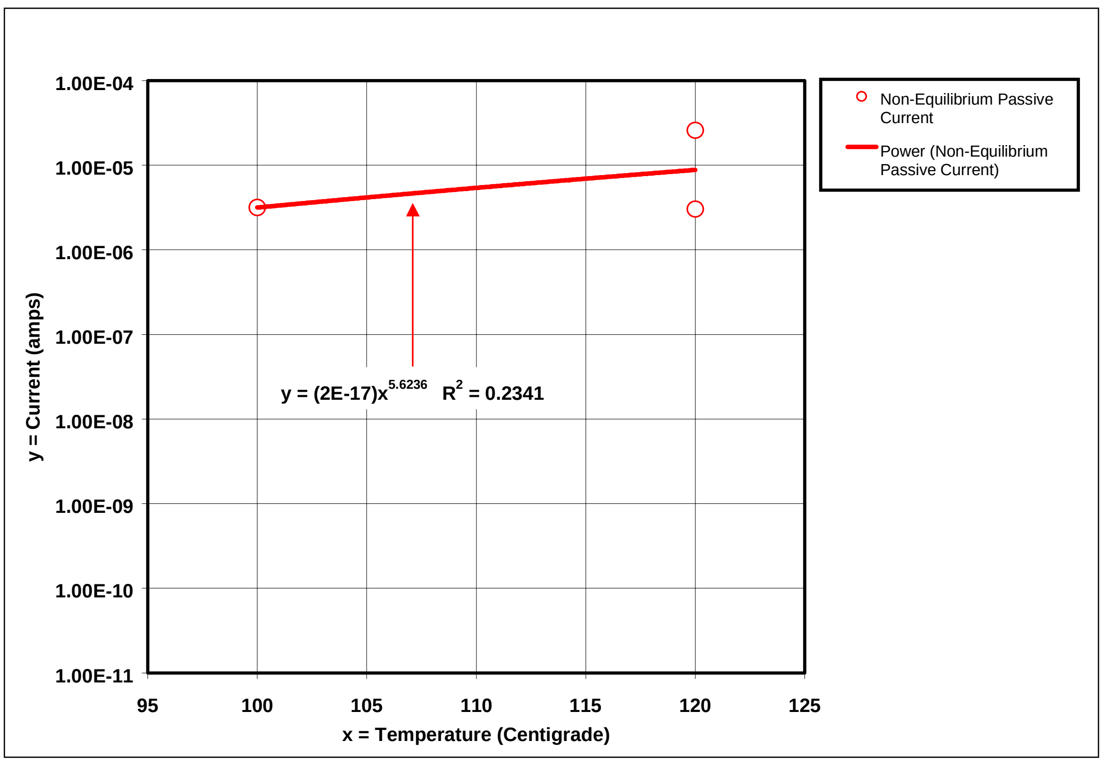
DTN: LL990610205924.075

Figure 19. Bounding Currents Versus Temperature, Alloy 22 in SCW



DTN: LL990610205924.075

Figure 20. Bounding Currents Versus Temperature, Alloy 22 in SAW



DTN: LL990610205924.075

Figure 21. Bounding Currents Versus Temperature, Alloy 22 in SSW

Table 14. Coefficients for Regression Equations Used to Represent Lower Bounds of Corrosion Current and Non-Equilibrium Passive Current

Figure	Medium	Curve	Current	Corresponding Potential	b_0	b_1	R^2
18	SDW	Type 2	Corrosion	E_{corr}	1.0E-16	3.7402	0.8288
18	SDW	Type 2	Passive	$E_{critical}$	2.0E-05	-0.5453	0.2869
19	SCW	Type 2	Corrosion	E_{corr}	1.0E-30	11.866	0.853
19	SCW	Type 2	Passive	$E_{critical}$	6.0E-07	0.6935	0.2258
20	SAW	Type 1	Corrosion	E_{corr}	2.0E-19	5.5868	0.6506
20	SAW	Type 1	Passive	$E_{critical}$	5.0E-07	0.549	0.5907
21	SSW	Type 1	Corrosion	E_{corr}			
21	SSW	Type 1	Passive	$E_{critical}$	2.0E-17	5.6236	0.2341

DTN: LL990610205924.075

Table 15. Rates Based Upon of Correlations of Lower Bounds of Corrosion Current and Non-Equilibrium Passive Current

Figure	Medium	Curve	Basis of Estimate Current – Temp.	Current (µA)	Current Density (µA cm^{-2})	Corrosion Rate (µm y^{-1})
18	SDW	Type 2	Corrosion – 90°C	2.04E-03	2.12E-03	1.99E-02
18	SDW	Type 2	Passive – 90°C	1.72	1.79	16.8
19	SCW	Type 2	Corrosion – 90°C	0.155	0.161	1.51
19	SCW	Type 2	Passive – 90°C	13.6	14.2	133.0
20	SAW	Type 1	Corrosion – 90°C	1.66E-02	1.73E-02	0.162
20	SAW	Type 1	Passive – 90°C	1.18	1.23	11.6
21	SSW	Type 1	Corrosion – 90°C			
21	SSW	Type 1	Passive – 90°C	9.82	10.3	96.4

DTN: LL990610205924.075

6.5.2 Corrosion Rates Based Upon Weight Loss Measurements

The LTCTF provides a complete source of corrosion data for Alloy 22 in environments relevant to the proposed high-level waste repository at Yucca Mountain. The LTCTF and results from that facility are described in detail in previous publications by the YMP (Estill 1998). The GC rates of Alloy 22 measured in the LTCTF should be representative of those expected in the repository. Testing includes a wide range of plausible generic test media, including SDW, SCW, Simulated Cement-Modified Water, and SAW. The SCW test medium is three orders-of-magnitude (1000×) more concentrated than J-13 well water and is slightly alkaline (pH~8). The SAW test medium is three orders-of-magnitude (1000×) more concentrated than J-13 well water and is acidic (pH~2.7) to mimic the evaporative concentration of electrolytes on the hot WP surface. Concentrated solutions are intended to mimic the evaporative concentration of the electrolytes on the hot WP surface. Two temperature levels (60 and 90°C) are included. The maximum observed rate, which is much less than 1 µm per year, clearly indicates that the life of the Alloy 22 outer barrier will not be limited by GC. It is also assumed that the corrosion rate is constant and does not decay with time. Less conservative corrosion models assume that the rate decays with time.

This facility is equipped with an array of fiberglass tanks. Each tank has a total volume of ~2000 L and is filled with ~1000 L of aqueous test solution. The solution in a particular tank is controlled at either 60 or 90°C, covered with a blanket of air flowing at approximately 150 cm^3 min^{-1}, and agitated. The descriptions and compositions of three of these solutions are summarized in Table 3. Four generic types of samples, U-bends, crevices, weight loss samples, and galvanic couples, are mounted on insulating racks and placed in the tanks. Approximately half of the samples are submersed, half are in the saturated vapor above the aqueous phase, and a limited number are at the water line. It is important to note that condensed water is present on specimens located in the saturated vapor.

After racks of samples were removed from the tank, samples were first rinsed with deionized water to remove salt solutions. Samples discussed have generic weight-loss or crevice geometry. Generic weight-loss samples were rectangular in shape (1 inch wide, 2 inches long, 1/8 inch thick). Generic crevice samples were square with a hole in the center (2 inches on each side, 1/8 inch thick, with a 0.312 inch diameter hole). Next, samples were removed from the rack by loosening fixture mounts with standard wrenches. The crevice assemblies described by Estill (1998) required further disassembly, which was also done with standard wrenches. After dismounting and disassembly, the metal samples of Alloy 22 were cleaned with the solution designated C.7.5 for stainless steels given in Table A1 of ASTM G 1-90 (ASTM 1997e). This solution consists of 100 ml HNO_3 (specific gravity ~ 1.42) and 20 ml HF (specific gravity ~ 1.198) in enough water to give a total volume of 1000 ml. Note that alternative solutions for nickel and nickel-based alloys, designated C.6.1 and C.6.2, could have also been used. These cleaner formulations are based upon aqueous solutions of HCl and H_2SO_4, respectively.

The crevice samples were configured in such a way as to reveal crevice corrosion if it occurred. Since no crevice attack was observed with the samples represented by these figures, it is assumed that all weight loss in the crevice samples was due to GC outside of the crevice region (area underneath washer). This is consistent with other *ex situ* examinations.

As previously discussed, GC measurements are based upon ASTM G 1-81 (ASTM 1987) or the more recent ASTM G 1-90 (ASTM 1997e). The GC (or penetration) rate of an alloy can be calculated from weight loss data as follows with the following general formula:

$$Corrosion\ Rate = \frac{(K \times W)}{(A \times T \times D)} \qquad \text{(Eq. 23)}$$

where K is a constant, T is the time of exposure in hours, A is the exposed area of the sample in square centimeters, W is the mass loss in grams, and D is the density in grams per cubic centimeter. The value of K used for the LTCTF data was 8.76×10^7 µm per year. This formula for corrosion rate can be rewritten in the following form:

$$\frac{dp}{dt} = \frac{w}{\rho \times t} \frac{1}{[2(a \times b) + 2(b \times c) + 2(a \times c)]} \qquad \text{(Eq. 24)}$$

where *dp/dt* is the corrosion rate, *w* is the mass loss in grams, ρ is the density in grams per cubic centimeter, *t* is the time of exposure in years, and the quantity in square brackets represents the exposed area of the sample in square centimeters. Without application of any conversion factor, the corrosion rate calculated with this formula has the units of centimeters per year. Multiplication of *dp/dt* by 10^4 µm cm^{-1} yields a corrosion rate with the units of µm per year. The weight loss and dimensional change were measured with electronic instruments calibrated to traceable standards. All data was digitally transferred to computer, minimizing the possibility of human typographical error.

Comparative sample calculations are used to compare the two formulae. With specific values assumed for the purpose of comparison, the first formula yields:

$$K = 8.76 \times 10^7 \, \mu m \; y^{-1} h \; cm^{-1}$$

$$W = 0.0001 \, gm$$

$$A = 1.0 \; cm^2$$

$$T = 4320 \, h$$

$$D = 8.69 \, gm \; cm^{-3}$$

$$Corrosion\ Rate = \frac{(8.76 \times 10^7 \, \mu m \; yr^{-1} h \; cm^{-1})(0.0001 \; gm)}{(1.0 \, cm^2)(4320 \; h)(8.69 \; gm \; cm^{-3})} = 0.23 \; \mu m \; y^{-1}$$

The density for Alloy 22 used in this sample calculation was taken from Section 7.1 of ASTM B 575-94 (ASTM 1997a). A calculation with the second formula and the same assumed values gives an identical result:

$$k = 10^4 \; \mu m \, cm^{-1}$$

$$w = 0.0001 \, gm$$

$$2(a \times b) + 2(b \times c) + 2(a \times c) = 1.0 \; cm^2$$

$$t = 0.5 \, y$$

$$\rho = 8.69 \; gm \;\; cm^{-3}$$

$$\frac{dp}{dt} = \frac{(10^4 \, \mu m \; cm^{-1})(0.0001 \, gm)}{(1.0 \; cm^2)(0.5 \, yr)(8.69 \; gm \;\; cm^{-3})} = 0.23 \; \mu m \;\; y^{-1}$$

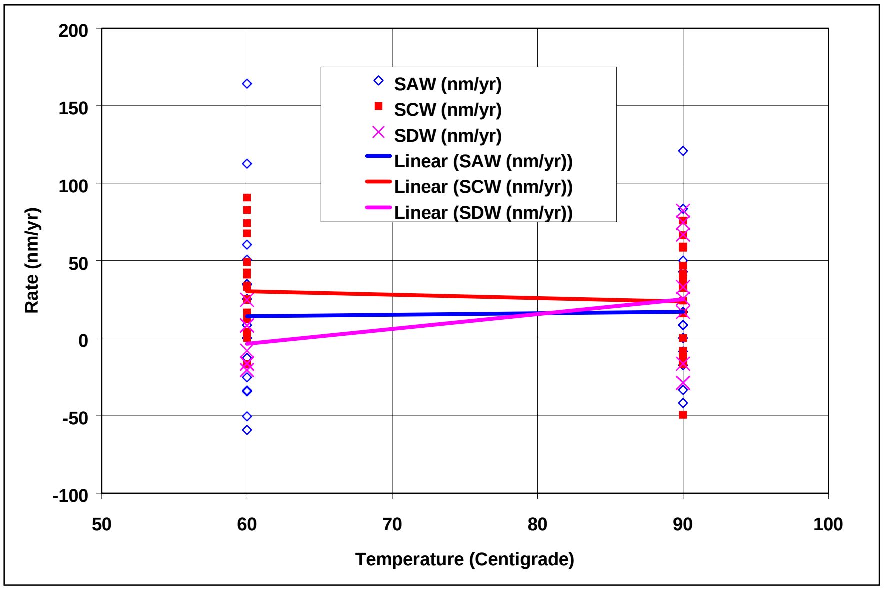
The second formula is used as the basis of a formal error analysis of GC rates determined from LTCTF data.

All GC rates for Alloy 22 based on LTCTF weight loss samples are shown in Figure 22. It appears that these measurements are independent of temperature between 60 and 90°C. Furthermore, the composition of the test medium (SDW, SCW, or SAW) appeared to have little impact on the measurements. Since the maximum observed rate is only 160 nm y^{-1}, it is concluded that the actual corrosion rate is below the detectable level. When all of the measured corrosion rates based upon the weight loss samples are ranked together, regardless of the test medium or temperature, the data appear to be normally distributed around a median value. This is illustrated by Figure 23.

All GC rates for Alloy 22 based on LTCTF crevice samples are shown in Figure 24 (rates based on areas outside of crevice). In this case, it also appears that the measurements are independent of temperature and test medium. When all of the measured corrosion rates based upon the weight loss samples are ranked together as shown in Figure 25, most of the data points fall below 160 nm y^{-1} and appear to be normally distributed around a median value. However, there are four data points that appear to lie above the detection limit (between 200 and 750 nm, per year). Since no crevice attack of these four samples is evident with microscopic examination, it is believed that these points are due to the accidental removal of material during mechanical assembly of the crevice sample (Section 6.5.5). The largest measured rate shown in Figure 25 will not lead to failure of the WP during the 10,000 year service life. Based upon these data, it does not appear that the life of the WP will be limited to less than 10,000 years by the GC of Alloy 22 at temperatures less than those involved in the test (90°C).

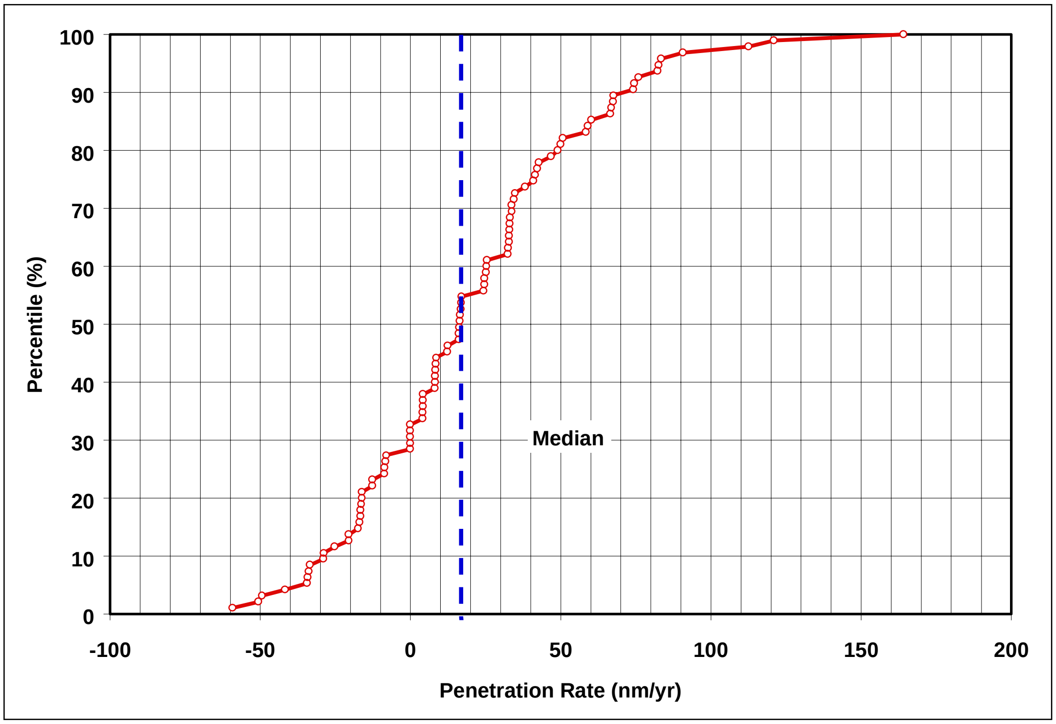
The mean and standard deviation are also determined through calculation (Burr 1974). The average corrosion rate based upon all weight loss samples is 20 nm y^{-1} with a standard deviation of 40 nm y^{-1}. This compares reasonably well with the values obtained by inspection of the plotted data in Figure 23. The average corrosion rate based upon all crevice samples is 71 nm y^{-1} with a standard deviation of 89 nm y^{-1}. If the four highest rates are omitted, the average rate is then calculated to be 57 nm y^{-1} with a standard deviation of 40 nm y^{-1}. This is consistent with the plotted data in Figure 25.

It should be noted that the distribution of corrosion rates includes some negative values. The negative corrosion rates correspond to cases where the samples actually appear to have gained weight during exposure, due to oxide growth or the formation of silicate deposits. To substantiate these interpretations, AFM has been used to inspect a number of samples removed from the LTCTF. Results are given in Section 6.5.6 and in Attachment I.



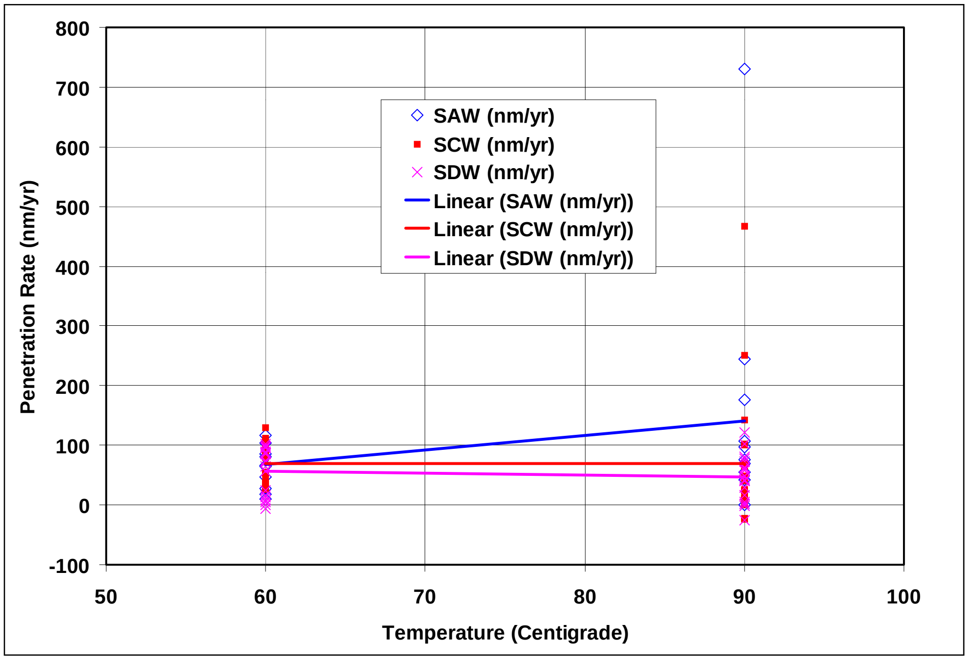
DTN: LL990610605924.079

Figure 22. GC of Alloy 22, 6, and 12 Month Weight Loss Samples from LTCTF, Corrosion Rate Versus Temperature



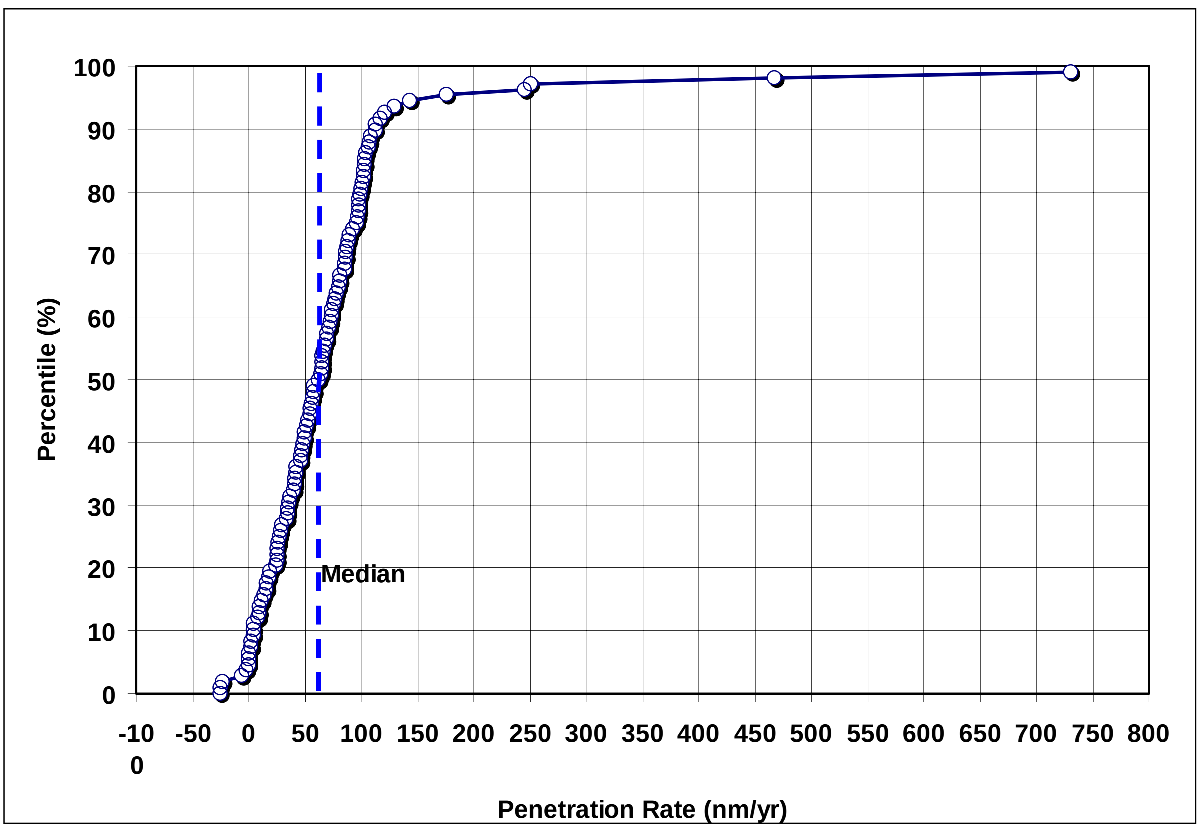
DTN: LL990610605924.079

Figure 23. GC of Alloy 22, 6, and 12 Month Weight Loss Samples from LTCTF, Percentile Versus Corrosion Rate



DTN: LL990610605924.079

Figure 24. GC of Alloy 22, 6, and 12 Month Crevice Samples from LTCTF, Corrosion Rate Versus Temperature



DTN: LL990610605924.079

Figure 25. GC of Alloy 22, 6, and 12 Month Crevice Samples from LTCTF, Percentile Versus Corrosion Rate

6.5.3 Error Analysis for Weight Loss Measurements

The general method used in the formal error analysis is now presented and is important since it enables sound interpretation of the data shown in Figures 23 and 25. Consider the dependent variable y defined by the following generic function:

$$y = f(x_1, x_2, x_3, x_4 \cdots x_n) \quad \text{(Eq. 25)}$$

where x_i is the i^{th} independent variable. The total derivative of y is then defined as follows:

$$dy = \frac{\partial y}{\partial x_1} dx_1 + \frac{\partial y}{\partial x_2} dx_2 + \frac{\partial y}{\partial x_3} dx_3 + \frac{\partial y}{\partial x_4} dx_4 + \cdots + \frac{\partial y}{\partial x_n} dx_n \quad \text{(Eq. 26)}$$

Based upon this definition, the maximum error in y can then be defined as:

$$\Delta y = \left|\frac{\partial y}{\partial x_1} \Delta x_1\right| + \left|\frac{\partial y}{\partial x_2} \Delta x_2\right| + \left|\frac{\partial y}{\partial x_3} \Delta x_3\right| + \left|\frac{\partial y}{\partial x_4} \Delta x_4\right| + \cdots + \left|\frac{\partial y}{\partial x_n} \Delta x_n\right| \quad \text{(Eq. 27)}$$

where Δx_i is the error in the i^{th} independent variable. Let the dependent variable y be the GC rate measured in the LTCTF:

$$y = \frac{dp}{dt} = \frac{w}{\rho \times t} \frac{1}{[2(a \times b) + 2(b \times c) + 2(a \times c)]} \quad \text{(Eq. 28)}$$

The total derivative of the corrosion rate is:

$$dy = \frac{\partial y}{\partial w} dw + \frac{\partial y}{\partial \rho} d\rho + \frac{\partial y}{\partial t} dt + \frac{\partial y}{\partial a} da + \frac{\partial y}{\partial b} db + \frac{\partial y}{\partial c} dc \quad \text{(Eq. 29)}$$

The maximum error in the corrosion rate is:

$$\Delta y = \left|\frac{\partial y}{\partial w} \Delta w\right| + \left|\frac{\partial y}{\partial \rho} \Delta \rho\right| + \left|\frac{\partial y}{\partial t} \Delta t\right| + \left|\frac{\partial y}{\partial a} \Delta a\right| + \left|\frac{\partial y}{\partial b} \Delta b\right| + \left|\frac{\partial y}{\partial c} \Delta c\right| \quad \text{(Eq. 30)}$$

The partial derivatives are:

$$\frac{\partial y}{\partial w} = \frac{1}{\rho \times t} \frac{1}{[2(a \times b) + 2(b \times c) + 2(a \times c)]} \quad \text{(Eq. 31)}$$

$$\frac{\partial y}{\partial \rho} = \frac{w}{\rho^2 \times t} \frac{1}{[2(a \times b) + 2(b \times c) + 2(a \times c)]} \quad \text{(Eq. 32)}$$

$$\frac{\partial y}{\partial t} = \frac{w}{\rho \times t^2} \frac{1}{[2(a \times b) + 2(b \times c) + 2(a \times c)]} \quad \text{(Eq. 33)}$$

$$\frac{\partial y}{\partial a} = \frac{w}{\rho \times t} \frac{[2b + 2c]}{[2(a \times b) + 2(b \times c) + 2(a \times c)]^2} \qquad \text{(Eq. 34)}$$

$$\frac{\partial y}{\partial b} = \frac{w}{\rho \times t} \frac{[2a + 2c]}{[2(a \times b) + 2(b \times c) + 2(a \times c)]^2} \qquad \text{(Eq. 35)}$$

$$\frac{\partial y}{\partial c} = \frac{w}{\rho \times t} \frac{[2a + 2b]}{[2(a \times b) + 2(b \times c) + 2(a \times c)]^2} \qquad \text{(Eq. 36)}$$

The maximum error in the corrosion rate is estimated by calculating numeric values of the partial derivatives from expected values of the independent variables, multiplication of each partial derivative by the corresponding error in independent variable (Δw, $\Delta\rho$, Δt, Δa, Δb, and Δc), and summation of the resulting products. The error based upon this method is shown in Table 16.

Table 16. Summary of Error Analysis for Corrosion Rates Based Upon Weight Loss Measurements

	Assumed Weight Loss		**0.0001 g** **Δy**	**0.0010 g** **Δy**	**0.0100 g** **Δy**
Case	Sample Configuration	Exposure Time	nm y^{-1}	nm y^{-1}	nm y^{-1}
1	Crevice	6 month	12.25	12.95	19.86
2	Weight Loss	6 month	23.27	24.64	38.33
3	Crevice	12 month	6.00	6.29	9.17
4	Weight Loss	12 month	11.40	11.98	17.72

From the estimated errors given in Table 16 that are based on Tables 17 through 20, it is concluded that the typical uncertainty observed in weight loss and dimensional measurements prevent determination of corrosion rates less than approximately 38 nm y^{-1}. The maximum uncertainty is estimated to be approximately 6 to 20 nm y^{-1} in the case of crevice samples and 11 to 38 nm in the case of weight loss samples. These estimates of probable error are believed to correspond to about one standard deviation (1σ). Therefore, any measured corrosion rate greater than 160 nm y^{-1} (4σ) should be easily distinguishable from measurement error. Any rate less than 160 nm y^{-1} guarantees that the WP outer barrier (wall thickness of 2 cm) will not fail by GC.

Table 17. Error Analysis for LTCTF Corrosion Rates – Definitions

Parameter	Parameter Definition	Units
w	Weight loss	g
ρ	Density	g cm^{-3}
t	Exposure time	hr
a	Length	in.
b	Width	in.
c	Thickness	in.
a	Length	cm
b	Width	cm
c	Thickness	cm
$\partial y/\partial w$	Partial derivative or rate with respect to weight loss	cm g^{-1} h^{-1}
$\partial y/\partial \rho$	Partial derivative of rate with respect to density	cm^4 g^{-1} h^{-1}
$\partial y/\partial t$	Partial derivative of rate with respect to exposure time	cm h^{-2}
$\partial y/\partial a$	Partial derivative of rate with respect to length	h^{-1}
$\partial y/db$	Partial derivative of rate with respect to width	h^{-1}
$\partial y/\partial c$	Partial derivative of rate with respect to thickness	h^{-1}
Δw	Error in weight loss	g
$\Delta \rho$	Error in density	g cm^{-3}
Δt	Error in exposure time	hr
Δa	Error in length	cm
Δb	Error in width	cm
Δc	Error in thickness	cm
$(\partial y/\partial w) \times (\Delta w)$	Weight loss product	cm
$(\partial y/\partial \rho) \times (\Delta \rho)$	Density product	cm
$(\partial y/\partial t) \times (\Delta t)$	Exposure time product	cm
$(\partial y/\partial a) \times (\Delta a)$	Length product	cm
$(\partial y/db) \times (\Delta b)$	Width product	cm
$(\partial y/\partial c) \times (\Delta c)$	Thickness product	cm
Δy	Sum of all products	cm h^{-1}
Δy	Sum of all products	μm y^{-1}
Δy	Sum of all products	nm y^{-1}

Table 18. Error Analysis for LTCTF Corrosion Rates – Assume Weight Loss of 0.0001 Grams

Parameter	Crevice 6 month	Weight Loss 6 month	Crevice 12 month	Weight Loss 12 month
w	0.0001	0.0001	0.0001	0.0001
ρ	8.69	8.69	8.69	8.69
t	4296	4296	8760	8760
a	2.0000	2.0000	2.0000	2.0000
b	2.0000	1.0000	2.0000	1.0000
c	0.1200	0.1200	0.1200	0.1200
a	5.0800	5.0800	5.0800	5.0800
b	5.0800	2.5400	5.0800	2.5400
c	0.3048	0.3048	0.3048	0.3048
∂y/∂w	4.6338E-07	8.7964E-07	2.2725E-07	4.3139E-07
∂y/∂ρ	5.3324E-12	1.0122E-11	2.6151E-12	4.9642E-12
∂y/∂t	1.0786E-14	2.0476E-14	2.5942E-15	4.9245E-15
∂y/∂a	8.6331E-12	1.6435E-11	4.2337E-12	8.0601E-12
∂y/db	8.6331E-12	3.1110E-11	4.2337E-12	1.5257E-11
∂y/∂c	1.6289E-11	4.4023E-11	7.9882E-12	2.1589E-11
Δw	0.0003	0.0003	0.0003	0.0003
Δρ	0.1	0.1	0.1	0.1
Δt	24	24	24	24
Δa	0.00254	0.00254	0.00254	0.00254
Δb	0.00254	0.00254	0.00254	0.00254
Δc	0.00254	0.00254	0.00254	0.00254
(∂y/∂w) × (Δw)	1.3902E-10	2.6389E-10	6.8174E-11	1.2942E-10
(∂y/∂ρ) × (Δρ)	5.3324E-13	1.0122E-12	2.6151E-13	4.9642E-13
(∂y/∂t) × (Δt)	2.5887E-13	4.9142E-13	6.2260E-14	1.1819E-13
(∂y/∂a) × (Δa)	2.1928E-14	4.1746E-14	1.0754E-14	2.0473E-14
(∂y/db) × (Δb)	2.1928E-14	7.9019E-14	1.0754E-14	3.8752E-14
(∂y/∂c) × (Δc)	4.1374E-14	1.1182E-13	2.0290E-14	5.4837E-14
Δy	1.3989E-10	2.6563E-10	6.8540E-11	1.3014E-10
Δy	1.2255E-02	2.3269E-02	6.0041E-03	1.1401E-02
Δy	1.2255E+01	2.3269E+01	6.0041E+00	1.1401E+01

Table 19. Error Analysis for LTCTF Corrosion Rates – Assume Weight Loss of 0.001 Grams

Parameter	Crevice 6 month	Weight Loss 6 month	Crevice 12 month	Weight Loss 12 month
w	0.0010	0.0010	0.0010	0.0010
ρ	8.69	8.69	8.69	8.69
t	4296	4296	8760	8760
a	2.0000	2.0000	2.0000	2.0000
b	2.0000	1.0000	2.0000	1.0000
c	0.1200	0.1200	0.1200	0.1200
a	5.0800	5.0800	5.0800	5.0800
b	5.0800	2.5400	5.0800	2.5400
c	0.3048	0.3048	0.3048	0.3048
∂y/∂w	4.6338E-07	8.7964E-07	2.2725E-07	4.3139E-07
∂y/∂ρ	5.3324E-11	1.0122E-10	2.6151E-11	4.9642E-11
∂y/∂t	1.0786E-13	2.0476E-13	2.5942E-14	4.9245E-14
∂y/∂a	8.6331E-11	1.6435E-10	4.2337E-11	8.0601E-11
∂y/db	8.6331E-11	3.1110E-10	4.2337E-11	1.5257E-10
∂y/∂c	1.6289E-10	4.4023E-10	7.9882E-11	2.1589E-10
Δw	0.0003	0.0003	0.0003	0.0003
Δρ	0.1	0.1	0.1	0.1
Δt	24	24	24	24
Δa	0.00254	0.00254	0.00254	0.00254
Δb	0.00254	0.00254	0.00254	0.00254
Δc	0.00254	0.00254	0.00254	0.00254
(∂y/∂w) × (Δw)	1.3902E-10	2.6389E-10	6.8174E-11	1.2942E-10
(∂y/∂ρ) × (Δρ)	5.3324E-12	1.0122E-11	2.6151E-12	4.9642E-12
(∂y/∂t) × (Δt)	2.5887E-12	4.9142E-12	6.2260E-13	1.1819E-12
(∂y/∂a) × (Δa)	2.1928E-13	4.1746E-13	1.0754E-13	2.0473E-13
(∂y/db) × (Δb)	2.1928E-13	7.9019E-13	1.0754E-13	3.8752E-13
(∂y/∂c) × (Δc)	4.1374E-13	1.1182E-12	2.0290E-13	5.4837E-13
Δy	1.4779E-10	2.8126E-10	7.1830E-11	1.3670E-10
Δy	1.2946E-02	2.4638E-02	6.2923E-03	1.1975E-02
Δy	1.2946E+01	2.4638E+01	6.2923E+00	1.1975E+01

Table 20. Error Analysis for LTCTF Corrosion Rates – Assume Weight Loss of 0.01 Grams

Parameter	Crevice 6 month	Weight Loss 6 month	Crevice 12 month	Weight Loss 12 month
w	0.0100	0.0100	0.0100	0.0010
ρ	8.69	8.69	8.69	8.69
t	4296	4296	8760	8760
a	2.0000	2.0000	2.0000	2.0000
b	2.0000	1.0000	2.0000	1.0000
c	0.1200	0.1200	0.1200	0.1200
a	5.0800	5.0800	5.0800	5.0800
b	5.0800	2.5400	5.0800	2.5400
c	0.3048	0.3048	0.3048	0.3048
$\partial y/\partial w$	4.6338E-07	8.7964E-07	2.2725E-07	4.3139E-07
$\partial y/\partial \rho$	5.3324E-10	1.0122E-09	2.6151E-10	4.9642E-10
$\partial y/\partial t$	1.0786E-12	2.0476E-12	2.5942E-13	4.9245E-13
$\partial y/\partial a$	8.6331E-10	1.6435E-09	4.2337E-10	8.0601E-10
$\partial y/db$	8.6331E-10	3.1110E-09	4.2337E-10	1.5257E-09
$\partial y/\partial c$	1.6289E-09	4.4023E-09	7.9882E-10	2.1589E-09
Δw	0.0003	0.0003	0.0003	0.0003
$\Delta \rho$	0.1	0.1	0.1	0.1
Δt	24	24	24	24
Δa	0.00254	0.00254	0.00254	0.00254
Δb	0.00254	0.00254	0.00254	0.00254
Δc	0.00254	0.00254	0.00254	0.00254
$(\partial y/\partial w) \times (\Delta w)$	1.3902E-10	2.6389E-10	6.8174E-11	1.2942E-10
$(\partial y/\partial \rho) \times (\Delta \rho)$	5.3324E-11	1.0122E-10	2.6151E-11	4.9642E-11
$(\partial y/\partial t) \times (\Delta t)$	2.5887E-11	4.9142E-11	6.2260E-12	1.1819E-11
$(\partial y/\partial a) \times (\Delta a)$	2.1928E-12	4.1746E-12	1.0754E-12	2.0473E-12
$(\partial y/db) \times (\Delta b)$	2.1928E-12	7.9019E-12	1.0754E-12	3.8752E-12
$(\partial y/\partial c) \times (\Delta c)$	4.1374E-12	1.1182E-11	2.0290E-12	5.4837E-12
Δy	2.2675E-10	4.3752E-10	1.0473E-10	2.0228E-10
Δy	1.9863E-02	3.8327E-02	9.1744E-03	1.7720E-02
Δy	1.9863E+01	3.8327E+01	9.1744E+00	1.7720E+01

6.5.4 Summary of General Corrosion Model

Based upon these data and the associated error analysis presented in the following sections, a simple and defensible representation of the observed corrosion rates is proposed. This approach involves combining the distributions of rates calculated from weight loss and shown in Figures 23 and 25. These data are for "Weight Loss" and "Crevice" samples, respectively. It is assumed that no scale formation occurs. Therefore, all negative rates are eliminated, and the entire distribution can be assumed to be due to uncertainty. As shown in the resultant Figure 26, the rate at the 50th percentile is approximately 50 nm y^{-1}; the rate at the 90th percentile is approximately 100 nm y^{-1}; and the maximum rate is 731 nm y^{-1}. About 10% of the values fall between 100 and 750 nm y^{-1}.

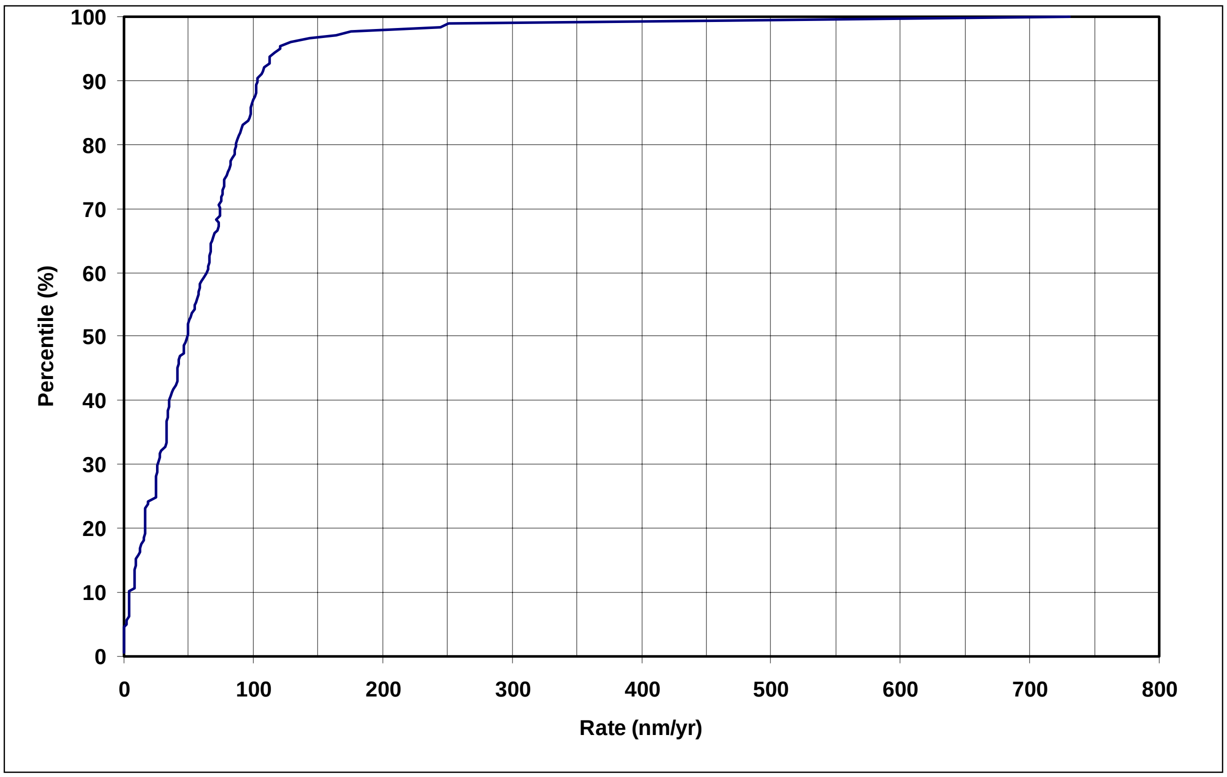


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Figure 26. GC Rates of Alloy 22 with Combined Data and Negative Values Neglected

It would appear that the maximum value in the distribution of variability would be no greater than the maximum value in the distribution of uncertainty. Therefore, a conservative assumption would be to assume that the variability obeys a triangular distribution between zero and the maximum observed rate of 750 nm y^{-1}. According to the literature (Evans et al. 1993) the distribution function is either

$$F(x) = \frac{(x-a)^2}{(b-a)(c-a)} \qquad a \le x \le b \tag{Eq. 37}$$

or

$$F(x) = 1 - \frac{(b-x)^2}{(b-a)(b-c)} \qquad c \le x \le b \tag{Eq. 38}$$

where c is the mode. The peak in the probability density function is about 2.0 and can be represented by either:

$$f(x) = \frac{2(x-a)}{(b-a)(c-a)} \qquad a \le x \le b \tag{Eq. 39}$$

or

$$f(x) = \frac{2(b-x)}{(b-a)(b-c)} \qquad c \le x \le b \tag{Eq. 40}$$

The mean and variance are given by:

$$\mu = \frac{(a+b+c)}{3} \tag{Eq. 41}$$

and

$$\sigma = \frac{a^2 + b^2 + c^2 - ab - ac - bc}{18} \tag{Eq. 42}$$

If the probability density function is skewed to the lower values (as observed here), the following expression for c can be used:

$$c = \alpha(b-a) \tag{Eq. 43}$$

where the adjustable parameter alpha (α) is less than 0.5.

6.5.5 Atomic Force Microscopy

The AFM has been used to characterize the surface topographies of weight-loss coupons of Alloy 22 that had been exposed to various environments in the YMP's LTCTF for one year. Having sub-nm vertical resolution, the AFM is an ideal tool for detecting extremely small penetrations in corrosion-resistant materials such as Alloy 22. As shown in Attachment I, Bedrossian and Fix have applied this technique to five Alloy 22 samples used for weight loss measurements (Bedrossian 1999). These samples include an unexposed control sample (DWA163), a sample exposed to aqueous phase SAW (DWA051), a sample exposed to vapor-phase SAW (DWA048), a sample exposed to aqueous-phase SCW (DWA120), and a sample exposed to vapor-phase SCW (DWA117). The sample numbers are official designations of the YMP. After the samples were removed from the LTCTF, they were ultrasonically agitated in deionized water, acetone, and methanol for ten minutes each. The digital instruments DM3100 AFM was then used for imaging. Each set of data consists of a large-area scan (25 μm × 25 μm), followed by smaller-area details of the region displayed in the large-area scan.

The gross surface topography is dominated by the machining grooves, with typical heights of several hundred nm and typical lateral periodicities of several μm features plainly visible on images of the control sample (DWA163, Figure 27). Samples removed from the LTCTF exhibit varying degrees of coverage by a deposit on top of this gross topography. The AFM images show that the most extensive deposit formation occurred on the sample exposed to aqueous-phase SAW (DWA051, Figure 28). The next, most-extensive deposit formation occurred on the sample exposed to vapor-phase SAW (DWA048). X-ray Diffraction scans of all five coupons show that the deposit is predominantly a silicate or SiO_2, with some NaCl appearing on the two samples which were in the SAW tank (Figure 29). Based upon both AFM and X-ray diffraction data, the two samples exposed to SCW showed lesser degrees of coverage by the silicate deposit. In some cases, depressions can be seen in the silicate deposit. However, it is not believed that any of these penetrate to the underlying metal.

At the present time, there is insufficient data to quantitatively determine the extent of silicate removal from exposed Alloy 22 samples by acid cleaning. In the future, an effort will be made to collect sufficient quantitative information to quantitatively determine how much silicate remains on the surface after the acid cleaning procedure. In the mean time, a worst-case estimate of the impact of SiO_2 on measured corrosion rates will be used.

The formation of SiO_2 deposits on the surface of the Alloy 22 could bias the distributions of GC rate shown in Sections 6.5.2 and 6.5.4. From various AFM images of Alloy 22 samples removed from the LTCTF, it appears that a typical deposit can have a thickness as great as 0.25 microns after 12 months of exposure. The resultant bias is then estimated. It is assumed that the deposit has the density of lechatelierite (amorphous SiO_2), which is approximately 2.19 g cm^{-3} (Weast 1978, p. B-161). It is further assumed that the surface is completely and uniformly covered by this deposit. The estimated surface areas of the weight-loss and crevice samples are 30.65 and 57.08 cm^2, respectively (4.75 and 8.85 in^2, respectively). Consequently, the deposit thickness translates into a mass change of 1.678 and 3.125 mg for weight-loss and crevice samples, respectively, after 12 months of exposure. Equation 24 is then applied to determine the impact of such a positive mass change on the calculated GC rate. In the case of the weight loss sample, the estimated bias is 0.063 microns per year (63 nm y^{-1}):

$k = 10^4\ \mu m\ cm^{-1}$

$\Delta w = 1.678 \times 10^{-3}\ gm$

$area = 30.645\ cm^{2}$

$t = 1.0\ y$

$\rho = 8.69\ gm\ \ cm^{-3}$

$$\Delta\left(\frac{dp}{dt}\right) = \frac{\left(10^4\ \mu m\ cm^{-1}\right)\left(1.678 \times 10^{-3}\ gm\right)}{\left(30.645\ cm^{2}\right)\left(1.0\ yr\right)\left(8.69\ gm\ \ cm^{-3}\right)} = 0.063\ \mu m\ y^{-1}$$

In the case of the crevice sample, the result is the same:

$k = 10^4\ \mu m\ cm^{-1}$

$\Delta w = 3.125 \times 10^{-3}\ gm$

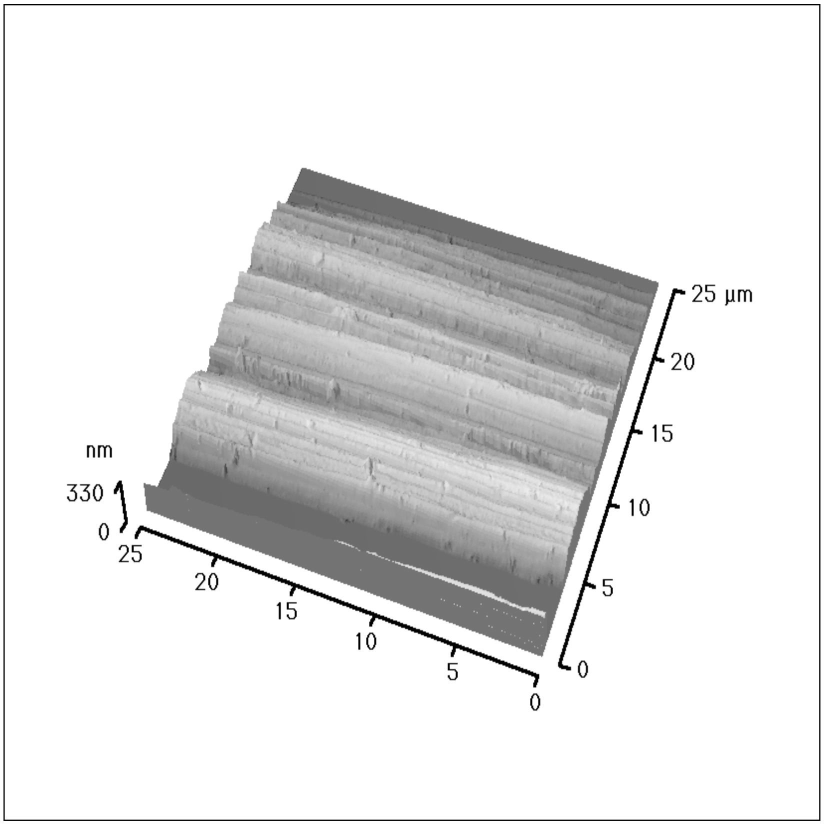
$area = 57.078\ cm^{2}$

$t = 1.0\ y$

$\rho = 8.69\ gm\ \ cm^{-3}$

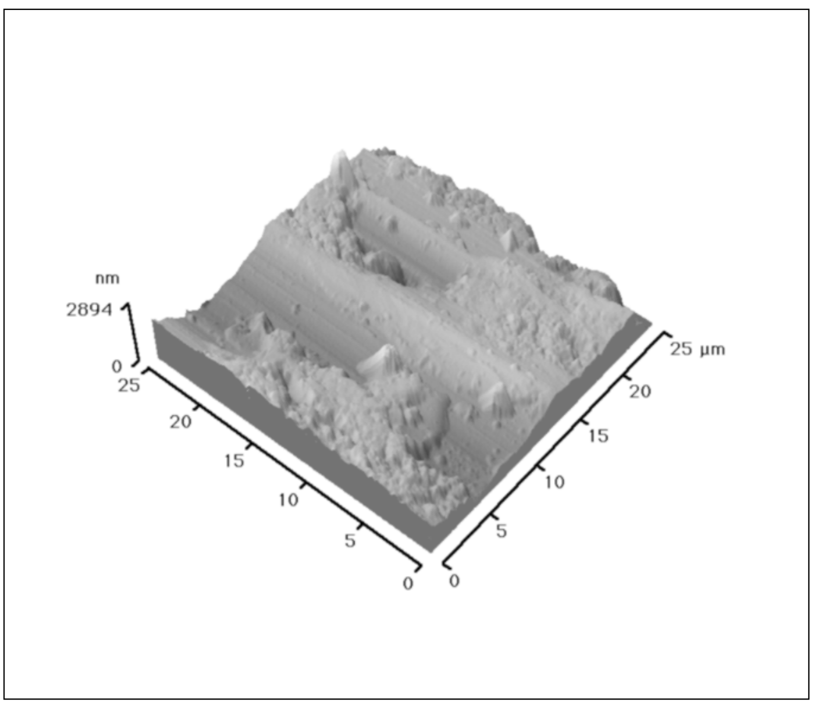
$$\Delta\left(\frac{dp}{dt}\right) = \frac{\left(10^4\ \mu m\ cm^{-1}\right)\left(3.125 \times 10^{-3}\ gm\right)}{\left(57.078\ cm^{2}\right)\left(1.0\ yr\right)\left(8.69\ gm\ \ cm^{-3}\right)} = 0.063\ \mu m\ y^{-1}$$

The distributions of GC rate shown in Sections 6.5.2 and 6.5.4 can be corrected for the maximum bias due to SiO_2 deposit formation by adding a constant value of 63 nm y-1 to each estimated value of the GC rate. This is equivalent to shifting the curves shown in Figures 23, 25, and 26 to the right by 63 nm y^{-1}.



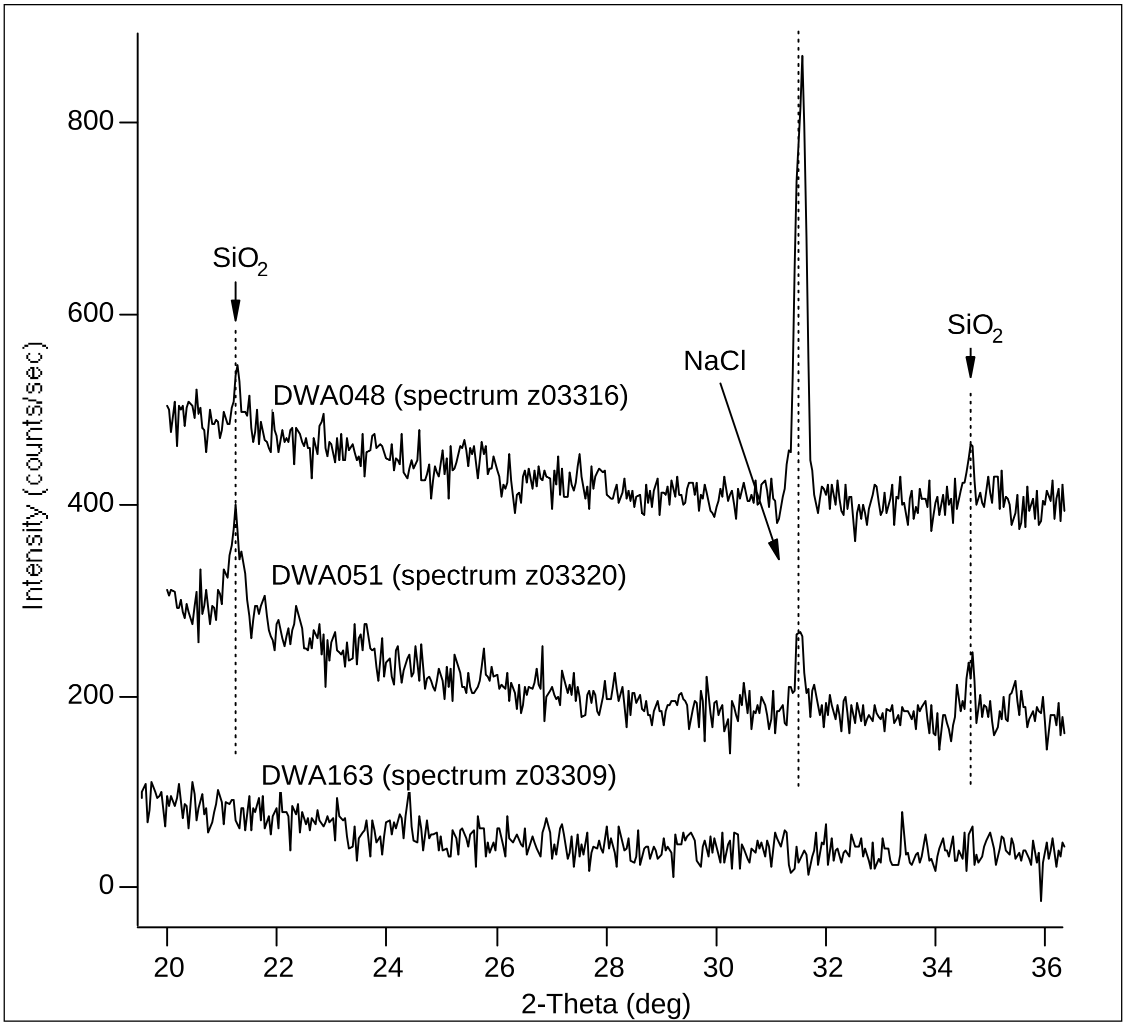
NOTE: Bedrossian (1999)

Figure 27. AFM Image of Alloy 22 Control Sample



NOTE: Bedrossian (1999)

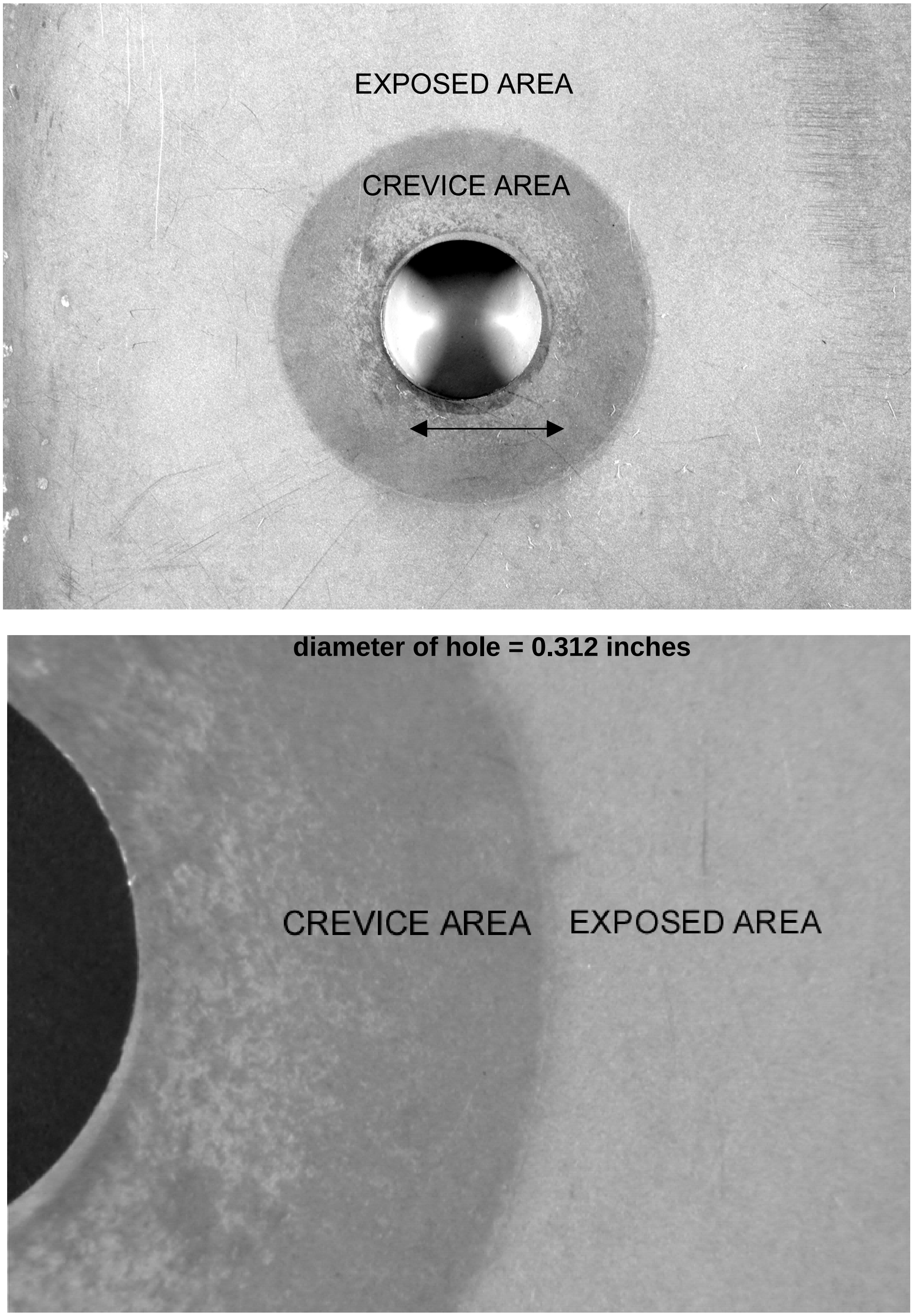
Figure 28. AFM Image of Alloy 22 Sample Removed from LTCTF



NOTE: Bedrossian (1999)

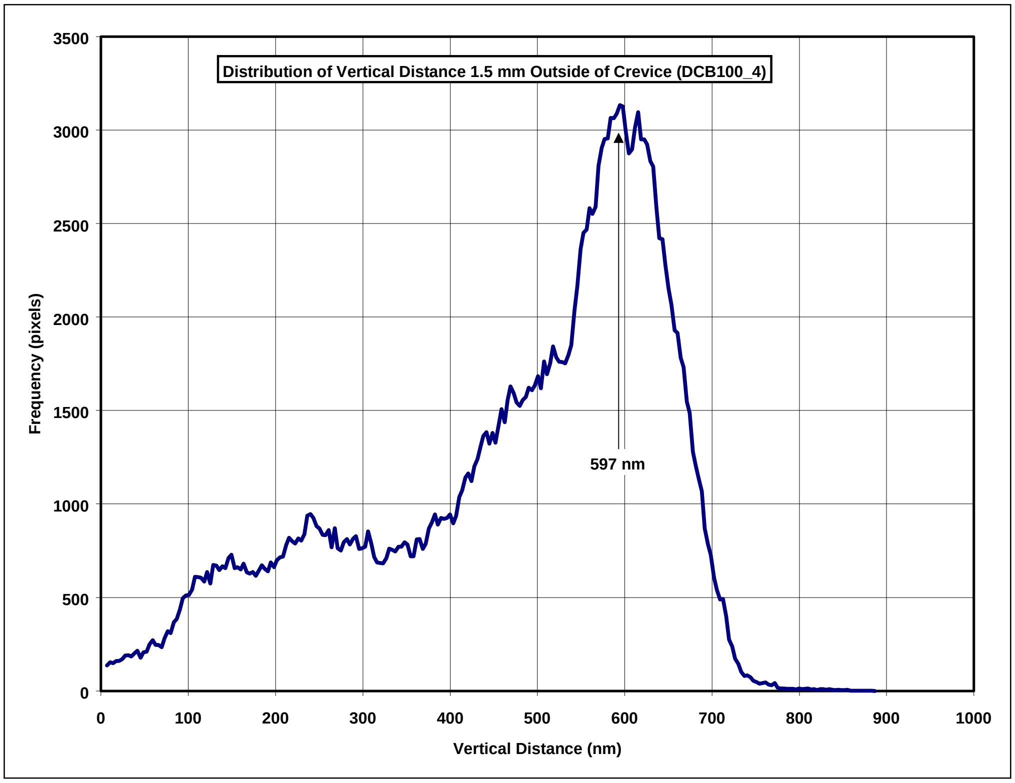
Figure 29. X-ray Diffraction Pattern of Silicate Deposit on Sample Exposed to LTCTF

The AFM has been used to examine areas inside and outside of Alloy 22 crevices exposed for 12 months to SCW at 90°C. Though the images were obtained with a welded sample (DCB100), the unwelded area was imaged with the AFM. Figure 30 shows two optical micrographs of the sample surface near the hole (0.312 inch diameter). The bottom image is a 10× magnification of the top image. There is some discoloration underneath the crevice, but no evidence of penetration. Figure 31 shows AFM data for an area 1.5 mm outside the crevice, plotted in the form of a probability density function for vertical distance. This distribution peaks at 597 nm. The corresponding three-dimensional image is shown in Figure 32. For comparison, Figure 33 shows AFM data for an area 1.5 mm inside the crevice, plotted in the form of a probability density function for vertical distance. This distribution peaks at 549 nm, very close to that determined for the area outside of the crevice. The corresponding three-dimensional image is shown in Figure 34. AFM line scans perpendicular to the edge, along the outside area, along the inside area, and along an area on an unexposed control sample are compared in Figure 35. There appears to be no significant difference between the roughness of the four areas that were examined. Because it has been observed that corrosion tends to roughen the surface, it is concluded that there is no more attack inside the crevice than outside.



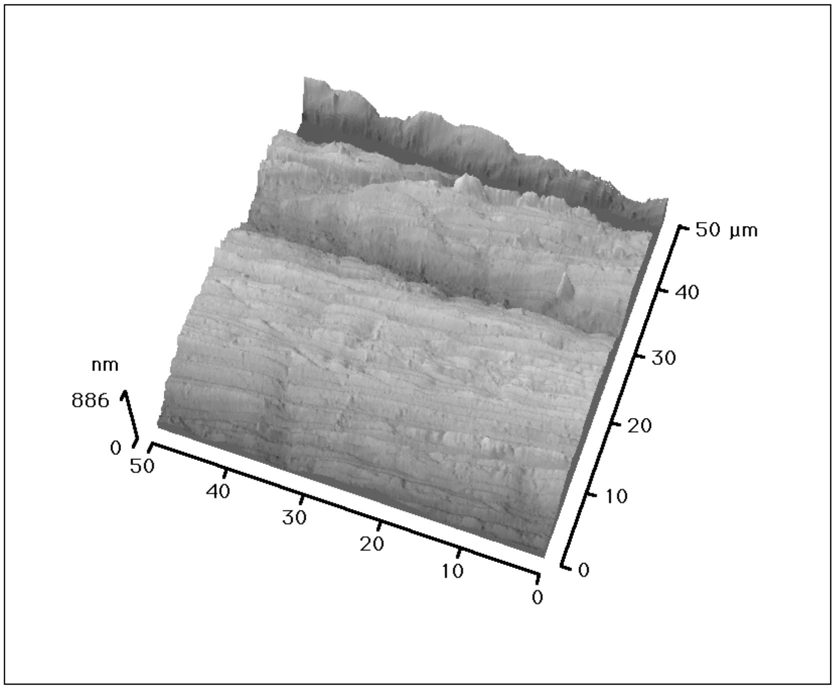
NOTE: The top image has a relative magnification factor of 1X. The bottom image has a relative magnification factor of 10X.

Figure 30. Photographs of Alloy 22 Crevice Area after 12-month Exposure to SCW Aqueous Phase at 90°C (DCA101).



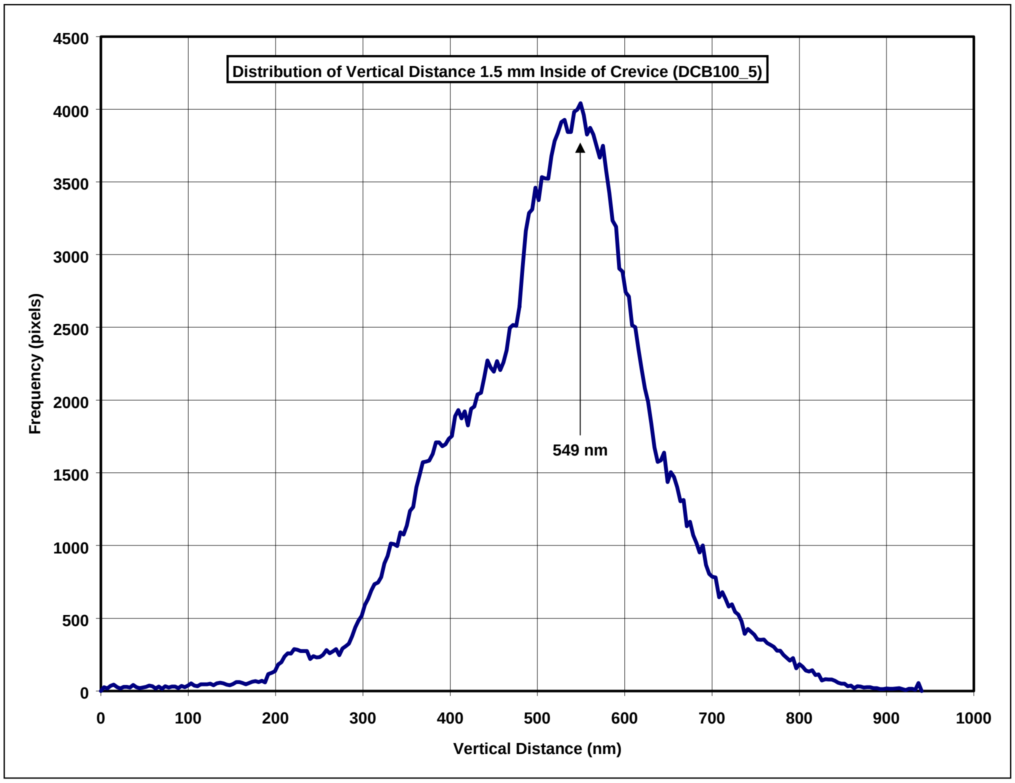
NOTE: Bedrossian (1999)

Figure 31. Histogram of AFM Measurements of Vertical Distance made 1.5 mm outside of Crevice (DCB100_4)



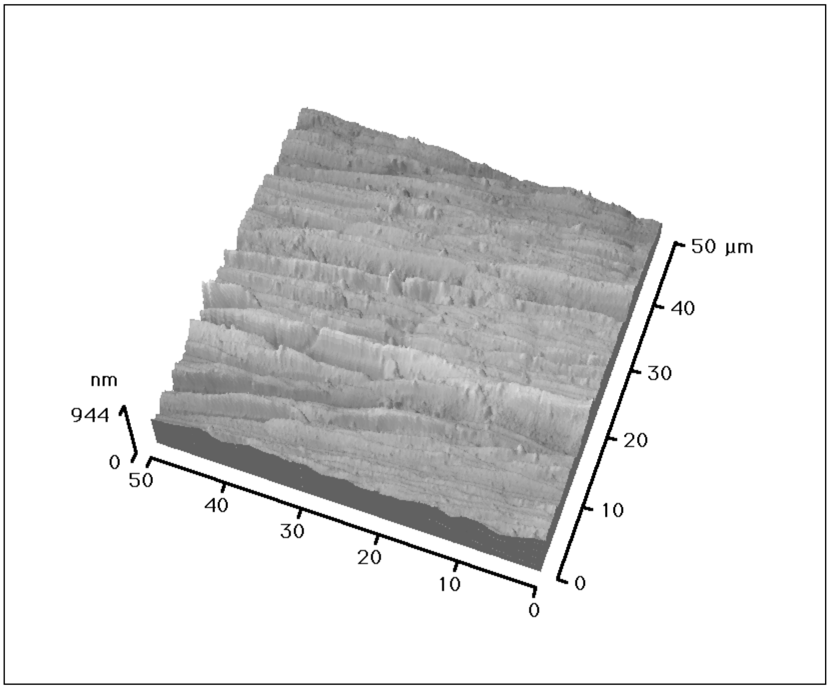
NOTE: Bedrossian (1999)

Figure 32. Three-dimensional AFM Image taken 1.5 mm outside of Crevice (DCB100_4)



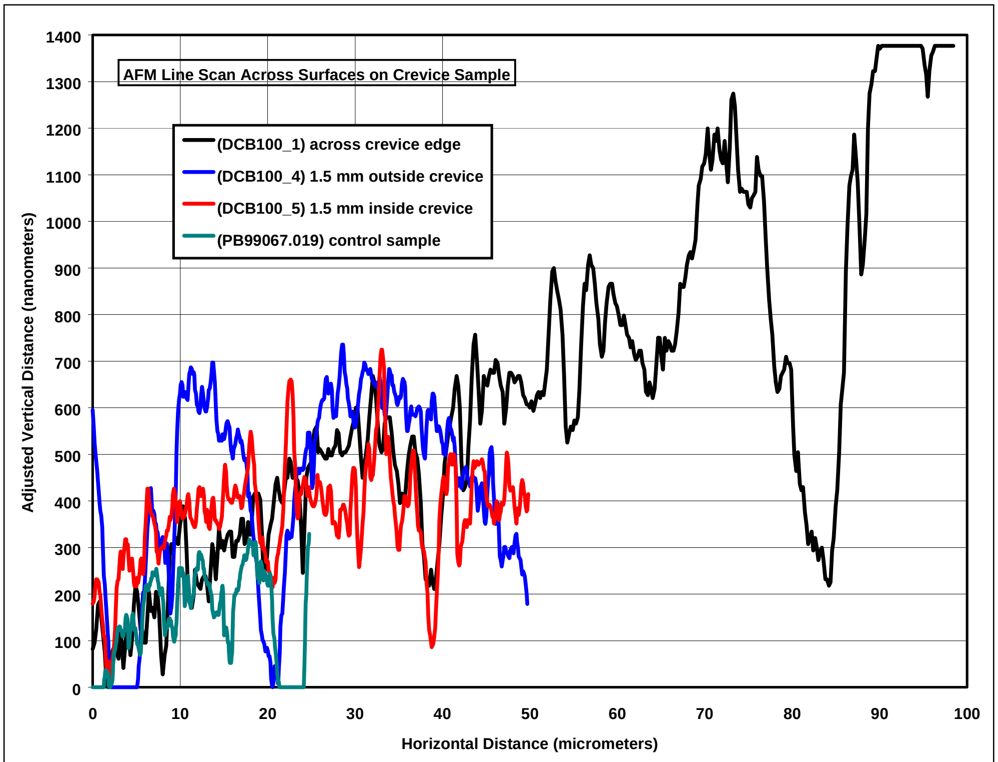
NOTE: Bedrossian (1999)

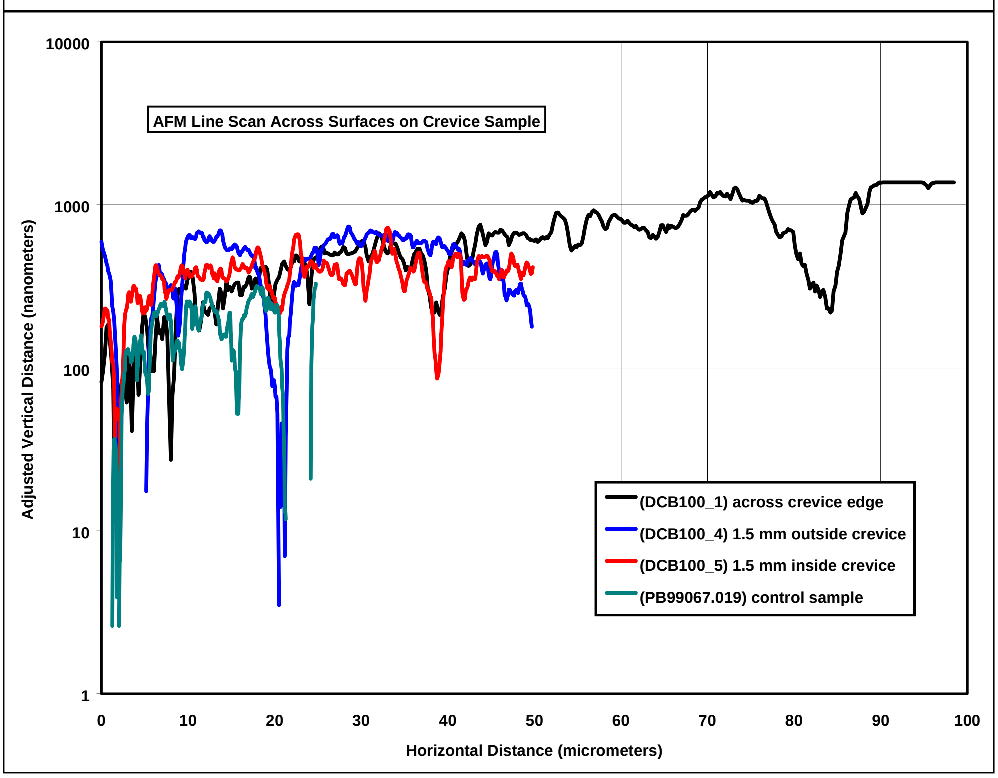
Figure 33. Histogram of AFM Measurements of Vertical Distance made 1.5 mm inside of Crevice (DCB100_5)



NOTE: Bedrossian (1999)

Figure 34. Three-dimensional AFM Image taken 1.5 mm inside of Crevice (DCB100_5)





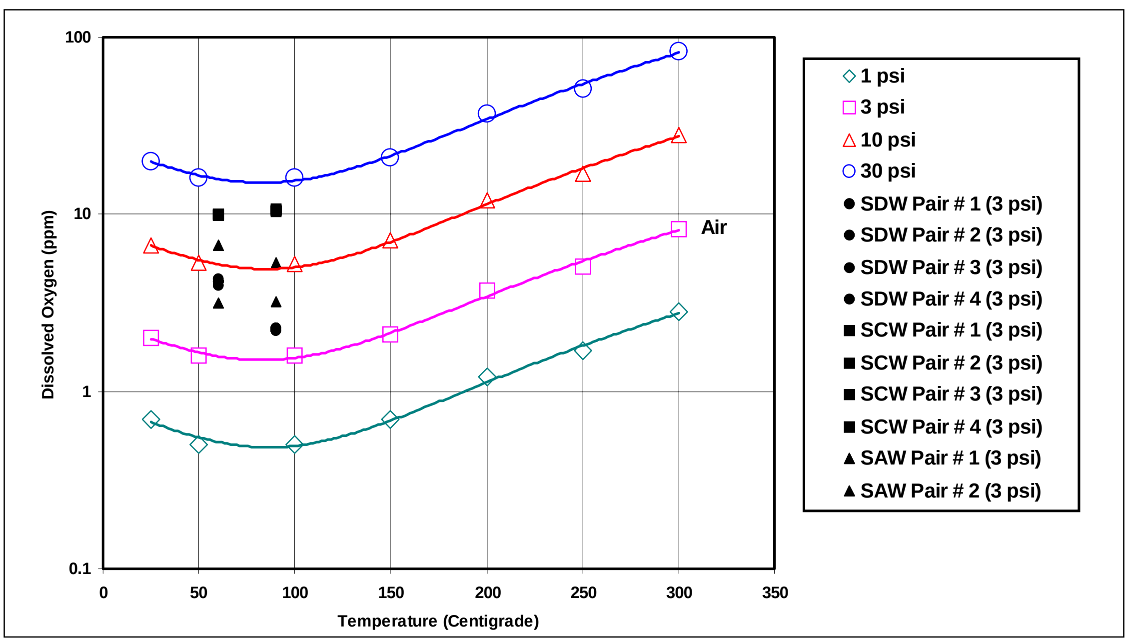
NOTE: Bedrossian (1999)
The top graph has a linear scale. The bottom graph has a logarithmic scale.

Figure 35. A Comparison of AFM Line Scans across Different Regions of Exposed Crevice Sample, with Comparison to Line Scan on Surface of Unexposed Control Sample

A study of four test coupons of Alloy 22 removed from the LTCTF after one year showed varying degrees of coverage by silicate deposits but no evidence of localized corrosion by pitting. The distributions of GC rate shown in Sections 6.5.2 and 6.5.4 can be corrected for the maximum bias due to SiO_2 deposit formation by adding a constant value of 63 nm y^{-1} to each estimated value of the GC rate. This is equivalent to shifting the curves shown in Figures 23, 25, and 26 to the right by 63 nm y^{-1}. The AFM has been used to examine areas inside and outside of Alloy 22 crevices exposed to SCW at 90°C for 12 months. AFM line scans perpendicular to the edge, along the outside area, along the inside area, and along an area on an unexposed control sample are compared in this AMR. There appears to be no significant difference between the roughness of the four areas that were examined. Since it has been observed that corrosion tends to roughen the surface, it is concluded that there is no more attack inside the crevice than outside.

6.5.6 Dissolved Oxygen in the Long Term Corrosion Test Facility

Corrosion rates in the LTCTF may depend upon the concentration of dissolved oxygen because the cathodic reduction of oxygen may be required to depolarize anodic dissolution reactions. The anodic dissolution of a metal requires a corresponding amount of cathodic reduction. Typically, dissolved oxygen or hydrogen ion is reduced. However, as previously discussed, other reactants such as hydrogen peroxide (due to gamma radiolysis) can also be reduced. Figure 36 shows a comparison of dissolved oxygen measurements in LTCTF to published data for synthetic geothermal brine (Cramer 1974). The published data spans the range of temperature from 20 to 300°C, and spans the range of oxygen partial pressures from 1 to 30 psi. Note that the partial pressure of oxygen in the atmosphere is about 3 psi. The points representing measurements from the LTCTF tanks are superimposed upon the published data. Clearly, the SDW, SCW, and SAW appear to be saturated (4-10 ppm dissolved oxygen).



DTN: LL990610605924.079

NOTE: Cramer (1974)

Figure 36. Comparison of Dissolved Oxygen Measurements in LTCTF to Data for Synthetic Geothermal Brine

6.6 CREVICE CORROSION

6.6.1 Scenarios Leading to Crevice Formation

At points of contact between the WP and other solid objects, crevices form occluded geometries, which lead to differential aeration of the crevice solution (electrolyte). Dissolved oxygen can become depleted deep within the crevice, while the oxygen concentration near the crevice mouth remains relatively high. Cathodic reduction of dissolved oxygen at the crevice mouth may create a sufficiently high electrochemical potential to drive anodic processes inside the crevice, thereby causing an anodic current to flow along the crevice towards the crevice mouth. Under realistic repository conditions, it is believed that the walls of the Alloy 22 crevice will remain passive. The potential at the mouth of a crevice is expected to be well below the threshold for localized attack, as determined with CP measurements. Anodic processes inside the crevice are, therefore, expected to occur at a rate that corresponds to the local passive current density. Two primary electrochemical processes can lead to acidification of the solution in a passive crevice, (1) the preferential transport of anions into the crevice from the mouth, driven by the electric field that accompanies the crevice current and (2) hydrolysis reactions of dissolved metal cations. Based upon experimental work with passive crevices without buffer, it is believed that the applied potentials required for significant acidification (pH<5) are not plausible. A minimum crevice pH of approximately 5 is assumed. Additional experimental work of the type discussed here is required to further substantiate this preliminary conclusion.

6.6.2 Crevice Chemistry and Lowering of Local pH

The hydrolysis of dissolved metal in crevices can lead to the accumulation of H^+ and the corresponding suppression of pH. For example, pH < 2 has been observed in crevices made of stainless steel, as discussed by Sedriks (1996). Metal ions produced by anodic dissolution are assumed to undergo the following hydrolysis reactions, as discussed by Oldfield and Sutton (1978):

$$Fe^{3+} + H_2O \longleftrightarrow Fe(OH)^{+} + H^{+} \qquad \text{(Eq. 44)}$$

$$Fe^{3+} + H_2O \longleftrightarrow Fe(OH)^{2+} + H^{+} \qquad \text{(Eq. 45)}$$

$$Ni^{2+} + H_2O \longleftrightarrow Ni(OH)^{+} + H^{+} \qquad \text{(Eq. 46)}$$

$$Cr^{3+} + H_2O \longleftrightarrow Cr(OH)^{2+} + H^{+} \qquad \text{(Eq. 47)}$$

$$Cr(OH)^{2+} + H_2O \longleftrightarrow Cr(OH)_2^{+} + H^{+} \qquad \text{(Eq. 48)}$$

If the dissolved metals exceed the solubility limits, precipitation will occur:

$$Fe(OH)_2(s) \longleftrightarrow Fe^{2+} + 2OH^{-} \qquad \text{(Eq. 49)}$$

$$Ni(OH)_2(s) \longleftrightarrow Ni^{2+} + 2OH^{-} \qquad \text{(Eq. 50)}$$

$$Cr(OH)_3(s) \longleftrightarrow Cr^{3+} + 3OH^- \quad \text{(Eq. 51)}$$

Precipitation of hydroxides are favored at more alkaline pH levels. In the case of Alloy 22, the hydrolysis of other dissolved metals such as molybdenum and tungsten ions may be important. The Oldfield-Sutton model does not account for the role of HCl in the crevice on destabilization of the passive film.

6.6.3 Chloride Transport by Electromigration

Chloride anion will be driven into the crevice by the potential gradient, as discussed in the literature (Pickering and Frankenthal 1972; Galvele 1976). The corresponding concentration in the crevice is:

$$[Cl^-] = [Cl^-]_0 \exp\left[-\frac{F}{RT}\Phi(x)\right] \quad \text{(Eq. 52)}$$

where $[Cl^-]_0$ is the concentration at the crevice mouth, $\Phi(x)$ is the potential in the crevice relative to that at the mouth, and (x) is the distance from the crevice mouth. Field-driven electromigration of Cl^- (and other anions) into crevice must occur to balance cationic charge associated with H^+ ions, as well as the charge associated with Fe^{2+}, Ni^{2+}, Cr^{3+}, and other cations. If such conditions do develop inside Alloy 22 crevices, the stage might be set for an accelerated attack of this material by localized corrosion or SCC.

6.6.4 Deterministic Models of the Crevice

A detailed deterministic model has been developed to calculate the spatial distributions of electrochemical potential and current density in WP crevices, as well as transient concentration profiles of dissolved metals and ions (Farmer and McCright 1998; Farmer et al. 1998). These quantities are calculated with the transport equations, which govern electromigration, diffusion, and convective transport. In cases with strong supporting electrolyte, electromigration can be ignored (Newman 1991). First, the axial current density along the length of the crevice is calculated by integrating the wall current density. The electrode potential along the length of the crevice can then be calculated from the axial current density. This technique is similar to that employed in other models (Nystrom et al. 1994). Such models show that the electrochemical potential decreases with increasing distance into the crevice. Therefore, the potential should never be more severe (closer to the threshold for LC) than at the crevice mouth. The partial differential equations that define transient concentrations in the crevice require determination of the potential gradient, as well as the local generation rates for dissolved species. The concentrations of dissolved metals at the crevice mouth are assumed to be zero. Computations are facilitated by assuming that the crevices are symmetric about a mirror plane where the flux is zero. This model has been used to estimate the extent of pH suppression in WP crevices due to the simultaneous hydrolysis and transport of dissolved Fe, Ni, Cr, Mo, and W.

6.6.5 Experimental Determinations of Crevice pH and Current

The local crevice environments for Alloy 22 and other relevant materials are being determined experimentally. This procedure is described in AP-E-20-81, Revision 1. Crevices have been constructed from square metallic samples, 2 inches on each side and 1/8 inch thick (same size as crevice samples used in the LTCTF). The samples are masked with plastic tape, thereby forming an exposed square area, 1.7 inches on each side. The exposed area is placed underneath a clear plastic window with an access port for a pH sensor in the center. In this case, the sensor is a miniature reference electrode separated from the crevice solution with a thin glass membrane. A second pH sensor is located at the mouth of the crevice, in close proximity to a saturated calomel reference electrode (SCE). The use of in situ sensors to determine crevice pH has also been described by Sridhar and Dunn (1994). In parallel experiments by Farmer et al. (1998), paper strips with a pH-sensitive dye (pH paper) have been sandwiched between the clear plastic window and photographed with a digital electronic camera in a time-lapse mode to add confidence to the measurements made with pH sensors. Spectroscopic-grade graphite counter electrodes are also placed in the electrolyte lying outside the mouth of the crevice. A potentiostat is then used to control the electrochemical potential at the mouth of the crevice. Temperature, potential, current, and pH is then recorded electronically during the course of the experiment.

Measurements of pH inside a crevice formed from 316L stainless steel are shown in Figure 37. The electrolyte was 4M NaCl and was maintained at ambient temperature. Since this electrolyte contains no buffer ions, it is considered to be a far more severe medium than those representative of various concentrations of J-13 well water. The electrochemical potential at the mouth was maintained at 200 mV versus Ag/AgCl. Crevice corrosion could be seen initiating near the crevice mouth and propagating towards the pH sensor, which was located about 0.5 cm inside the crevice mouth. When the corrosion front reached the pH sensor, the pH dropped from the initial value (pH~7) to a very low value (pH~1). The fixed one-liter volume of electrolyte outside of the crevice became slightly alkaline. The pH of this solution reached a maximum (pH~10) and then fell to a slightly lower steady-state value (pH~9). Active corrosion inside the crevice is evident since the color of the crevice solution becomes emerald green. In similar experiments with 316L exposed to SCW, no significant lowering of the pH was observed.

Measurements of pH inside crevices formed with Alloy 22 surfaces are shown in Figures 38 through 42. Figure 39 shows the evolution of pH in a crevice with a potential of 800 mV versus Ag/AgCl applied at the mouth. The electrolyte was 4M NaCl and was maintained at ambient temperature. The Alloy 22 surface remained passive underneath the window, with no visible signs of localized attack. However, the passive current flow from within the crevice was sufficient to cause the pH to be immediately lowered from the initial value (pH~6.5) to a minimum value (pH~3.3), after which the pH gradually increased over several hours (pH~4.5). The fixed one-liter volume of electrolyte outside of the crevice became slightly alkaline (pH~8.3) before the data acquisition was started and dropped gradually over several hours (pH~7). The lowering of pH inside of passive Alloy 22 crevices with high-applied potential has been verified by independent technique-development tests with indicator paper, as discussed in AP-E-20-81 Rev. 1. Figures 38 through 41 illustrate the effect of increasing the applied potential above the threshold required for localized breakdown of the passive film. As shown in Figure 39, an applied potential of 1100 mV can drive the pH to extremely low levels (pH~0.2) in Alloy 22 crevices. Figures 40 and 41 show the effect of incremental changes in applied potential on both crevice pH and crevice current. At an applied potential of 400 mV, the steady-state crevice pH remained close to neutrality (pH~6.1). As the potential was stepped to 1000 mV, which is slightly above the repassivation potential measured by Gruss et al. (1998), the crevice current increased dramatically and the pH dropped below one. At an applied potential of 1100 mV, extreme localized attack of the Alloy 22 was observed at the crevice mouth, with a crevice pH slightly less than zero. At the end of the experiment, the crevice sensor was immediately submersed in a buffer solution (pH 7) and shown to be in good calibration (virtually no drift during test). Figure 42 shows the effect of buffer ions on crevice chemistry. In this case, SCW was used as the electrolyte. Even at an applied potential of 800 mV, no significant lowering of the pH was observed. The Alloy 22 inside the crevice appeared to be unchanged from its initial state, with no evidence of localized attack.

Figure 43 is a summary of several experiments where crevice pH was determined in situ as a function of applied potential. These data are represented by the following polynomial:

$$y = b_0 + b_1 x + b_2 x^2 \qquad \text{(Eq. 53)}$$

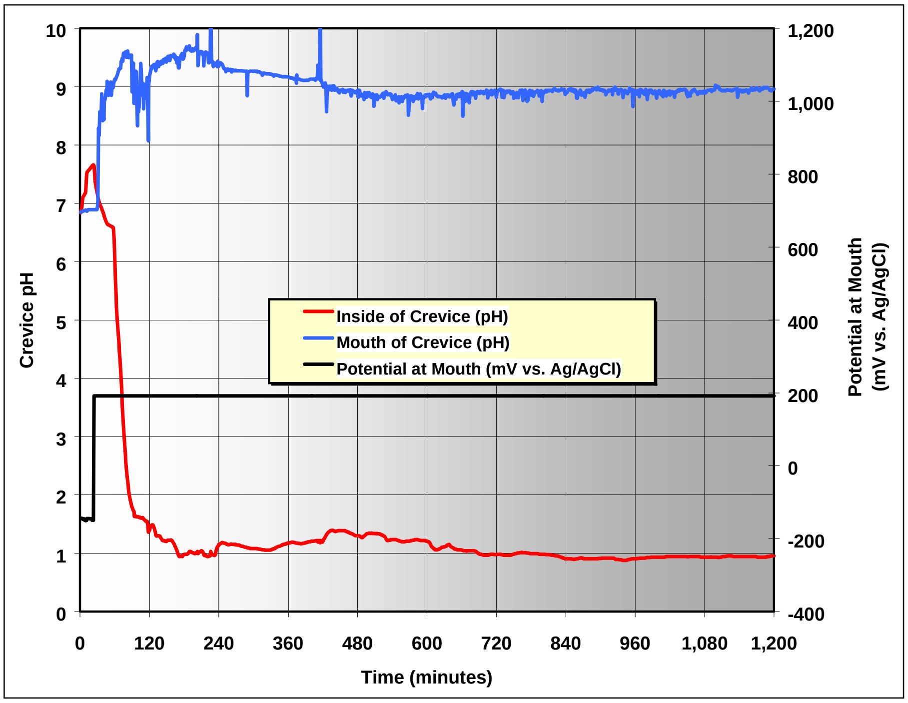
where x is the potential applied at the crevice mouth (mV versus Ag/AgCl) and y is the steady-state pH inside the crevice. Coefficients for the above equation are summarized in Table 21, representing both Alloy 22 and 316L in under a broad range of conditions. The correlations for 4M NaCl and SCW should be used to bound the crevice pH, using linear interpolation between the two limits, based upon the concentration of buffer ion.

Table 21. Coefficients for the Correlation of Crevice pH with Applied Potential

Material	**Medium**	**Crevice Spacer (μm)**	b_0	b_1	b_2	R^2
Alloy 22	4M NaCl	110	7.2716	-0.0012	-5.0E-06	0.9782
Alloy 22	4M NaCl	540	7.0227	-0.0015	-4.0E-06	~1
Alloy 22	SCW	540	8.276	0.0003		0.9646
316L	4M NaCl	540	1.035	-0.00001		0.0005
316L	SCW	540	8.1175	-0.00006		~1

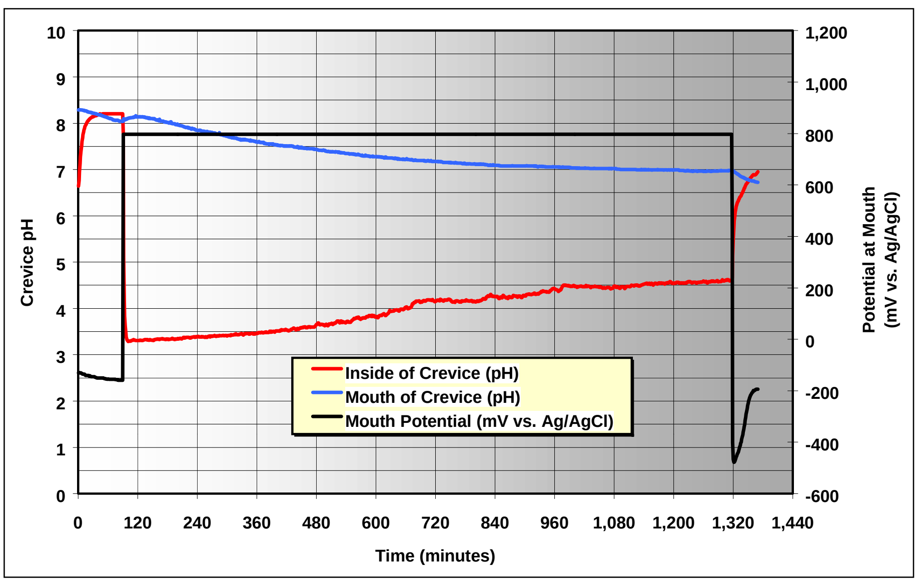
DTN: LL991208605924.100

In summary, there was no visible evidence of localized corrosion of the metal inside the crevice at applied potentials less than the threshold. However, even though the crevice remained passive, the passive current density and imposed electric field within the crevice was sufficient to cause significant acidification. In many of the experiments described here, both the applied potential and the test medium are more severe than those expected in the repository. However, the temperature of aqueous solutions on the WP surface may be significantly higher (120°C). Work is in progress to obtain comparable data at higher temperature. The experimental data support published numerical simulations (Farmer et al. 1998; Farmer et al. 1999).



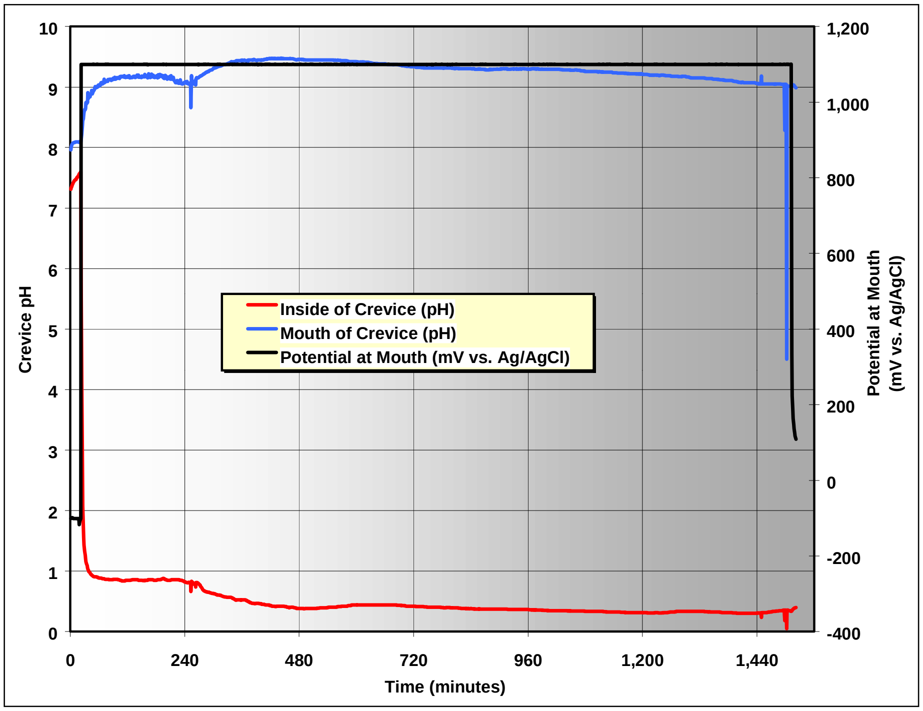
DTN: LL990610505924.078

Figure 37. Stainless Steel 316L, 4M NaCl, 200 mV and 23 °C, Crevice pH Versus Time



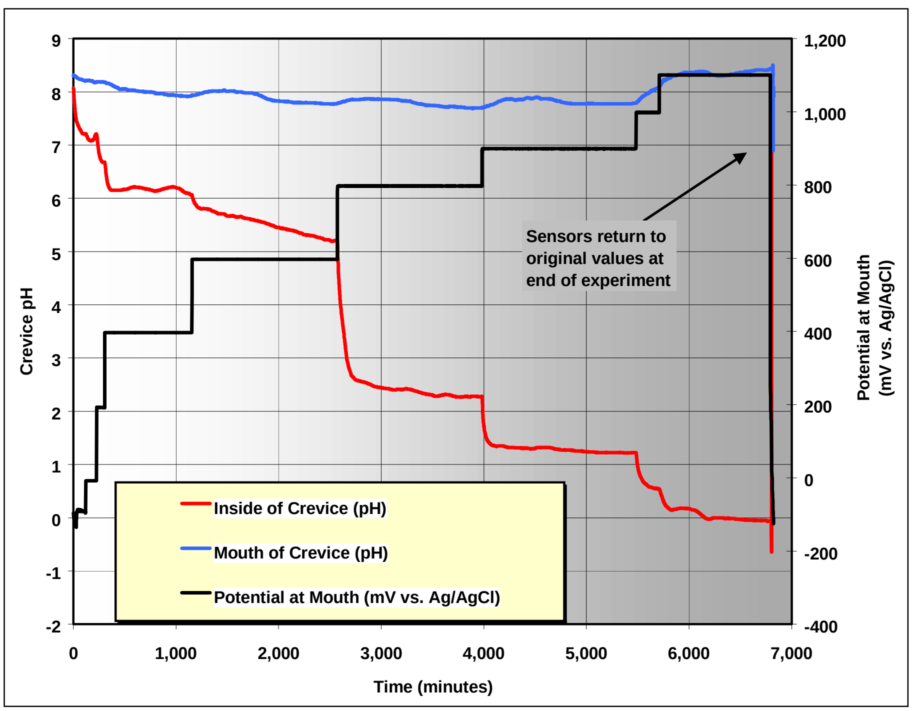
DTN: LL990610505924.078

Figure 38. Alloy 22, 4M NaCl, 800 mV and 23 °C, Crevice pH Versus Time



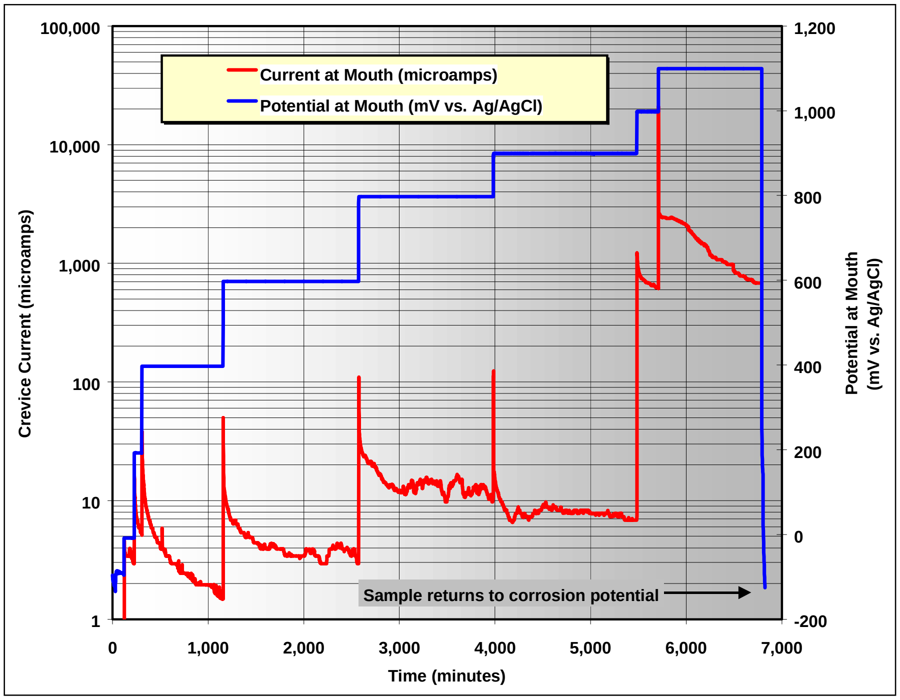
DTN: LL990610505924.078

Figure 39. Alloy 22, 4M NaCl, 1100 mV and 20 °C, Crevice pH Versus Time



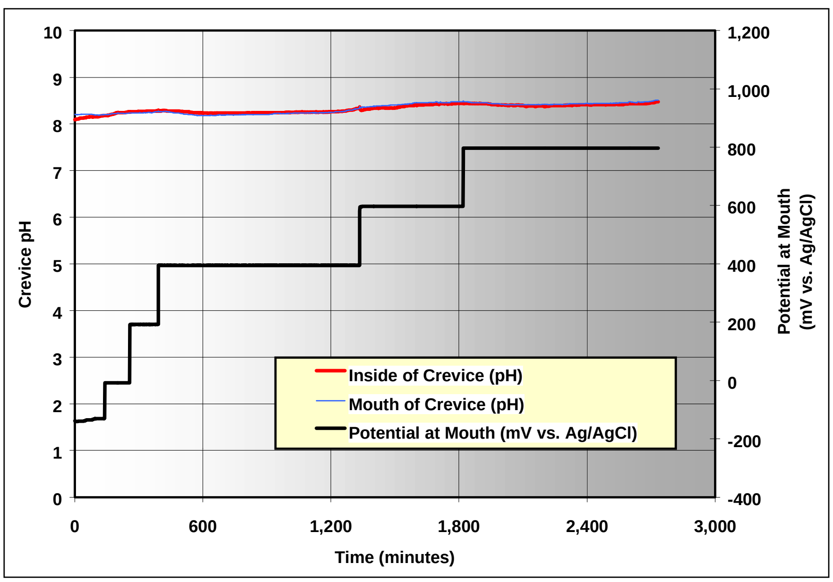
DTN: LL990610505924.078

Figure 40. Alloy 22, 4M NaCl at 23 °C, Crevice pH Versus Time



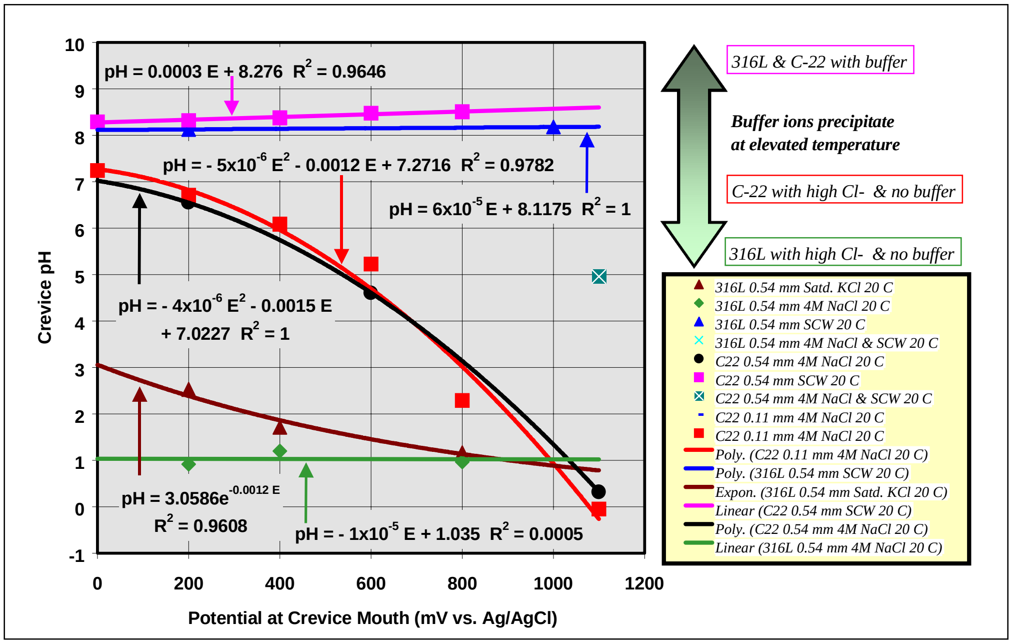
DTN: LL990610505924.078

Figure 41. Alloy 22, 4M NaCl at 23 °C, Crevice Current Versus Time



DTN: LL990610505924.078

Figure 42. Alloy 22, SCW at 23 °C, Crevice pH Versus Time



DTN: LL990610305924.076

Figure 43. Determination of Crevice pH for WP Materials

6.6.6 Estimated Rate of Localized Corrosion

If the threshold potential for localized attack is exceeded, a corrosion rate representative of LC must be assumed. Due to the outstanding corrosion resistance of Alloy 22, very little data exists for such localized corrosion under plausible conditions. Work originally published by Asphahani (1980) and later reviewed by Gdowski (1991) indicates that the corrosion rate of Alloy 22 in 10 wt% $FeCl_3$ at 75°C might be as high as 12.7 µm per year. This rate is significantly higher than those measured in the LTCTF and may be representative of the types of rates expected for LC, including crevice corrosion. In a solution composed of 7 vol% H_2SO_4, 3 vol% HCl, 1 wt% $FeCl_3$, and 1 wt% $CuCl_2$, a penetration rate of 610 µm per year was observed at 102°C. From 9.12 (Sedriks 1996), the corrosion rate of Alloy C-276 in dilute HCl at the boiling point is somewhere between 5 and 50 mils per year (127 and 1270 µm per year). Comparable rates would be expected for Alloy 22. The highest passive current density found in Figures 15 through 18 is approximately 10 µA cm^{-2}, which corresponds to a corrosion rate of approximately 100 µm per year. For the time being, it is expected that the logarithm of the localized corrosion rate of Alloy 22 is normally distributed, as shown in Table 22. This distribution reasonably bounds those extreme penetration rates found in the literature and is centered around the rate corresponding to the passive current density.

Table 22. Distribution of LC Rates for Alloy 22

Percentile (%)	Localized Corrosion Rate (µm per year)
0^{th}	12.7
50^{th}	127
100^{th}	1270

NOTE: Asphahani (1980); Gdowski (1991); Sedriks (1996)

6.7 EFFECT OF AGING AND PHASE INSTABILITY ON CORROSION

The WP surface temperature is always below 300°C. With this constraint, the impact of aging and phase instability on the corrosion of Alloy 22 will be insignificant. An extrapolation of the curves given in the companion AMR on aging and phase stability does not indicate that the phase stability of Alloy 22 *base metal* will be a problem at less than about 300°C (CRWMS M&O 2000b). However, it must be emphasized that such estimates are preliminary and uncertain. Much additional work is needed in this area. Rebak et al. have investigated the effects of high-temperature aging on the corrosion resistance of Alloy 22 in concentrated hydrochloric acid. However, due to the temperature used to age the samples (922-1033 K) and the extreme test media used (boiling 2.5% HCl and 1 M HCl at 339 K), these data are not considered relevant to performance assessment for the repository. This data will soon be published by R. B. Rebak, N. E. Koon, and P. Crook in an article entitled "Effect of High Temperature Aging on the Electrochemical Behavior of C-22 Alloy." This paper will appear in the Proceedings of the 50th Meeting of the International Society of Electrochemistry, which documents a conference held in Pavia, Italy, in September 1999.

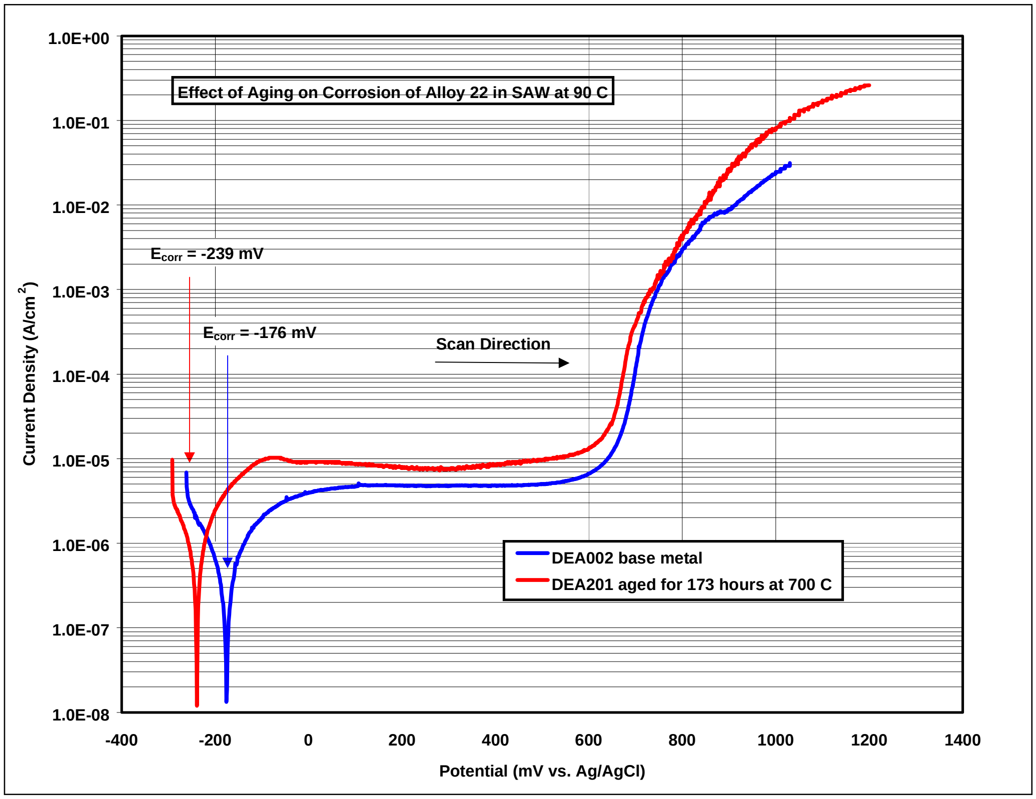
6.7.1 Corrosion Testing of Aged Samples in Standard Simulated Acidic Concentrated Water and Simulated Concentrated Water Test Media

Samples of Alloy 22 were aged at 700°C for either 10 or 173 hours. The corrosion resistance of these aged samples is compared to that of base metal in various standardized test media. Figure 44 shows a comparison of CP curves for base metal and thermally aged material in SAW at 90°C. Both curves exhibit generic type 1 behavior. In this case, aging appears to shift the corrosion potential to less noble values from -176 to -239 mV verses a standard Ag/AgCl reference electrode. The passive current density may be increased slightly, which would be indicative of a slight increase in corrosion rate. The highest non-equilibrium passive current observed for the base metal is approximately 4 μA cm^{-2} compared to approximately 10 μA cm^{-2} for fully aged material. The effect of thermal aging on the corrosion rate is accounted for in the enhancement factor, G_{aged}, and is based upon a ratio of the non-equilibrium current densities for base metal and aged material.

$$\left.\frac{dp}{dt}\right|_{effective} = G_{aged} \times \left.\frac{dp}{dt}\right|_{effective} \qquad \text{(Eq. 54)}$$

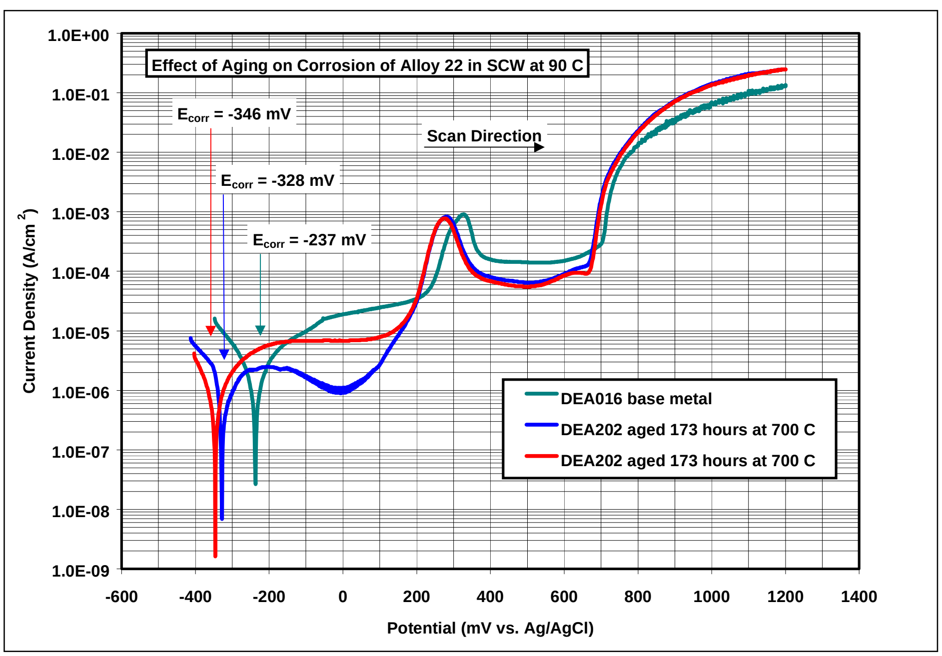
The value of G_{aged} for base metal is approximately one ($G_{aged} \sim 1$), whereas the value of G_{aged} for fully aged material is larger ($G_{aged} \sim 2.5$). Material with less precipitation than the fully aged material would have an intermediate value of G_{aged} ($1 \leq G_{aged} \leq 2.5$).

Figure 45 shows a comparison of CP curves for base metal and thermally aged material in SCW at 90°C. In this case, aging also appears to shift the corrosion potential to less noble values from -237 to somewhere between -328 and -346 mV verses a standard Ag/AgCl reference electrode. In all three cases, the anodic oxidation peak that is characteristic of generic type 2 behavior is observed.



DTN: LL991208705924.101

Figure 44. Effect of Thermal Aging for 173 Hours at 700°C on the Corrosion Resistance of Alloy 22 in SAW at 90°C (DEA002 and DEA201)



DTN: LL991208705924.101

Figure 45. Effect of Thermal Aging for 173 hours at 700°C on the Corrosion Resistance of Alloy 22 in SCW at 90°C (DEA016, DEA202 and DEA203)

6.7.2 Worst-case Test for Aged Samples

CP curves for base metal and thermally aged material in a new test medium of interest, BSW-13 at 110°C, are also compared. These data represent a worst-case test for Alloy 22, a combination of extreme thermal aging, extreme water chemistry, and a temperature approaching the boiling point. The BSW composition was established on the basis of results from a distillation experiment (CRWMS M&O 2000a). The total concentration of dissolved salts in the starting liquid was approximately five times more concentrated than that in the standard SCW solution. It was prepared by using five times the amount of each chemical that is specified for the preparation of SCW. After evaporation of ~90% of the water from the starting solution, the residual solutions reaches the highest chloride concentration and has a boiling point of ~111°C. The resultant BSW solution contains (sampled at 111°C) 9% chloride, 9% nitrate, 0.6% sulfate, 0.1% fluoride, 0.1% metasilicate, 1% TIC (total inorganic carbon from carbonate and bicarbonate), 5% potassium ion, and 11% sodium ion. A recipe for preparing synthetic BSW is shown below in Table 23.

Table 23. Initial BSW Solution Recipe

Chemical	Quantity (g)
Na_2CO_3 (anhydrous)	10.6
KCl	9.7
NaCl	8.8
NaF	0.2
$NaNO_3$	13.6
Na_2SO_4 (anhydrous)	1.4
H_2O	55.7
pH	11.3 (measured at room temperature)

DTN: LL991213805924.110

The synthetic BSW solution represented by Table 23 has been slightly modified for these and other corrosion tests, yielding BSW-11, BSW-12, and BSW-13. The three solutions have pH values of approximately 13, 12, and 11 respectively. All BSW-type solutions contain 9% chloride, 9% nitrate, 0.6% sulfate, and 0.1% fluoride. Sodium and potassium ions are used to balance the charge. More specifically, each testing solution contains 8.7 g KCl, 7.9 g NaCl, 0.2 g NaF, 13.6 g $NaNO_3$, and 1.4 g Na_2SO_4 (anhydrous). The pH 13 solution (BSW-13) was prepared by adding 65 mL of water and 2.0 mL of the 10 N NaOH to the chemicals (total weight = 100 g). The measured pH was 13.13. The pH 12 solution (BSW-12) was prepared by adding 66 mL of water and 2.0 mL of the 1 N NaOH to the chemicals. The measured pH was 12.25. The pH 11 solution (BSW-11) was prepared by adding 66 mL of water and 2.0 mL of the 0.1 N NaOH to the chemicals. The measured pH was 11.11. These recipes are summarized below in Table 24. It should be pointed that the modified BSW solutions are not buffered.

Table 24. Modified BSW Solution Recipes

Chemical	BSW-13 Quantity	BSW-12 Quantity (g)	BSW-11 Quantity (g)
KCl	8.7 g	8.7 g	8.7 g
NaCl	7.9 g	7.9 g	7.9 g
NaF	0.2 g	0.2 g	0.2 g
$NaNO_3$	13.0 g	13.0 g	13.0 g
Na_2SO_4 (anhydrous)	1.4 g	1.4 g	1.4 g
H_2O (deionized)	66 ml	66 ml	66 ml
10N NaOH	2 ml		
1N NaOH		2 ml	
0.1N NaOH			2 ml
CO_2 partial pressure	0	0	0
pH (measured at room temperature)	13.13	12.25	11. 11

DTN: LL991213805924.110

NOTE: The CO_2 partial pressure can be minimized by either scrubbing laboratory air or purchasing CO_2 free air.

In order to add some soluble silica to the solution, the BSW solution recipe was later revised to contain 4.0 g (~1% metasilicate) by adding sodium metasilicate ($Na_2SiO_3 \cdot 9H_2O$). With the addition of the metasilicate, the pH was increased from 11.3 to 13 as measured at room temperature.

It has been noted that the pH of aqueous solutions is dependent on the partial pressure of gaseous CO_2. The implication of this is that unless many constraints are taken to control the pH of the BSW solution, the pH may vary with test conditions. It is not known with what partial pressure of CO_2 that the revised BSW solution is in equilibrium. In order to conduct a long time testing (few months to a year), the testing environments should be stable. It was decided that to make stable testing solutions, carbonate and silicates should not be added to the test solution as both species can affect solution pH. Instead, sodium hydroxide will be used to maintain the higher pH values of solution. Gaseous CO_2 must be also removed from the air passing above the solution because, as noted above, it will affect the solution pH. With no gaseous CO_2 in contact with the solution and no carbonate/bicarbonate and silicates in solution, the testing environments should be stable.

In tests with BSW-13 (Figure 46), aging also appears to shift the corrosion potential to less noble values. A sample aged for only 10 hours has a corrosion potential of only -227 mV verses a standard Ag/AgCl reference electrode, whereas a sample aged for 173 hours has a corrosion potential of -372 mV relative to the same reference. The difference $E_{critical}$-E_{corr} is about 800 mV for an aged sample in either SAW and BSW. The non-equilibrium current densities (corrosion rates) at 0 mV are also similar. However, more quantitative test are required for any definitive statements regarding corrosion rate.

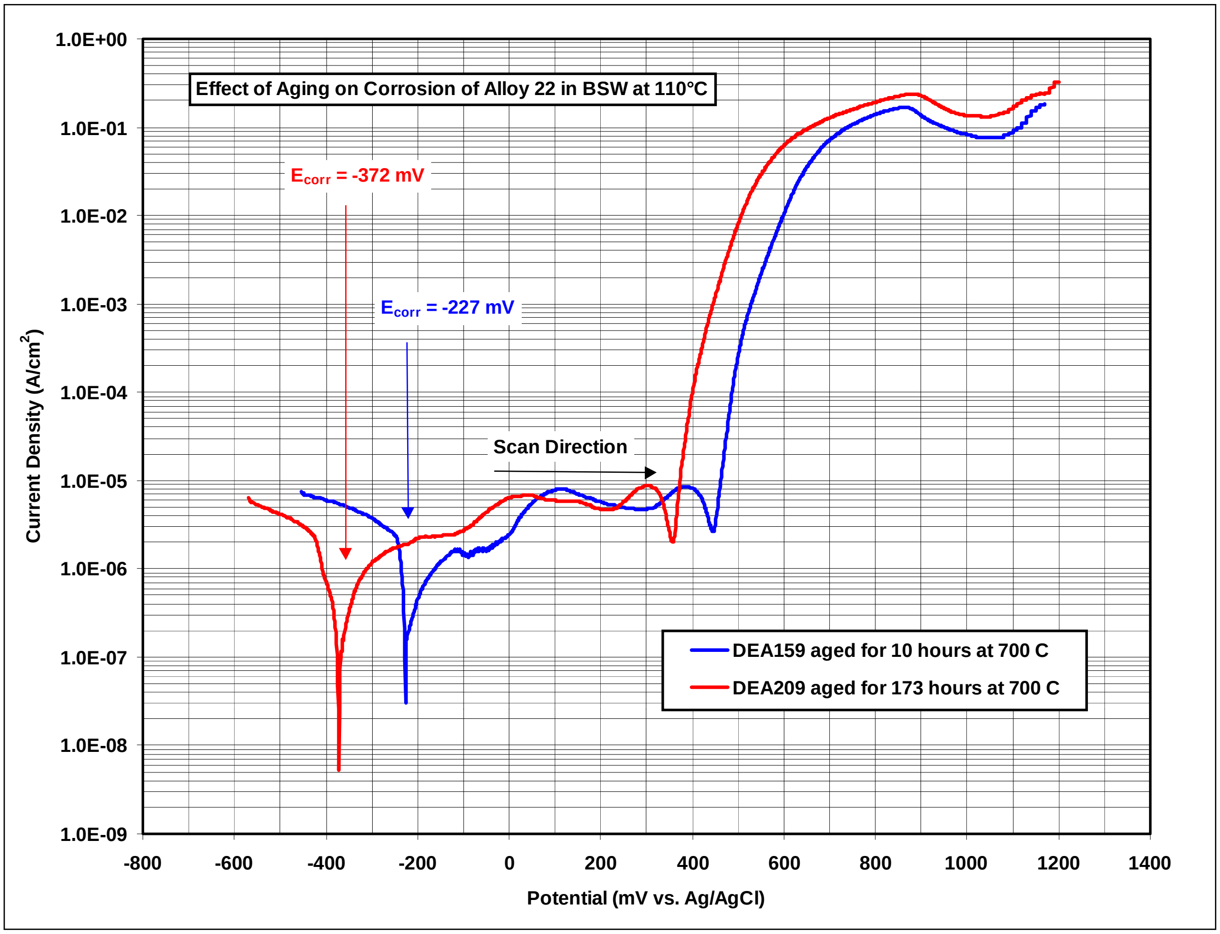


Figure 46. Effect of Thermal Aging at 700°C on the Corrosion Resistance of Alloy 22 in BSW-13 at 110°C (DEA159 and DEA209)

6.7.3 Accounting for Overall Effect of Thermal Aging on Corrosion

A fully aged sample of Alloy 22 appears to exhibit a less noble corrosion potential, shifted in the cathodic direction by approximately: 63 mV in the case of SAW at 90°C; 109 mV in the case of SCW at 90°C; and by more than 100 mV in the case of BSW at 110°C. It is assumed that E_{corr} can be corrected to account for fully aged material by subtracting approximately 100 mV from values calculated for the base metal. The shift in $E_{critical}$ (threshold potential 1) also appears to be approximately 100 mV in most cases. Thus, the difference $E_{critical}$-E_{corr} appears to be virtually unchanged.

The effect of thermal aging on the corrosion rate is accounted for in the enhancement factor, G_{aged}, and is based upon a ratio of the non-equilibrium current densities for base metal and aged material. The value of G_{aged} for base metal is approximately one (G_{aged} ~ 1) whereas the value of G_{aged} for fully aged material is larger (G_{aged} ~ 2.5). Material with less precipitation than the fully aged material would have an intermediate value of G_{aged} ($1 \leq G_{aged} \leq 2.5$). Assume that G_{aged} is uniformly distributed between these limits and that this distribution is half uncertainty and half variability.

6.8 MICROBIAL INFLUENCED CORROSION

It has been observed that nickel-based alloys such as Alloy 22 are relatively resistant to microbial influenced corrosion (Lian et al. 1999). Furthermore, it is believed that microbial growth in the repository will be limited by the availability of nutrients. For example, H^+ is known to be generated by bacterial isolates from Yucca Mountain. Furthermore, thiobaccilus ferro-oxidans oxidize Fe^{2+}, while geobacter metallireducens reduce Fe^{3+}. Other microbes can reduce SO_4^{2-} and produce S^{2-}. Ultimately, the impact of MIC will be accounted for by adjusting E_{corr}, $E_{critical}$, pH, and the sulfide concentration. The possible acceleration of abiotic corrosion processes by microbial growth is addressed here. Horn (1999) has shown that MIC can enhance corrosion rates of Alloy 22 by a factor of at least two. Measurements for Alloy 22 and other similar materials are shown in Table 25. Figure 47 is a schematic representation of the corrosion model for the Alloy 22 outer barrier. The augmentation of corrosion rates due to MIC are accounted for in the model as shown in Figure 48; here G_{MIC} is the enhancement factor.

$$\left.\frac{dp}{dt}\right|_{effective} = G_{MIC} \times \left.\frac{dp}{dt}\right|_{effective} \qquad \text{(Eq. 55)}$$

This factor is calculated as the ratio of corrosion rates (microbes to sterile) and from Table 25. The value of G_{MIC} for Alloy 22 in sterile media is approximately one ($G_{MIC} \sim 1$), whereas the value of G_{MIC} for Alloy 22 in inoculated media is larger ($G_{MIC} \sim 2$). Assume that G_{MIC} is uniformly distributed between these limits and that this distribution is half uncertainty and half variability. A patch experiencing both thermal aging an MIC would have a corrosion rate enhanced by the factor $G_{aged} \times G_{MIC}$.

The principal nutrient-limiting factor to microbial growth *in situ* at Yucca Mountain has been determined to be low levels of phosphate. There is virtually no phosphate contained in J-13 groundwater. Yucca Mountain bacteria grown in the presence of Yucca Mountain tuff are apparently able to solubilize phosphate contained in the tuff to support growth to levels of 10^6 cells ml^{-1} of groundwater. When exogenous phosphate is added (10 mM), the levels of bacterial growth increase to 10^7 to 10^8 cells ml^{-1}. The one to two orders-of-magnitude difference in bacterial growth with and without the presence of exogenous phosphate is almost certainly not significant with respect to effects on corrosion rates. Therefore, nutrient limitation, at least at a first approximation, was not factored into the overall MIC model. It may be noted, however, that the two-fold G_{MIC} included in the model was in the presence of sufficient phosphate to sustain higher levels of bacterial growth (in an effort to achieve accelerated conditions).

Other environmental factors that could effect levels of bacterial growth include temperature and radiation. These factors, however, are closely coupled to RH; as temperature and radiation decrease in the repository, RH is predicted to increase. At the same time, while there are some types of microorganisms that can survive elevated temperatures ($\leq 120^{o}C$) and high radiation doses if there is no available water, then bacterial activity is completely prevented. Thus, because water availability is the primary limiting factor and this factor is coupled to other less critical limiting factors, water availability (as expressed by RH) was used as the primary gauge of microbial activity.

Determination of a critical mass of *total* bacteria required to cause MIC is not an issue that needs to be addressed in the MIC model. Bacterial densities in Yucca Mountain rock have been determined to be on the order of 10^4 to 10^5 cells gm^{-1} of rock. In absolute terms, this is almost certainly above the threshold required to cause MIC. Further, bacterial densities were shown to increase one to two orders-of-magnitude when water is available (above). A more germane concern is the *types* of bacteria present, their abundance, and how their relative numbers are affected when water is available for growth. Corrosion rates will be affected (at least on some WP materials) for example, if organic acid producers out compete sulfate reducers or inorganic acid producers for available nutrients when water is sufficient to support growth. No data is currently available regarding the composition of the bacterial community over the changing environmental conditions anticipated during repository evolution. Instead, this issue has been addressed in the current model by determining overall corrosion rates under a standardized set of conditions, in the presence and absence of a defined set of characterized Yucca Mountain bacteria. Clearly, more data is required to better predict MIC on any given material with respect to this concern. Corrosion rates are currently being determined in the presence of Yucca Mountain rock containing the complete complement of Yucca Mountain bacteria and under conditions more representative of the repository.

MIC is defined as a localized effect; thus, not all areas are equivalent on any given waste package with respect to bacterial colonization. It is well documented that bacteria preferentially colonize weldments, heat-affected zones, and charged regions (Borenstein and White 1989; Walsh 1989; Enos and Taylor 1996). However, the current model is based on data collected using unwelded specimens. In order to account for preferential areas of colonization in the model, it might be assumed that G_{MIC} is uniformly distributed with respect to a real distribution.

Table 25. Alterations in Corrosion Potentials Associated with Microbial Degradation

Tested Sample Initial Condition	**Average Corrosion Rate (µm/yr)**	**Corrosion Potential E_{corr} (V vs. SCE)**	
		Initial	Endpoint
CS1020 + YM Microbes	8.8	-0.660	-0.685
Sterile CS 1020	1.4	-0.500	-0.550
M400 + YM Microbes	1.02	-0.415	-0.315
Sterile M400	0.005	-0.135	-0.070
C-22 + YM Microbes	0.022	-0.440	-0.252
Sterile C-22	0.011	-0.260	-0.200
I625 + YM Microbes	0.013	-0.440	-0.285
Sterile I625	0.003	-0.160	-0.130
304SS + YM Microbes	0.035	-0.540	-0.280
Sterile 304SS	0.003	-0.145	-0.065

DTN: LL991203505924.094

NOTE: Horn (1999)

6.9 RECENTLY GENERATED DATA FOR ABSTRACTION AMRS

6.9.1 Two-Year LTCTF Data

Rates of GC based upon 6- and 12-month exposures are discussed in Section 6.5.2. Very recently, data representing 24 months of exposure has become available. Those data are included in this section so that it can also be included in Abstraction AMRs and WAPDEG analyses.

As previously discussed, tests in the LTCTF represent three generic water chemistries. SDW has 10× the ionic content of J-13 well water, while SCW has 1000× the ionic content. The measured pH levels of the 10× and 1000× J-13 well waters are 9.5 to 10. SAW is an acidified water that is around 4000× the ionic content of J-13 well water with a pH of approximately 2.7. Not all salts in the water will concentrate to these levels because of their limited solubilities, but the more soluble anions such as chloride, sulfate, and nitrate (which have the biggest effects on corrosion) will concentrate to these levels.

Specimens are tested at two temperatures (60 and 90°C) for each of the three water chemistries. Half of the numbers of specimens are fully immersed in the water while the remaining half are exposed to the wet vapor above the water. A few specimens are also placed right at the water line so that their exposed area is half in the vapor, half in the water. Half of the numbers of test specimens contain welds. There were at least 144 test specimens measured during each exposure period.

These general corrosion rates are obtained gravimetrically by the weight loss experienced during the exposure periods. The variation in measured general corrosion rates on Alloy 22 is decreasing with increased exposure time. The ranges of general corrosion rates measured at three time intervals (6-, 12-, and 24-months of exposure) are:

6-month exposure: range -0.06 to +0.73 $\mu m\ y^{-1}$, mean 0.05 $\mu m\ y^{-1}$

12-month exposure: range -.0.04 to +0.10 $\mu m\ y^{-1}$, mean 0.03 $\mu m\ y^{-1}$

24-month exposure: range -0.03 to +0.07 $\mu m\ y^{-1}$, mean 0.01 $\mu m\ y^{-1}$

Measurements on the order of 0.01 $\mu m\ y^{-1}$ are around the experimental accuracy of this method. By far, the greatest variation in corrosion rates was measured in the first 6 months of exposure.

The mean value of the corrosion rate after 24 months of exposure is 0.01 $\mu m\ y^{-1}$. The corrosion rates do not appear to depend much at all on the temperature and chemical composition of the water tested thus far. Extrapolation of this mean value to 10,000 years would mean an average consumption of only 0.1 mm out of a thickness of 2 cm proposed for the Alloy 22 outer barrier of the waste package. Even at the highest rate measured in this data set, the maximum consumption would be less than 1 mm over the 10,000 year time period. Negative corrosion rates indicate a weight gain by the specimen even after all corrosion products and oxides from the surface have been thoroughly cleaned off.

Cumulative distribution functions generated with 24-month data alone are shown in Figures 47 through 50. Cumulative distribution functions generated with a combined data set representing 6, 12- and 24-month data are shown in Figures 51 and 52. The curve shown in Figure 51 includes apparent negative rates, while those negative values have been eliminated from the curve shown in Figure 52. The curve shown in Figure 52 is summarized in Table 26. The distributions based upon the 24-month data are more narrow than comparable distributions based upon 6- and 12-month data. Since rates are calculated by dividing exposure time into the weight loss, a doubling of exposure time reduces the estimated error by a factor of two. While outliers were observed in the 6- and 12-month data, none were observed in the 24-month (two-year) data. It is believed that these more recent data will greatly alleviate the range of predicted failure times to times well beyond the period sought for compliance with the requirement of substantially complete containment.

In observing the surfaces of the exposed specimens for all three time-periods, no evidence of LC has been observed. Specimens are mounted to the supporting test racks by Teflon® coated fasteners and washers. These washers create an intentional crevice to provide a surface area where crevice effects (electrolyte more concentrated than base solution). In addition, one type of specimen uses a special Teflon crevice former that is spring loaded to ensure that the contact is maintained between washer and specimen (crevice effects are more severe in tight crevices). Teflon has a tendency to creep at these test temperatures resulting in a looser crevice with the passage of time.

Examination of plastically strained U-bend specimens, again for all three time periods, indicates no initiation of SCC in both the base material and in the welded material. Half the number of these U-bend specimens contained welds.

The significance of the observations indicating no localized corrosion (that is no pits, no crevice attack, no intergranular attack) and no stress corrosion crack initiation, as well as a very low general corrosion rate, assures that Alloy 22 will provide an extremely long lived waste package. The longer these corrosion tests operate, the greater will be our assurance of the performance of this material. In the coming year, we plan to add another test environment in the long term corrosion test facility, an environment corresponding to 'saturated' conditions of water dripping, evaporating, and ionic salt concentrating on a hot metal surface. This environment will be more concentrated in chloride and nitrate (most soluble of the ionic species) and somewhat higher in pH than the solutions already under test. Short-term electrochemical tests already indicate that Alloy 22 does not corrode appreciably in this environment, but the longer term exposure test will be needed for confirmation of these results.

Thus, the results from the two-year exposure period are very encouraging for Alloy 22. Compared to data generated from earlier exposure time periods, the most recent data set provides greater confidence of the projected corrosion performance of this material.

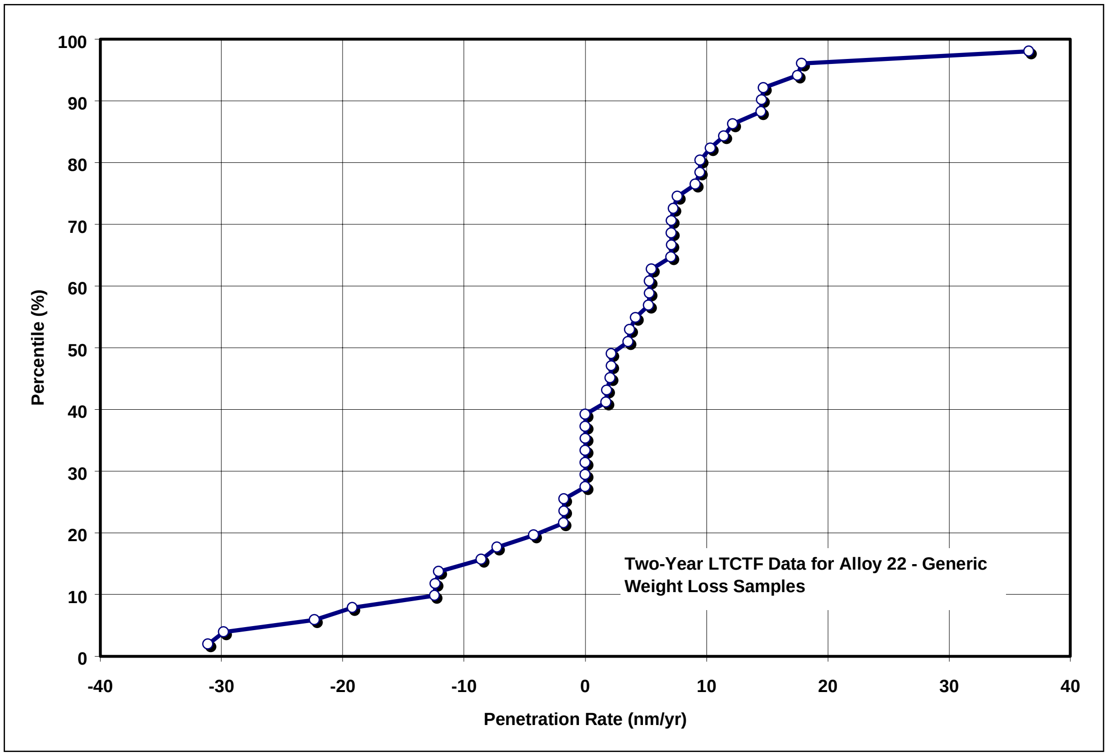


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Figure 47. Additional Two-Year GC Corrosion Rate Data from LTCTF Based upon Generic Weight Loss Samples

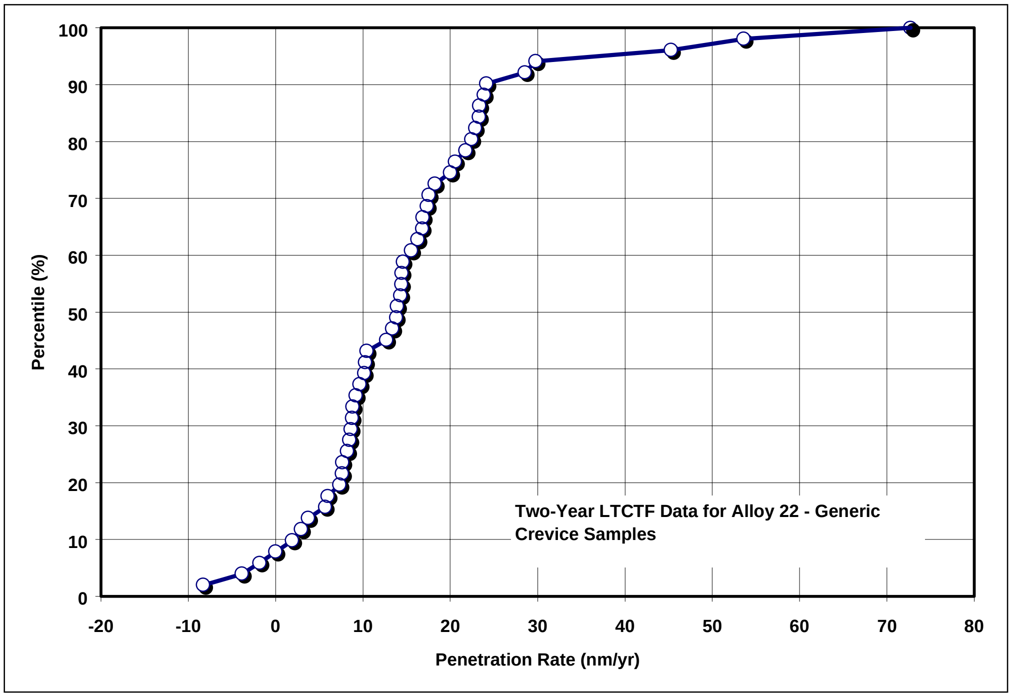

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Figure 48. Additional Two-Year GC Corrosion Rate Data from LTCTF Based upon Generic Crevice Samples

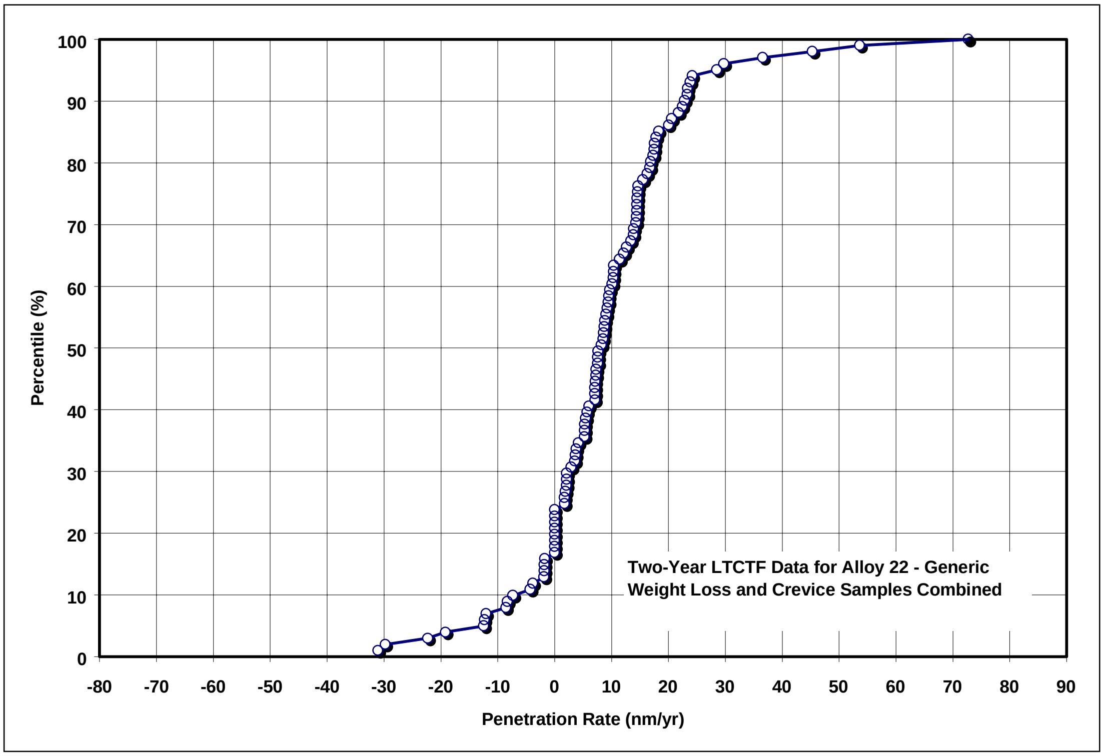

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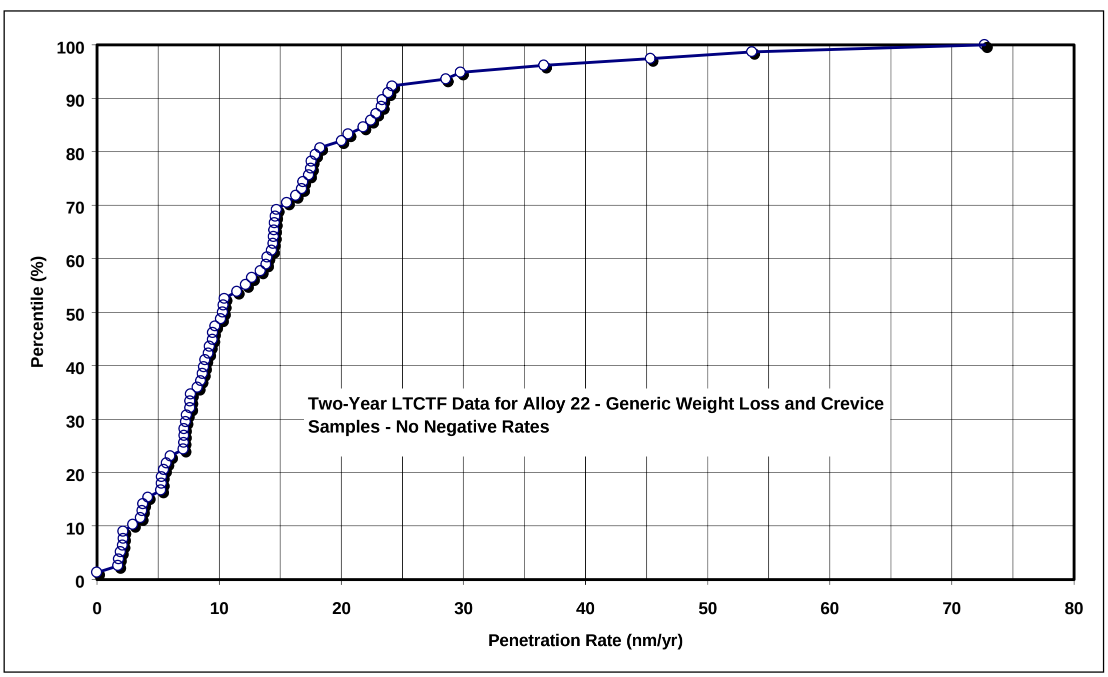
Figure 49. Additional Two-Year GC Corrosion Rate Data from LTCTF Based upon Both Generic Weight Loss and Crevice Samples, including those with Apparent Negative Rates



DTN: LL000112205924.112

Figure 50. Additional Two-Year GC Corrosion Rate Data from LTCTF Based upon Both Generic Weight Loss and Crevice samples, including those with Apparent Negative Rates

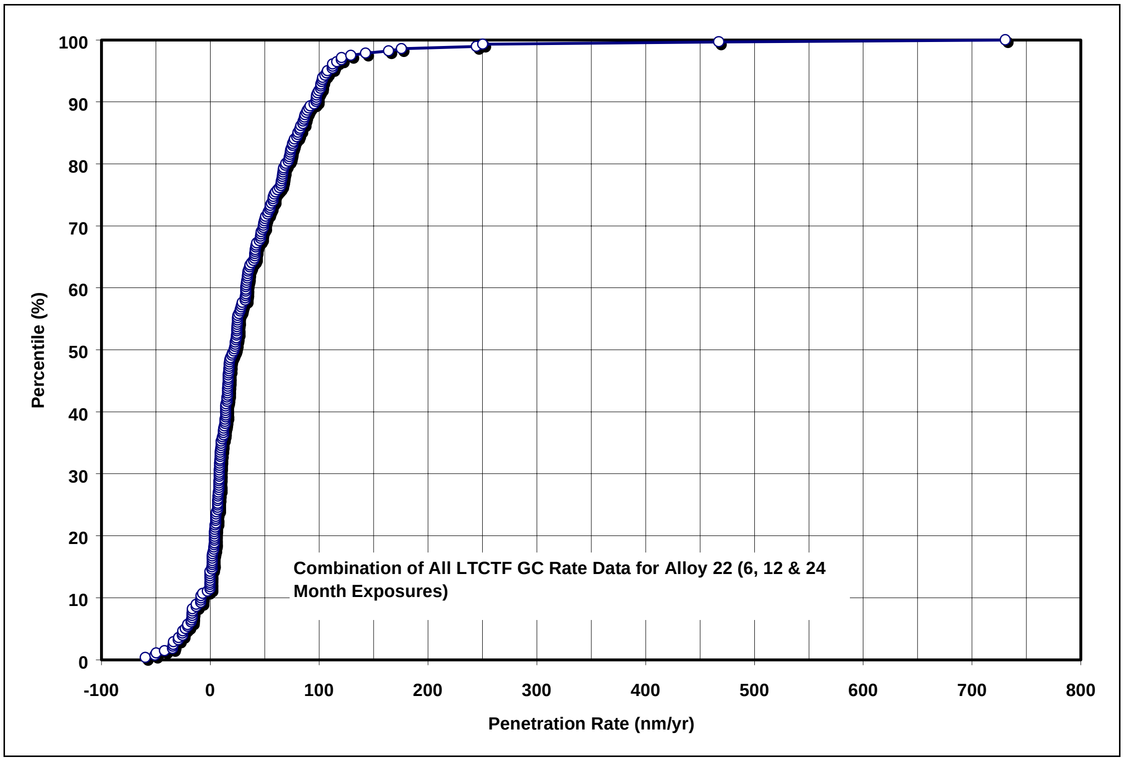


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Figure 51. Combination of All GC Rate Data for Alloy 22 from LTCTF, including 6-, 12- and 24-Month (Two-Year) Exposures

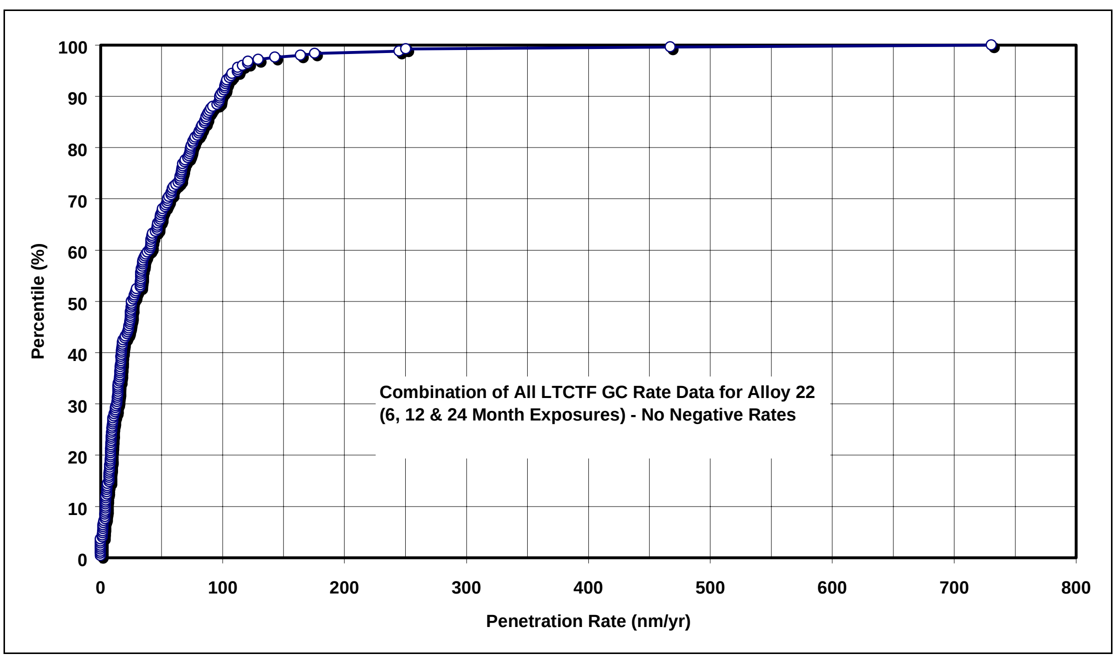

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Figure 52. Combination of All GC Rate Data for Alloy 22 from LTCTF, including 6-, 12- and 24-Month (Two-Year) Exposures with Negative Rates Excluded

Table 26. Summary of the Distribution Shown in Figure 52

Percentile (%)	Penetration Rate (nm y-1)
0.00	0
5.20	2.07
10.00	4.21
50.40	26.64
90.00	97.99
95.20	112.54
97.60	143.08
99.20	250.56
99.60	467.28
100.00	730.77

DTN: LL000112205924.112

6.9.2 Additional CP Data for BSW Test Media

Several CP measurements have now been made with BSW electrolytes and are summarized in Table 27. The corresponding curves are shown in Figures 53 through 56. As previously discussed, extreme aging of Alloy 22 can shift the corrosion potential in a less noble (cathodic) direction by approximately 100 mV. This is accompanied by a slight increase in non-equilibrium passive current densities. There is some evidence of an anodic oxidation peak, characteristic of type 2 curves. For the present time, we will classify these CP curves as type 1-2.

Table 27. Electrochemical Potentials Determined from CP Curves

Sample ID	Aging Time	Aging Temp.	Medium	Temp.	Reversal Potential	Corrosion Potential	Threshold Potential 1	CP Curve Type
	hours	^oC		^oC	mV	mV	mV	
DEA158	10	700	BSW	110^{o}C	1200	-233	418	Type 1-2
DEA159	10	700	BSW	110^{o}C	1200	-257	419	Type 1-2
DEA208	173	700	BSW	110^{o}C	1200	-345	394	Type 1-2
DEA209	173	700	BSW	110^{o}C	1200	-372	361	Type 1-2

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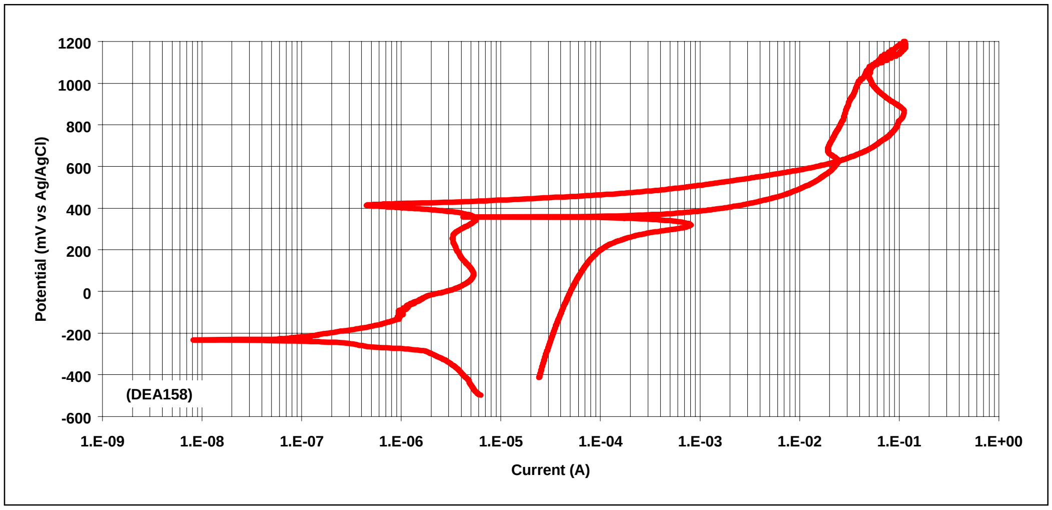

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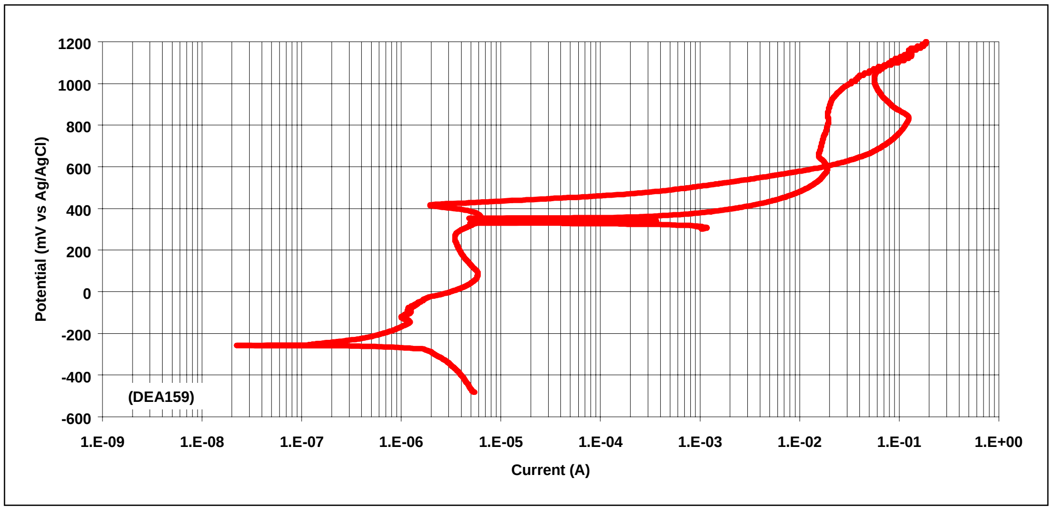
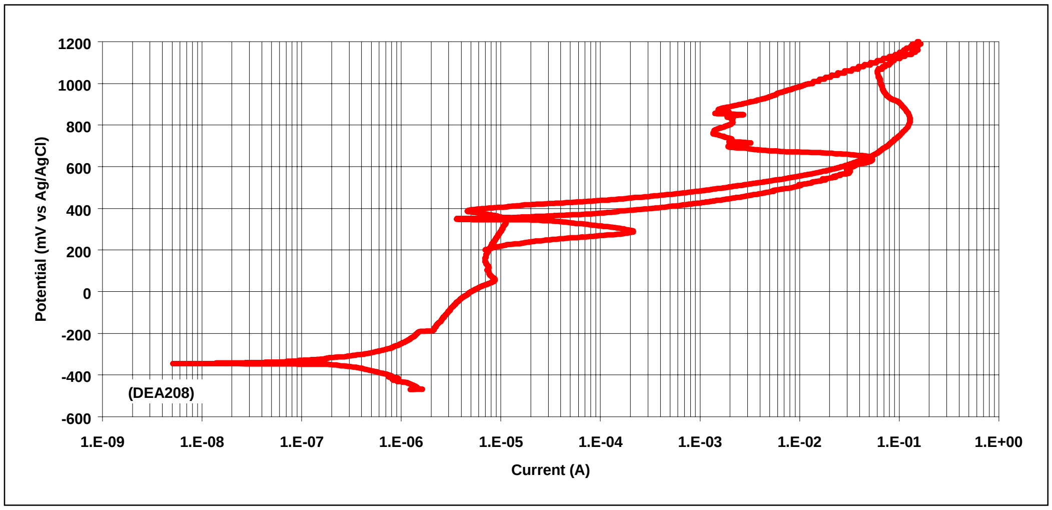
Figure 53. CP Curve for Thermally Alloy 22 in 110°C BSW – Aged at 700°C for 10 Hours (DEA158)



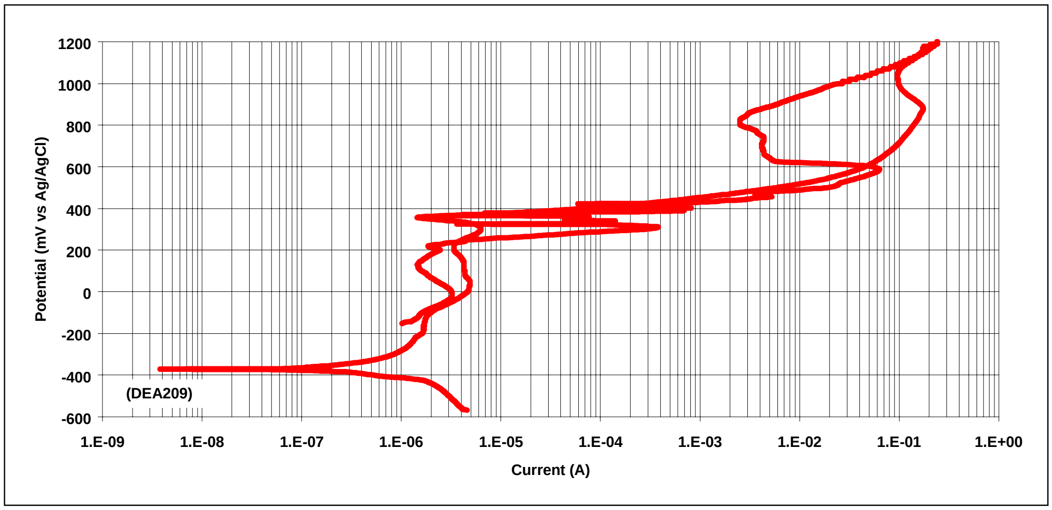
DTN: LL000112105924.111

Figure 54. CP Curve for Thermally Alloy 22 in 110°C BSW – Aged at 700°C for 10 Hours (DEA159)



DTN: LL000112105924.111

Figure 55. CP Curve for Thermally Alloy 22 in 110°C BSW – Aged at 700°C for 173 Hours (DEA208)



DTN: LL000112105924.111

Figure 56. CP Curve for Thermally Alloy 22 in 110°C BSW – Aged at 700°C for 173 Hours (DEA209)

6.10 SUMMARY OF MODEL

The model for the general and localized corrosion of Alloy 22 is summarized in Figures 57 and 58. The threshold RH is first used to determine whether or not DOX will take place. If DOX is determined to occur, the parabolic growth law represented by Equations 11 and 13 is then used to calculate the corrosion rate as a function of temperature. If the threshold RH is exceeded, HAC will occur in the absence of dripping water, and APC will occur in the presence of dripping water. If APC is assumed to occur, the corrosion and critical potentials are used to determine whether the mode of attack is general or localized. The correlations represented by Equation 17 and Table 5 can be used as the basis for estimating these potentials at the 50^{th} percentile. Since the material specifications can be based partly on the measured corrosion and critical potentials, it can be assumed that these potentials will be uniformly distributed about the 50^{th} percentile values determined from the correlation. For example, the 0^{th} and 100^{th} percentile values of E_{corr} can be assumed to be at E_{corr} (50^{th} percentile) ± 75 mV. This acceptable margin was determined by splitting the differences shown in Table 6. Similarly, the 0^{th} and 100^{th} percentile values of $E_{critical}$ can be assumed to be at $E_{critical}$ (50^{th} percentile) ± 75 mV. In principle, material falling outside of these specified ranges would not be accepted. Other equivalent correlations of E_{corr} and $E_{critical}$, based upon data relevant to the repository, can also be used. If the comparison of E_{corr} to $E_{critical}$ indicates GC, the distribution of rates determined from the LTCTF will be used as the basis of the GC rate. A study of four test coupons of Alloy 22 removed from the LTCTF after one year showed varying degrees of coverage by silicate deposits but no evidence of localized corrosion by pitting. The distributions of GC rate shown in Sections 6.5.2 and 6.5.4 can be corrected for the maximum bias due to SiO_2 deposit formation by adding a constant value of 63 nm y^{-1} to each estimated value of the GC rate. This is equivalent to shifting the curves shown in Figures 23, 25 and 26 to the right by 63 nm y^{-1}. If the comparison indicates localized corrosion, the distribution of rates presented in Table 22 will be used. Corrosion rates will be enhanced to account for MIC above 90% RH. The effect of thermal aging on the corrosion rate is accounted for in the enhancement factor, G_{aged}, and is based upon a ratio of the non-equilibrium current densities for base metal and aged material. The value of G_{aged} for base metal is approximately one (G_{aged} ~ 1), whereas the value of G_{aged} for fully aged material is larger (G_{aged} ~ 2.5). Material with less precipitation than the fully aged material would have an intermediate value of G_{aged} ($1 \leq G_{aged} \leq 2.5$).

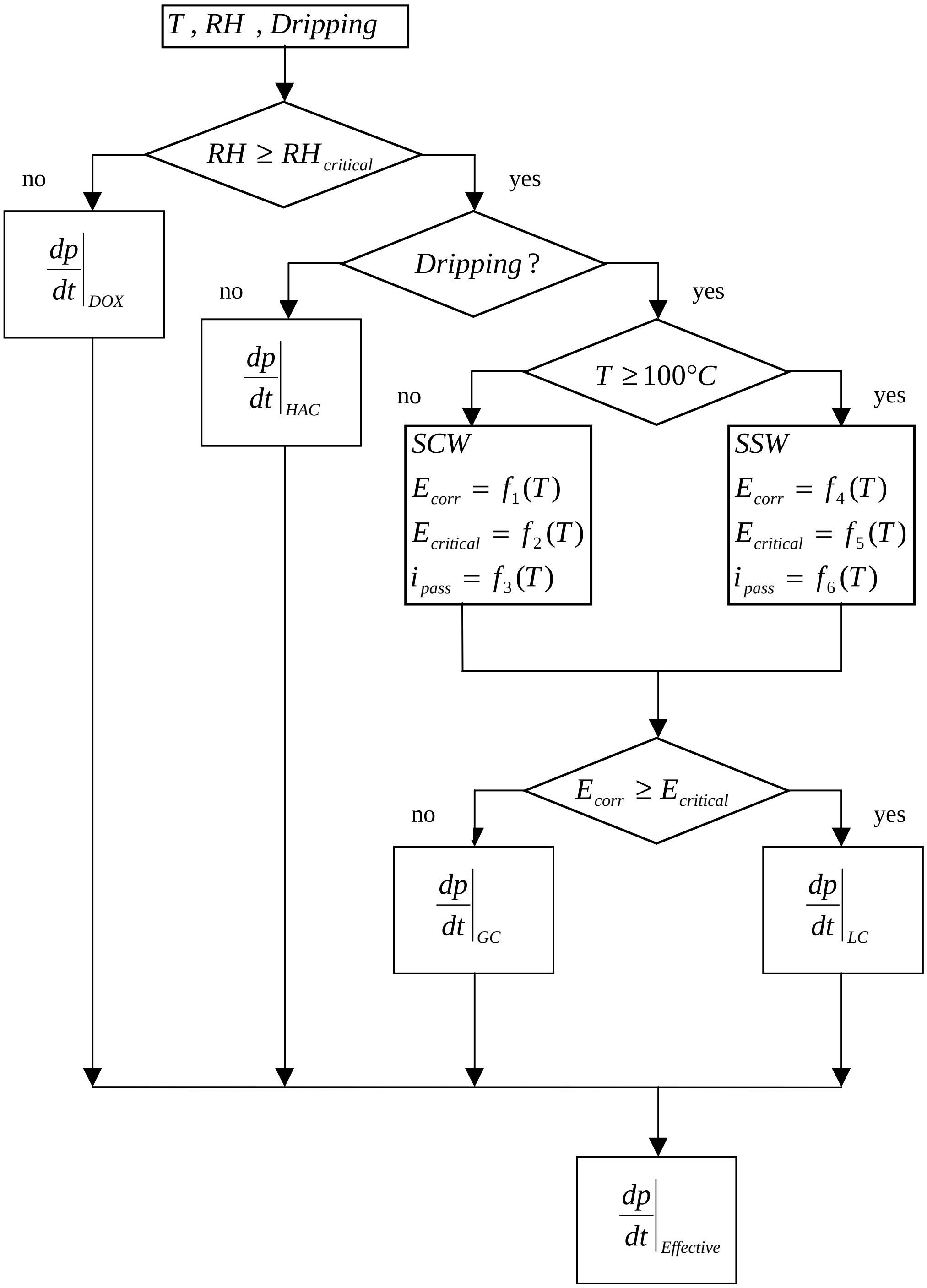


Figure 57. Schematic Representation of Corrosion Model for Alloy 22 Outer Barrier

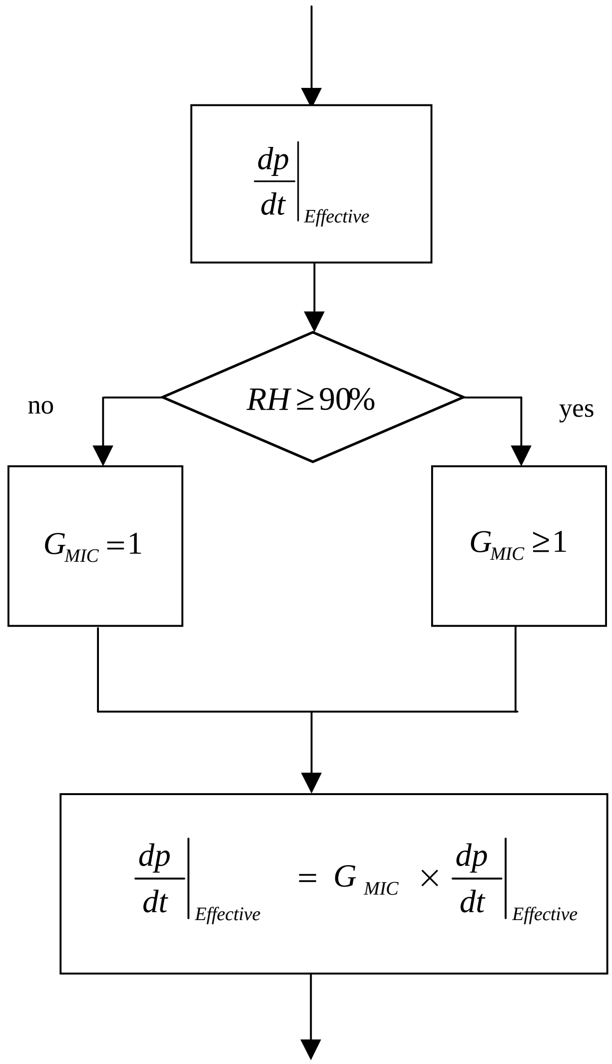


Figure 58. Schematic Representation Showing Augmentation of Model to Account for MIC

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7. CONCLUSIONS

Alloy 22 is an extremely Corrosion Resistant Material, with a very stable passive film. Based upon exposures in the LTCTF, the GC rates of Alloy 22 are typically below the level of detection, with four outliers having reported rates up to 0.75 µm per year. In any event, over the 10,000 year life of the repository, GC of the Alloy 22 (assumed to be 2 cm thick) should not be life limiting. Because measured corrosion potentials are far below threshold potentials, localized breakdown of the passive film is unlikely under plausible conditions, even in SSW at 120°C. The pH in ambient-temperature crevices formed from Alloy 22 have been determined experimentally, with only modest lowering of the crevice pH observed under plausible conditions. Extreme lowering of the crevice pH was only observed under situations where the applied potential at the crevice mouth was sufficient to result in catastrophic breakdown of the passive film above the threshold potential in non-buffered conditions not characteristic of the Yucca Mountain environment. In cases where naturally occurring buffers are present in the crevice solution, little or no lowering of the pH was observed, even with significant applied potential. With exposures of twelve months, no evidence of crevice corrosion has been observed in SDW, SCW, and SAW at temperatures up to 90°C. An abstracted model has been presented, with parameters determined experimentally, that should enable performance assessment to account for the general and localized corrosion of this material. A feature of this model is the use of the materials specification to limit the range of corrosion and threshold potentials, thereby making sure that substandard materials prone to localized attack are avoided. Model validation will be covered in part by a companion AMR on abstraction of this model.

This document and its conclusions may be affected by technical product input information that requires confirmation. Any changes to the document or its conclusions that may occur as a result of completing the confirmation activities will be reflected in subsequent revisions. The status of the input information quality may be confirmed by review of the Document Input Reference System database. As examples, the status of AFM results shown here will have little impact on quantitative results, as the data is only corroborative and any MIC or aging results could impact GC rates by a factor of four.

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8. REFERENCES

Andresen, P.L. 198. "Modeling of Water and Material Chemistry Effects on Crack Tip Chemistry and Resulting Crack Growth Kinetics." *Proceedings of the Third International Symposium on Environmental Degradation of Materials in Nuclear Power Systems-Water Reactors held August 30-September 3, 1987 in Traverse City, Michigan.* 301-312. Warrendale, Pennsylvania: The Metallurgical Society. TIC: 246608.

Asphahani, A.I. 1980. "Corrosion Resistance of High Performance Alloys." Materials Performance, 19, (12), 33-43. Houston, Texas: National Association of Corrosion Engineers. TIC: 240562.

ASTM (American Society for Testing and Materials) 1987. ASTM G1-81. 1987. Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens. Philadelphia, Pennsylvania: American Society for Testing and Materials. TIC: 246089.

ASTM 1989. ASTM G5-87. 1989. *Standard Reference Test Method for Making Potentiostatic and Potentiodynamic Anodic Polarization Measurements.* Philadelphia, Pennsylvania: American Society for Testing and Materials. TIC: 246088.

ASTM 1997a. ASTM B 575-94. 1994. *Standard Specification for Low-Carbon Nickel-Molybdenum-Chromium and Low-Carbon Nickel-Chromium-Molybdenum Steel Alloy Plate, Sheet, and Strip.* Philadelphia, Pennsylvania: American Society for Testing and Materials. TIC: 237683.

ASTM 1997b. Not used.

ASTM 1997c. Not used.

ASTM 1997d. ASTM G 5 - 94. *Standard Reference Test Method for Making Potentiostatic and Potentiodynamic Anodic Polarization Measurements.* Philadelphia, Pennsylvania: American Society for Testing and Materials. TIC: 231902.

ASTM 1997e. ASTM G 1-90 (Reapproved 1999). 1990. *Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 238771.

Bard, A.J. and Faulkner, L.R. 1980. *Electrochemical Methods, Fundamentals and Applications.* 62-72. New York, New York: John Wiley & Sons. TIC: 245183.

Bedrossian, P. 1999. *High-Resolution Measurements of Aqueous and Environmental Corrosion and Oxidation Processes Using Photolithography and Atomic Force Microscopy.* AP-E-20-70. Livermore, California: Lawrence Livermore National Laboratory. ACC: MOL.19991203.0258.

Borenstein, S.W. and White, D.C. 1989. "Influence of Welding Variables on Microbiologically Influenced Corrosion of Austenitic Stainless Steel Weldments." *Corrosion 89 April-17-21, 1989*

New Orleans Convention Center, New Orleans, Louisiana, Paper Number 183, 183/1 - 183/13. Houston, Texas: National Association of Corrosion Engineers. TIC: 246583.

Burr, I.W. 1974. "The Normal Curve." *Applied Statistical Methods.* 135-142. New York, New York: Academic Press. TIC: 245317.

Cramer, S.D. 1974. "The Solubility of Oxygen in Geothermal Brines." *Corrosion Problems in Energy Conversion and Generation.* Tedmen, C.S., Jr., ed. 251-262. Princeton, New Jersey: Electrochemical Society. TIC: 245180.

CRWMS M&O 1999a. *License Application Design Selection Report.* B00000000-01717-4600-00123 REV 01 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990908.0319.

CRWMS M&O 1999b. *General Corrosion and Localized Corrosion of Waste Package Outer Barrier.* Work Direction and Planning Document. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990708.0230.

CRWMS M&O 1999c. *Classification of the MGR Uncanistered Spent Nuclear Fuel Disposal Container System.* ANL-UDC-SE-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990928.0216.

CRWMS M&O 1999d. *11017040 Long Term Materials Testing and Modeling.* Activity Evaluation. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990224.0429.

CRWMS M&O 1999e. *Waste Package Material Properties.* BBA000000-01717-0210-00017 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990407.0172.

CRWMS M&O 1999f. *Uncanistered Spent Nuclear Fuel Disposal Container System Description Document.* SDD-UDC-SE-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991217.0512.

CRWMS M&O 2000a. *Input Transmittal for Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier.* WP-LNL-00018.T. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000118.0316.

CRWMS M&O 2000b. *Input Transmittal for Aging and Phase Stability of Waste Package Outer Barrier Model.* WP-LNL-00019.T. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000118.0317.

CRWMS M&O 2000c. *Input Transmittal for General Corrosion and Localized Corrosion of the Drip Shield.* WP-LNL-00022T. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000118.0318.

DOE (U.S. Department of Energy) 1998. *Quality Assurance Requirements and Description.* DOE/RW-0333P, Rev. 8. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19980601.0022.

Enos, D.G. and Taylor, S.R. 1996. "Influence of Sulfate-Reducing Bacteria on Alloy 625 and Austenitic Stainless Steel Weldments." Corrosion *Science, 52,* (11), 831-843. Houston, Texas: National Association of Corrosion Engineers International. TIC: 246554.

Estill, J.C. 1998. *"Long-Term Corrosion Studies." Engineered Materials Characterization Report.* UCRL-ID-119564. Vol. 3. Livermore, California: Lawrence Livermore National Laboratory. ACC: MOL.19981222.0137.

Evans, M.; Hastings, N.; and Peacock, B. 1993. *Statistical Distributions.* 2nd Edition. New York, New York: John Wiley & Sons. TIC: 246114.

Farmer, J.C. and McCright, R.D. 1998. "Crevice Corrosion and Pitting of High-Level Waste Containers: Integration of Deterministic and Probabilistic Models." *Proceedings of Corrosion 98, March 22-27, 1998, San Diego, California,* 160/1 to 160/24. Houston, Texas: NACE International. TIC: 238172.

Farmer, J.C.; McCright, R.D.; Estill, J.C.; and Gordon, S.R. 1998. *Development of Integrated Mechanistically-Based Degradation-Mode Models for Performance Assessment of High-Level Waste Containers.* URCL-JC-130811, Rev. 1. Livermore, California: Lawrence Livermore National Laboratory. ACC: MOL.19990729.0007.

Farmer, J.C.; McCright, R.D.; Estill, J.C.; and Gordon, S.R. 1999. "Development of Integrated Mechanistically-Based Degradation-Mode Models for Performance Assessment of High-Level Waste Containers." *Scientific Basis for Nuclear Waste Management XXII, Materials Research Society Symposium held November 30-December 4, 1998, Boston, Massachusetts, U.S.A.,* D.J. Wronkiewicz and J.H. Lee eds. *556,* 855-862. Warrendale, Pennsylvania: Materials Research Society. TIC: 246426.

Galvele, J.R. 1976. "Transport Processes and the Mechanism of Pitting of Metals." *Journal Electrochemical Society, 123,* (4), 464-474. New York, New York: Electrochemical Society. TIC: 239904.

Gartland, P.O. 1997. "A Simple Model of Crevice Corrosion Propagation for Stainless Steels in Seawater." *Corrosion 97,* 417/1 to 417/17. Houston, Texas: NACE International. TIC: 245216.

Gdowski, GE 1991. *Survey of Degradation Modes of Four Nickel-Chromium-Molybdenum Alloys.* UCRL-ID-108330. Livermore, California: Lawrence Livermore National Laboratory. ACC: NNA.19910521.0010.

Gdowski, G.E. 1997a. *Formulation and Make-Up of Simulated Dilute Water, Low Ionic Content Aqueous Solution.* UCRL-ID-132285. Livermore, California: Lawrence Livermore National Laboratory. TIC: 245767.

Gdowski, G.E. 1997b. *Formulation and Make-Up of Simulated Concentrated Water(SCW), High Ionic Content Aqueous Solution.* UCRL-ID-132286. Livermore, California: Lawrence Livermore National Laboratory. TIC: 245768.

Gdowski, G.E. 1997c. . *Formulation and Make-Up of Simulated Acidic Concentrated Water (SAW), High Ionic Content Aqueous Solution.* UCRL-ID-132287. Livermore, California: Lawrence Livermore National Laboratory. TIC: 245766.

Glass, R.S.; Overturf, G.E.; Van Konynenburg, R.A.; and McCright, R.D. 1986. "Gamma Radiation Effects on Corrosion-I. Electrochemical Mechanisms for the Aqueous Corrosion Processes of Austenitic Stainless Steels Relevant to Nuclear Waste Disposal in Tuff." *Corrosion Science, 26,* (8), 577-590. Oxford, Great Britain: Pergamon. TIC: 226179.

Green, R.A. 1999. "Data Acquisition System Software Routines for Activity E-20-81, Development of Crevice Corrosion Models" Letter from Green, R.A. (LLNL) to Farmer, J., June, 17, 1999, CMS 99-006, with attachments ACC: MOL.20000125.0685.

Gruss, K.A.; Cragnolino, G.A.; Dunn, D.S.; and Sridhar, N. 1998. "Repassivation Potential for Localized Corrosion of Alloys 625 and C22 in Simulated Repository Environments." *Proceedings of Corrosion 98, March 22-27, 1998, San Diego, California,* 149/1 to 149/15. Houston, Texas: NACE International. TIC: 237149.

Hack, H.P. 1983. "Crevice Corrosion Behavior of Molybdenum-Containing Stainless Steels in Seawater." *Materials Performance, 22,* (6), 24-30. Houston, Texas: NACE International. TIC: 245826.

Harrar, J.E.; Carley, J.F.; Isherwood, W.F.; and Raber, E. 1990. *Report of the Committee to Review the Use of J-13 Well Water in Nevada Nuclear Waste Storage Investigations.* UCID-21867. Livermore, California: Lawrence Livermore National Laboratory. ACC: NNA.19910131.0274.

Haynes International. 1988. Hastelloy Alloy C-22. Kokomo, Indiana: Haynes International. TIC: 239938.

Haynes International. 1987. Hastelloy Alloy C-276. Kokomo, Indiana: Haynes International. TIC: 234999.

Horn, J.A. 1999. Approach and Supporting Data for MIC Modeling. WP267DM5. Livermore, California: Lawrence Livermore National Laboratory. ACC: MOL.20000125.0687.

Horn, J.M.; Rivera, A.; Lian, T.; and Jones, D. 1998. "MIC Evaluation and Testing for the Yucca Mountain Repository." *Proceedings of Corrosion 98, National Association of Corrosion Engineers, March 22-27, San Diego, California,* 152/2 to 152/14. Houston, Texas: NACE International. TIC: 237146.

Jones, D.A. 1996. *Principles and Prevention of Corrosion.* 2nd Edition. Upper Saddle River, New Jersey: Prentice Hall. TIC: 241233.

Kim, Y.J. 1987. "Effect of Gamma Radiation on Electrochemical Behavior of 9 Cr-1Mo Alloy in NaCl Solutions." *Journal of the Corrosion Science Society of Korea, 16,* (1), 25-30. Seoul, Korea: Corrosion Science Society of Korea. TIC: 246337.

Kim, Y-K. 1988. "Electrochemical Mechanisms for Radiation Corrosion Processes of 316 Austenitic Stainless Steel in Chloride Environment." Journal of the Corrosion Science Society of Korea, 17, (1), 20-26. Seoul, Korea: Korean Corrosion Science Society. TIC: 246622.

Kim, Y-J. 1999a. "Analysis of Oxide Film Formed on Type 304 Stainless Steel in 288[degrees]C Water Containing Oxygen, Hydrogen, and Hydrogen Peroxide." *Corrosion, 55,* (1), 81-88. Houston, Texas: NACE International. TIC: 245184.

Kim, Y-J. 1999b. "In-Situ Electrochemical Impedance Measurement of Oxide Film on 304 SS in 288°C Water." *Proceedings of Corrosion 99, April 25-30, 1999, San Antonio, Texas* , 437/1 to 437/11. Houston, Texas: NACE International. TIC: 246024.

Leygraf, C. 1995. "Atmospheric Corrosion." Chapter 12 of *Corrosion Mechanisms in Theory and Practice.* Marcus, P. and Oudar, J., eds. New York, New York: Marcel Dekker. TIC: 104415.

Lian, T.; Martin, S.; Jones, D.; Rivera, A.; and Horn, J. 1999. "Corrosion of Candidate Container Materials by Yucca Mountain Bacteria." *Corrosion 99, Paper No. 476,* Houston, Texas: NACE International. TIC: 245833

LL990610105924.074. Cyclic Polarization Calculations. Submittal date: 06/12/1999.

LL990610205924.075. Cyclic Polarization Calculations with CPDATA2C. Submittal date: 06/12/1999.

LL990610305924.076. Crevice Corrosion Data from Scientific Notebook SN051999. Submittal date: 06/12/1999.

LL990610505924.078. Crevice Corrosion Data for 316L and C-22. Submittal date: 06/13/99.

LL990610605924.079. LTCTF Data for C-22, TIGR7, TIGR12 and TIGR16. Submittal date: 06/13/1999.

LL991203505924.094. Approach and Supporting Data for MIC Modeling. Submittal date: 12/13/1999. ACC: MOL.20000128.0142

LL991208205924.096. Deliquescence Point for Sodium Nitrate Solutions. Submittal date: 12/20/1999. ACC: MOL.20000128.0145

LL991208505924.099. GC Rates of Alloy 22. Submittal date: 12/20/1999. ACC: MOL.20000128.0140

LL991208605924.100. Coefficients for the Correlation of Crevice pH with Applied Potential. Submittal date: 12/20/1999. ACC: MOL.20000128.0139

LL991208705924.101. Effect of Thermal Aging on the Corrosion Resistance of Alloy 22. Submittal date: 12/20/99. ACC: MOL.20000128.0138

LL991213805924.110. BSW Recipes. Submittal date: 01/03/2000. ACC: MOL.20000128.0137.

LL000112105924.111. Corrosion and Potential Data Associated with High pH Saturated Water. Submittal date: 01/25/2000.

LL000112205924.112. BSW Water Data. Submittal date: 01/25/2000.

Newman, J.S. 1991. "Infinitely Dilute Solutions." *Electrochemical Systems, 2nd Edition.* Section 11.5. 250-251. Englewood Cliffs, New Jersey: Prentice Hall. TIC: 245901.

NRC 1999. *Issue Resolution Status Report Key Technical Issue: Container Life and Source Term Rev. 2.* Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 245538.

Nystrom, E.A.; Lee, J.B.; Sagues, A.A.; and Pickering, H.W. 1994. "An Approach for Estimating Anodic Current Distributions in Crevice Corrosion from Potential Measurements." *Journal of the Electrochemical Society, 141,* (2), 358-361. Pennington, New Jersey: Electrochemical Society. TIC: 236472.

Oldfield, J.W. and Sutton, W.H. 1978. "Crevice Corrosion of Stainless Steels. I. A Mathematical Model." *British Corrosion Journal, 13,* (1), 13-22. London, England: Institute of Materials. TIC: 212461.

Pickering, H.W. and Frankenthal, R.P. 1972. "On the Mechanism of Localized Corrosion of Iron and Stainless Steel. I. Electrochemical Studies." *Journal of the Electrochemical Society, 119,* (10), 1297-1304. Pennington, New Jersey: Journal of the Electrochemical Society. TIC: 245828.

Scully, J.R.; Hudson, J.L.; Lunt, T.; Ilevbare, G.; and Kehler, B. 1999. *Localized Corrosion Initiation and* Transition *to Stabilization in Alloys 625 and C-22.* 1-27. Charlottesville, Virginia: University of Virginia. TIC: 246630.

Sedriks, A.J. 1996. *Corrosion of Stainless Steels.* 2nd Edition. 179, 377. New York, New York: John Wiley & Sons. TIC: 245121.

Sridhar, N. and Dunn, D.S. 1994. "Effect of Applied Potential on Changes in Solution Chemistry Inside Crevices on Type 304L Stainless Steel and Alloy 825." *Corrosion, 50,* (11), 857-872. Houston, Texas: National Association of Corrosion Engineers International. TIC: 245832.

Treseder, R.S.; Baboian, R.; and Munger, C.G. 1991. *NACE Corrosion Engineer's Reference Book.* 156-181. Houston, Texas: NACE International. TIC: 245834.

Walsh, D.W. 1999. "The Effects of Microstructure on MIC Susceptibility in High Strength Aluminum Alloys." *Corrosion 99, Paper 187,* 1-13. Houston, Texas: National Association of Corrosion Engineers. TIC: 246549.

Walton, J.C.; Cragnolino, G.; and Kalandros, S.K. 1996. "A Numerical Model of Crevice Corrosion for Passive and Active Metals." *Corrosion Science, 38,* (1), 1-18. Amsterdam, The Netherlands: Pergamon. TIC: 233439.

Weast, R.C., ed. 1974. *CRC Handbook of Chemistry and Physics.* 59th Edition. Page B-161. West Palm Beach, Florida: CRC Press. TIC: 246619.

Welsch, G. and Pramod, D.D. eds. 1996. *Oxidation and Corrosion of Intermetallic Alloys.* West Layfayette, Indiana: Purdue University. TIC: 245280.

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ATTACHMENTS

Attachments to this document are listed below. The CD Rom includes a data inventory in the form of an Excel spreadsheet.

Attachment	Title
I	Report on AFM Study
II	Data Inventory Sheet

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ATTACHMENT I

REPORT ON AFM STUDY BY P. J. BEDROSSIAN

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Surface Topographies
of
One-Year Weight-Loss Coupons of Alloy C-22™
from
Long-Term Corrosion Testing

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11 June 1999

1. ABSTRACT

An atomic force microscope (AFM) to characterize the surface topographies of weight-loss coupons of Alloy C-22™ which had been exposed to two different environments in the Long-Term Corrosion Test Facility (LTCTF) at LLNL has been used for one year. A silicate deposit on these coupons, with the most extensive coverage occurring on the coupon immersed in an acidified bath has been observed. Localized corrosion on these coupons has not been detected.

2. INTRODUCTION

The LTCTF at LLNL is an array of tanks holding various aqueous baths with controlled electrolyte concentrations at 60 or 90°C, in which coupons of candidate materials for the Waste Package are held in either aqueous (below the water line) or vapor (above the water line) phase conditions and removed periodically for analysis. Although the LTCTF coupons have primarily been used for analysis of general corrosion via weight loss, the objective of the present study has been the search for signs of localized corrosion, if any. The "weight loss" coupons are 2 inches long, 1 inch wide, and 1/8 inch thick. Descriptions of the LTCTF and its uses, along with the detailed composition of the aqueous environments, are contained in Reference [1].

The AFM, with sub-nanometer vertical resolution, is an ideal tool for detecting pit initiation in localized areas. We have applied AFM to five "weight loss" coupons of Alloy C-22™: one control coupon that was never in any bath (DWA163), one aqueous phase sample from a simulated acidified well water SAW (DWA051), one vapor phase sample from SAW (DWA048), one aqueous phase sample from a simulated alkaline concentrated water SCW (DWA120) and one vapor phase sample from SCW (DWA117).

3. RESULTS AND DISCUSSION

Representative AFM data are collected and displayed below. Each set of data consists of a large-area scan of at least 25x25 µm followed by smaller-area details of the region displayed in the large-area scan. We have used a Digital Instruments DM3100 AFM. After the coupons were removed from the LTCTF, they were ultrasonically agitated in deionized water, acetone, and methanol for ten minutes each.

In general, the gross surface topography of the weight-loss coupons is dominated by the machining grooves, with typical heights of several hundred nanometers and typical lateral periodicities of several microns. The machining features on a bare surface are plainly visible on the images of coupon DWA163. Those samples which were removed from the LTCTF exhibit varying degrees of coverage by a deposit on top of this gross topography.

X-ray diffraction scans of all five coupons show that the deposit is predominantly a silicate or SiO_2, with some NaCl appearing on the two samples which were exposed in the SAW tank. The AFM images show that the most extensive coverage of the deposit occurred on test coupon DWA051, which was immersed in the SAW bath. The next most extensive coverage occurred on test coupon DWA048, which was held above the water line in the SAW bath. The two test coupons removed from the SCW bath showed lesser degrees of coverage by the silicate deposit in both the AFM images and the X-ray diffraction scans.

Incomplete surface coverage by the silicate deposit often results in the appearance of surface depressions, particularly on the DWA051 coupon. Data collected to date do not show any of these depressions extending below the metal surface, because the bottoms of the holes are typically flat. One illustration of the analysis leading to this conclusion is shown below in the profile measured along the line trace marked in the image pb990607.023, which spans two such holes. As shown in the profile, the bottoms of the holes are flat, as would be expected for an interruption that occurs only in the silicate deposit.

The following data are presented in this attachment, with page numbers listed.

FIGURES

Page

4. SUMMARY

A study of four test coupons of Alloy C-22™ removed from the LTCTF after one year showed varying degrees of coverage by silicate deposits but no evidence of localized corrosion by pitting.

5. ACKNOWLEDGMENTS

The author is grateful to David Fix for his extensive AFM data collection, to Dominic Delgiudice for the x-ray measurements, to John Estill and Kenneth King for providing samples from the LTCTF, and to Joseph Farmer, Daniel McCright, and Ronald Musket for helpful discussions. This work was conducted at LLNL under the auspices of the US Department of Energy under Contract W-7405-Eng-48, and was supported by the Yucca Mountain Program.

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[1] J C Farmer, et al., "Development of Integrated Meghanistically-Based Degradation-Mode Models for Performance Assessment of High-Level Waste Containers," UCRL-ID-130811 (1998), pp. 3 and 49 (Farmer et al. 1998).

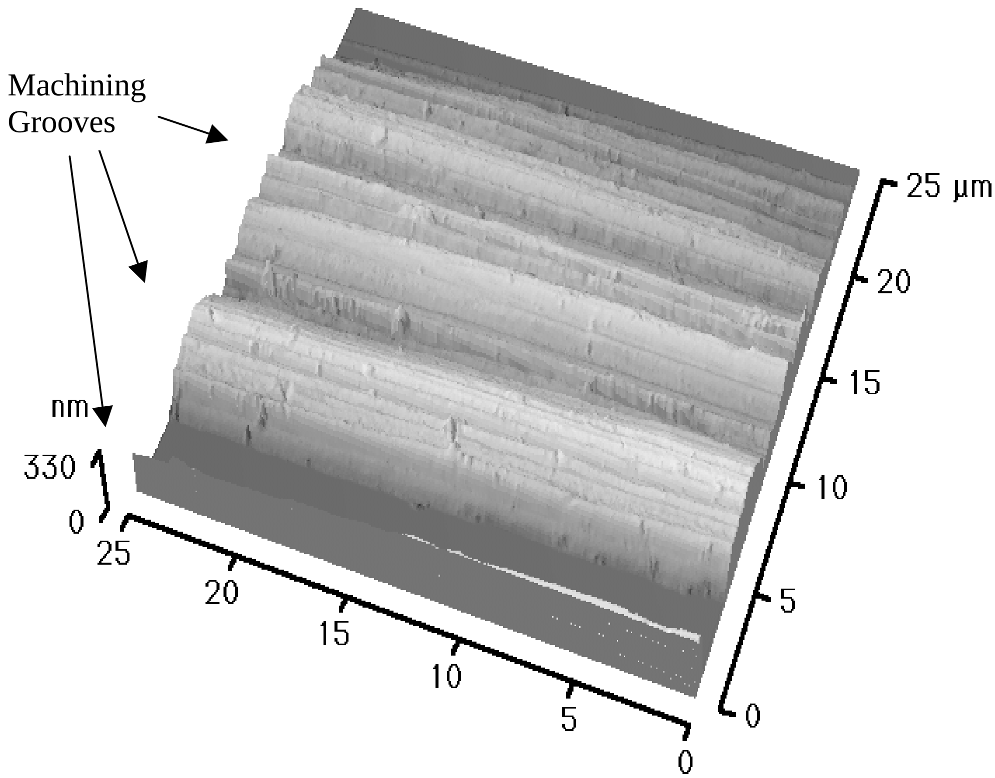


Figure 1. Control Coupon DWA163 pb990607.019 AFM Image

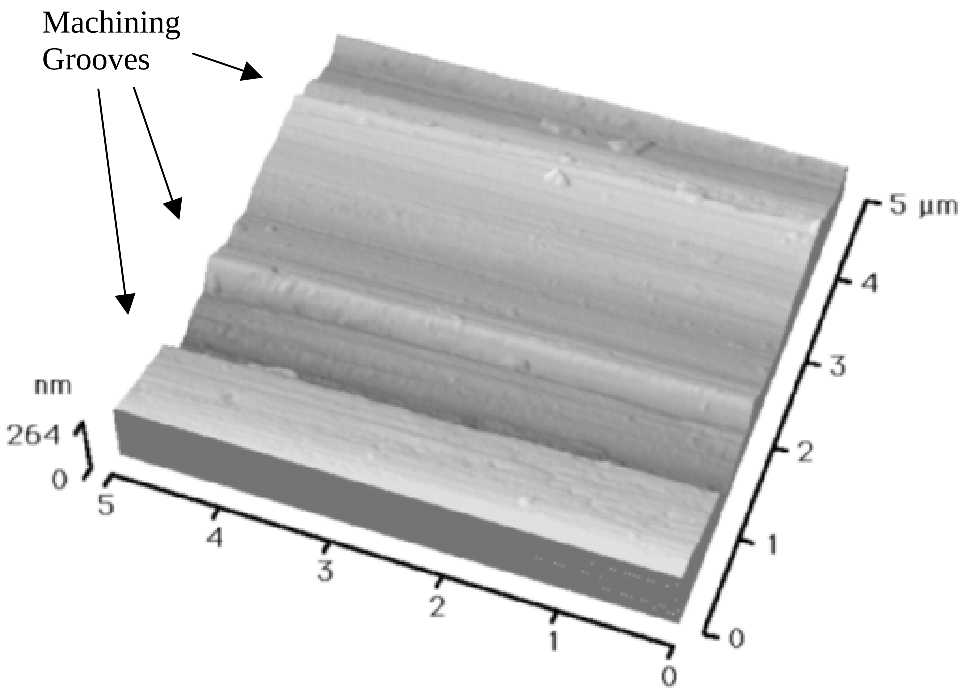


Figure 2. Control Coupon DWA163 pb990607.020 AFM Image

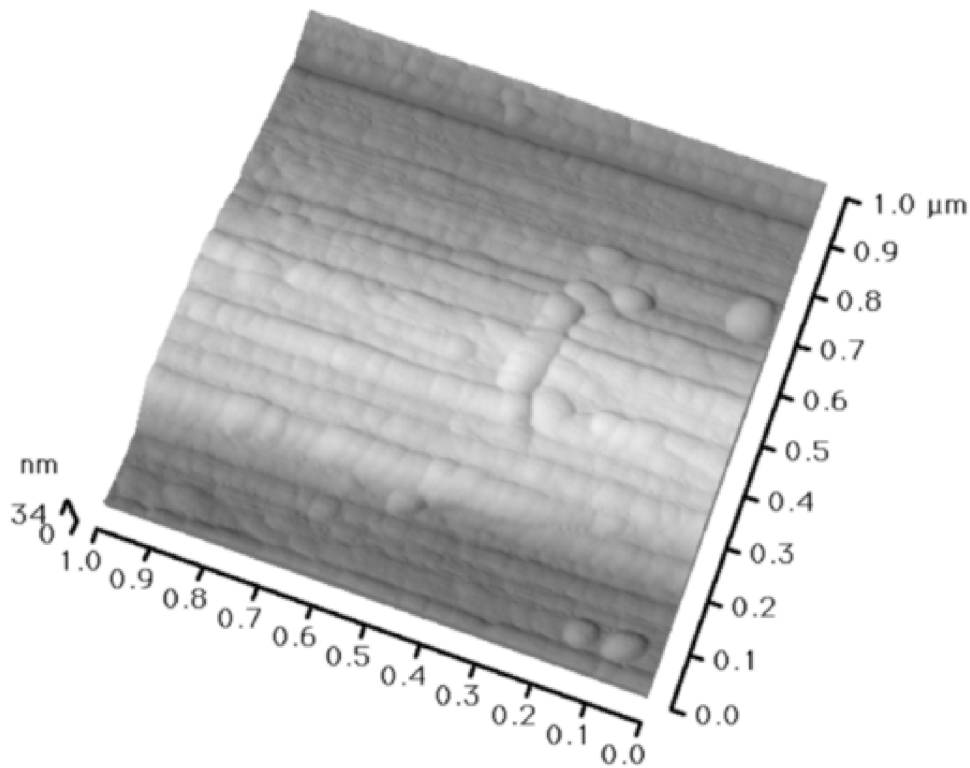


Figure 3. Control Coupon DWA163 pb990607.021 AFM Image

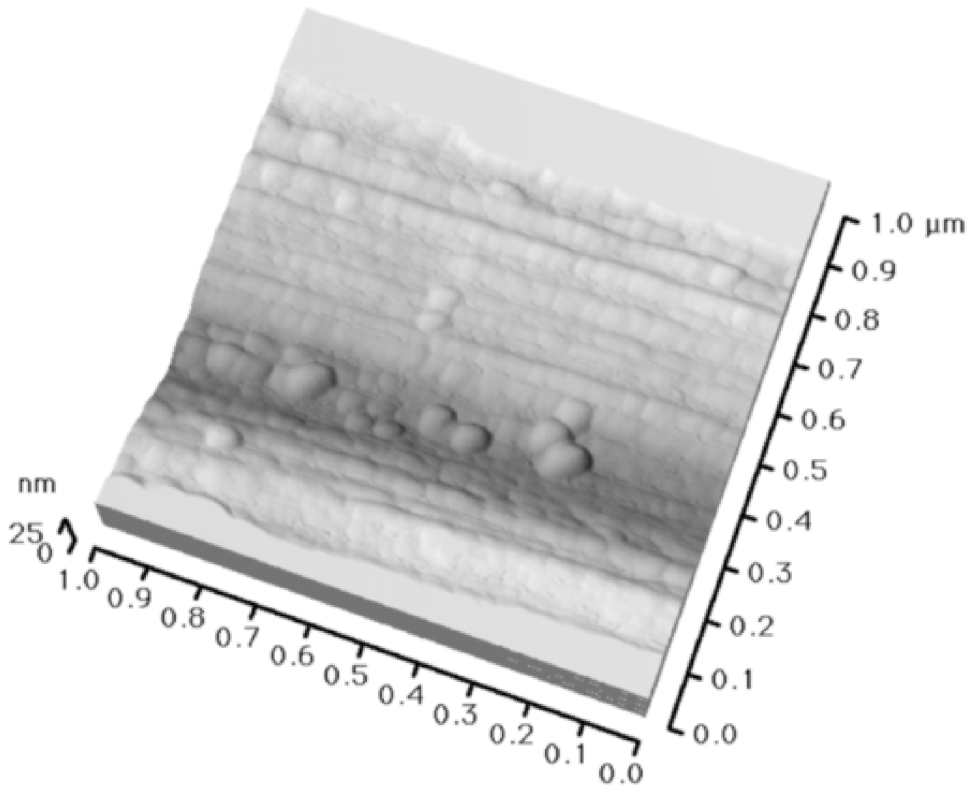


Figure 4. Control Coupon DWA163 pb990607.022 AFM Image

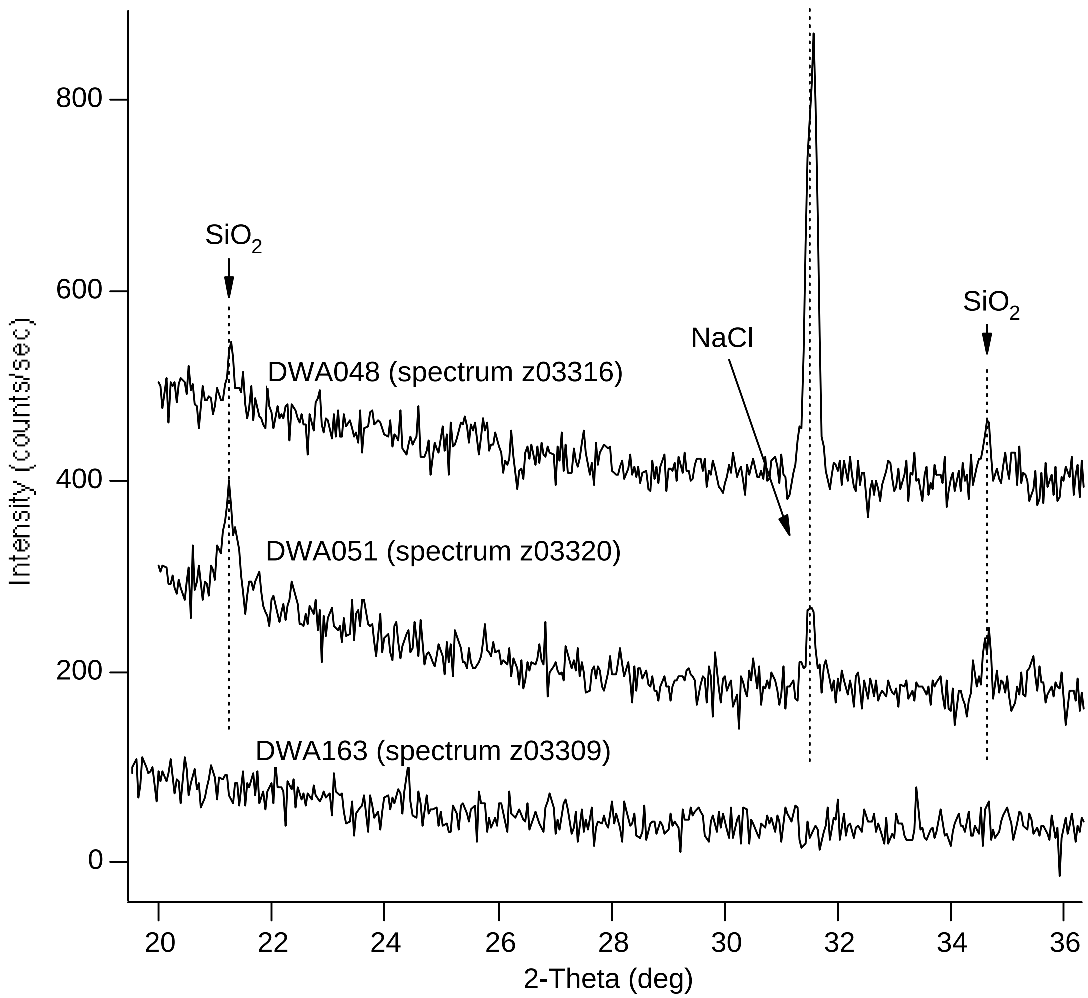


Figure 5. SAW Test Coupons: X-Ray Spectra of scales on SAW Coupons

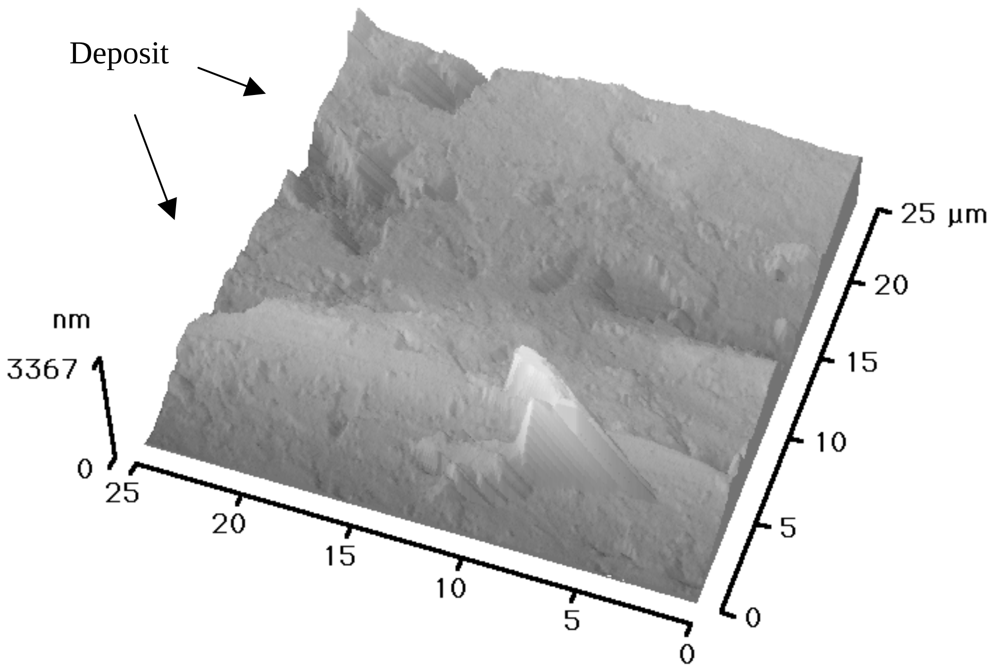


Figure 6. SAW, 90°C, Aqueous DWA051 pb990607.023 AFM Image

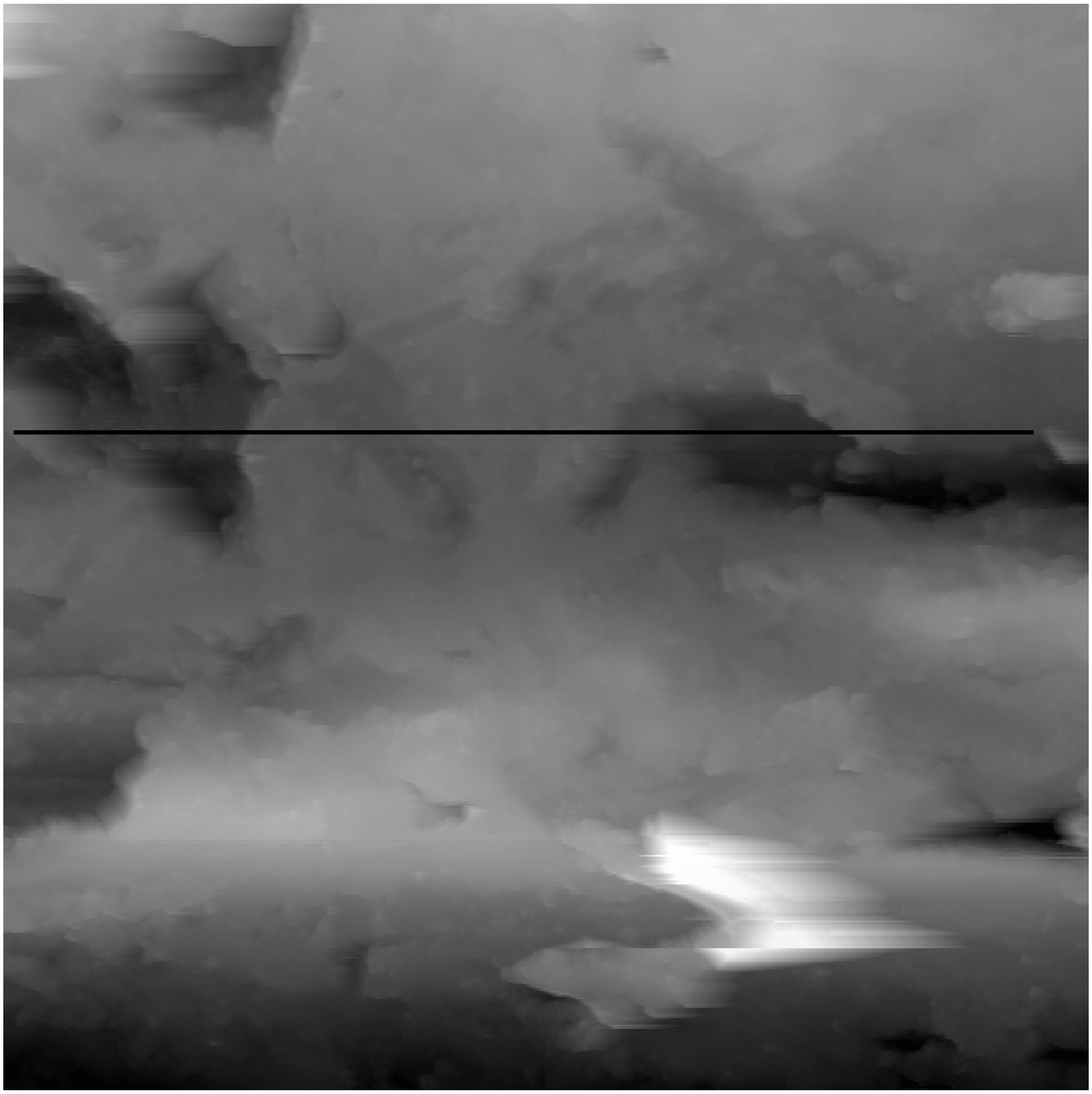


Figure 7. SAW, 90°C, Aqueous DWA051 pb990607.023 AFM Image, top view

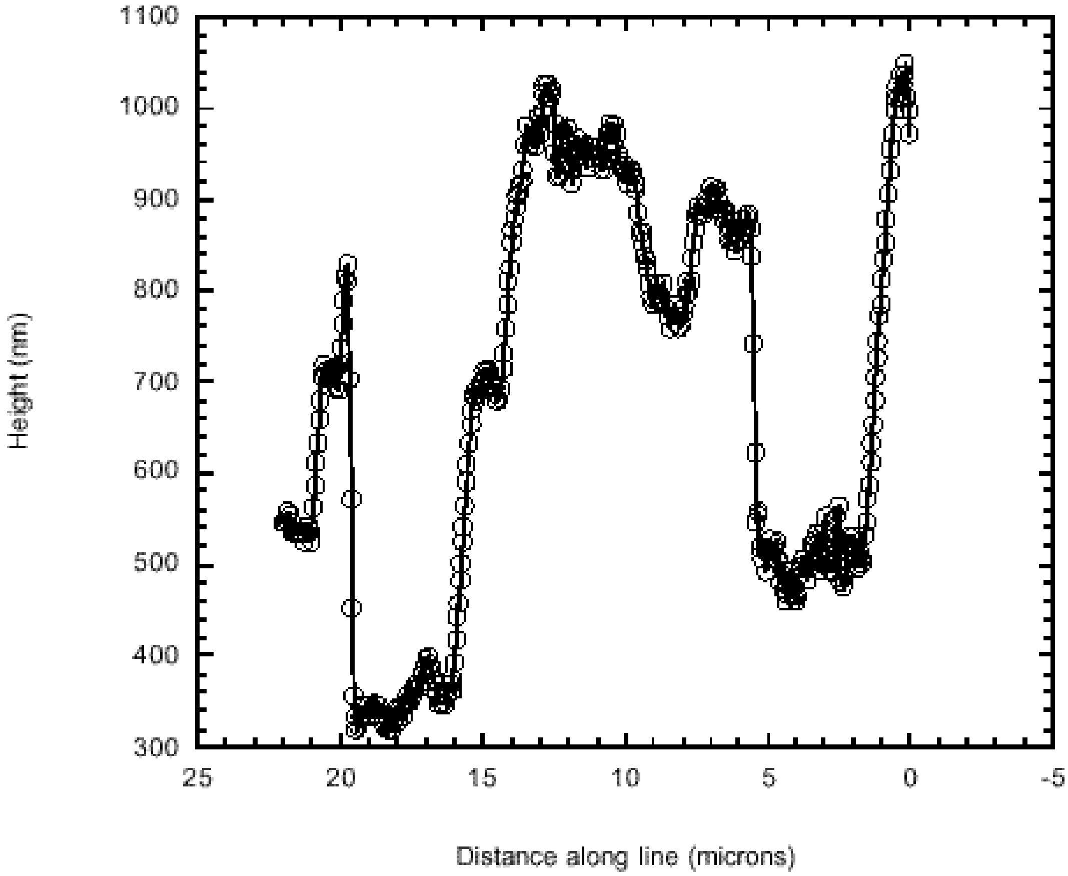


Figure 8. SAW, 90°C, Aqueous DWA051 Line Profile in pb990607.023 AFM Image

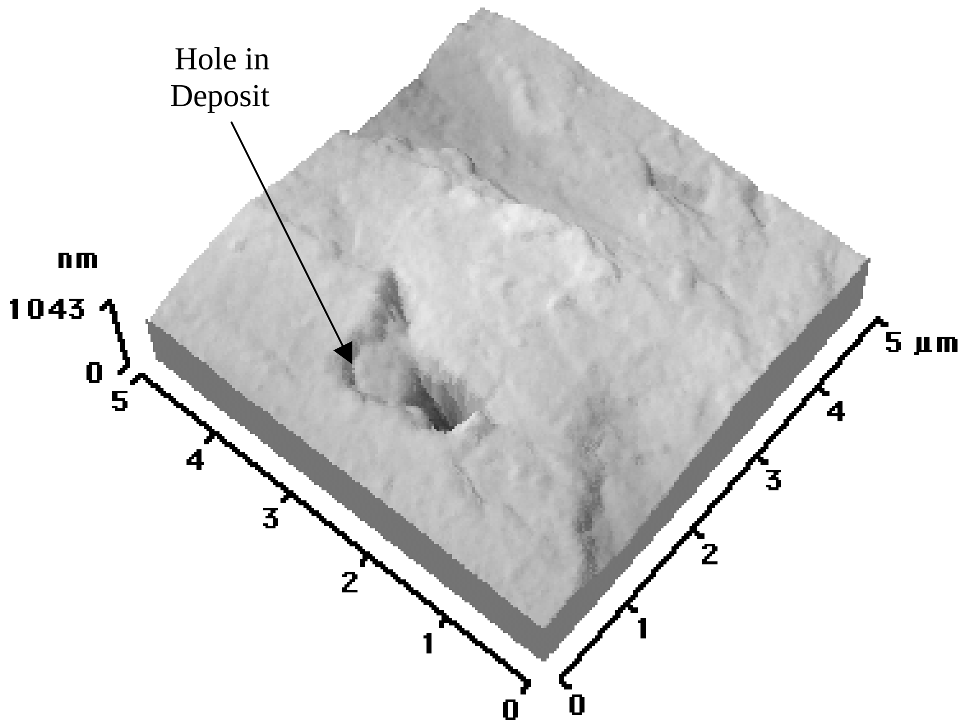
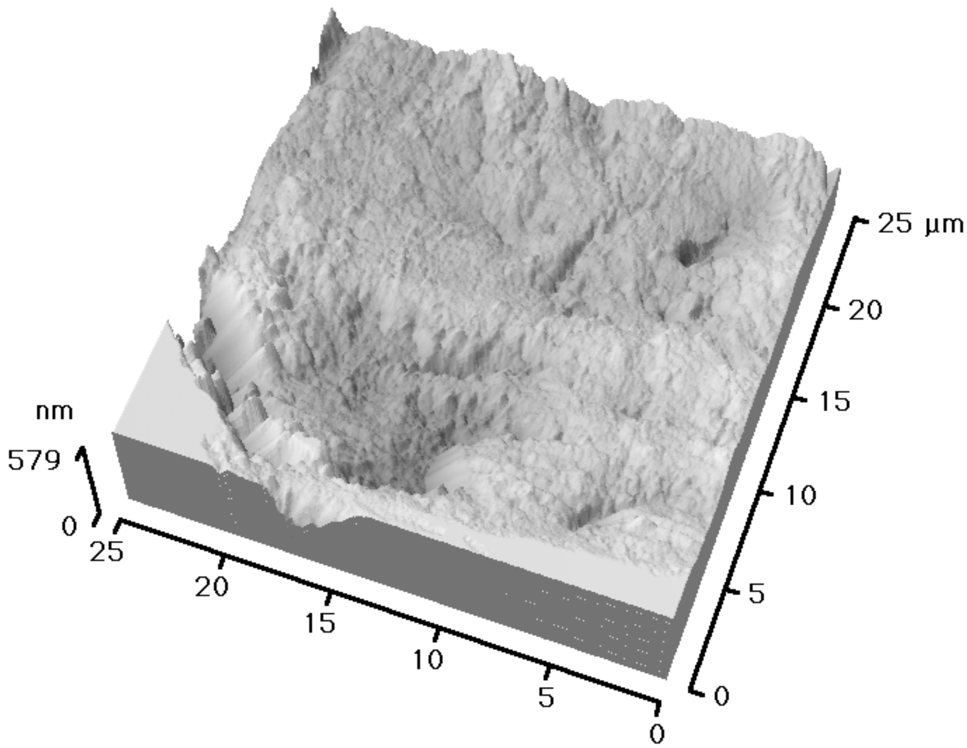


Figure 9. SAW, 90°C, Aqueous DWA051 pb990607.024 AFM Image



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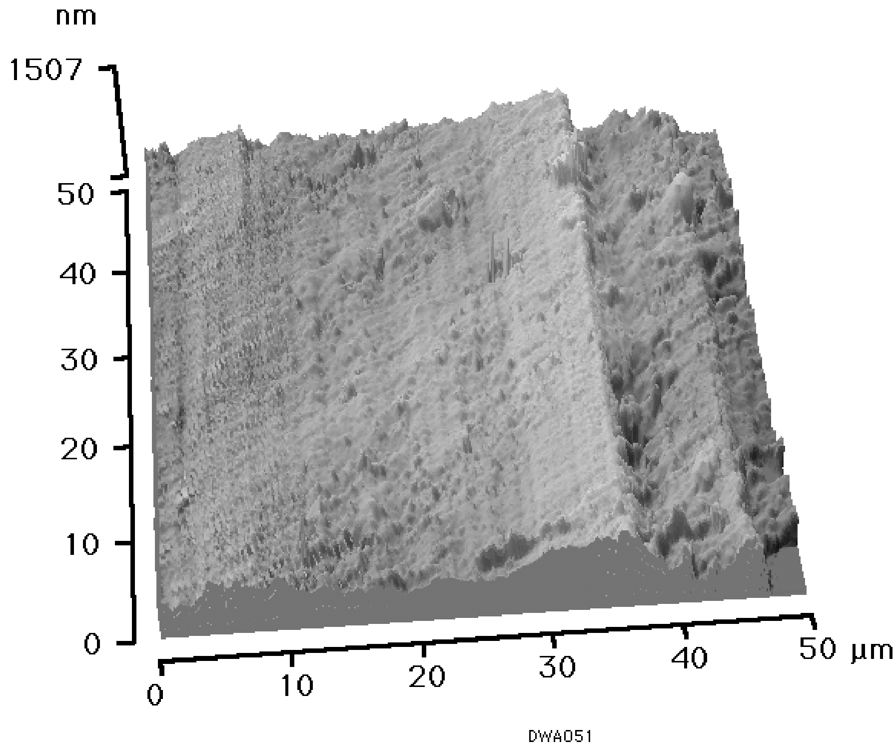

Figure 11. SAW, 90°C, Aqueous DWA051 pb990607.033 AFM Image

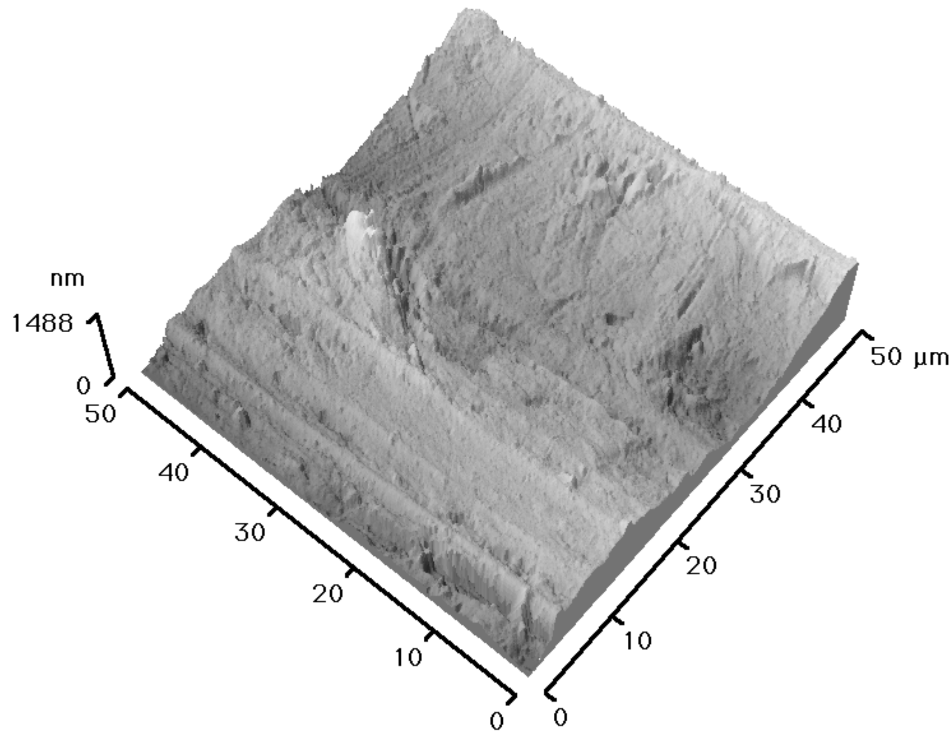

Figure 12. SAW, 90°C, Aqueous DWA051 pb990607.029 AFM Image

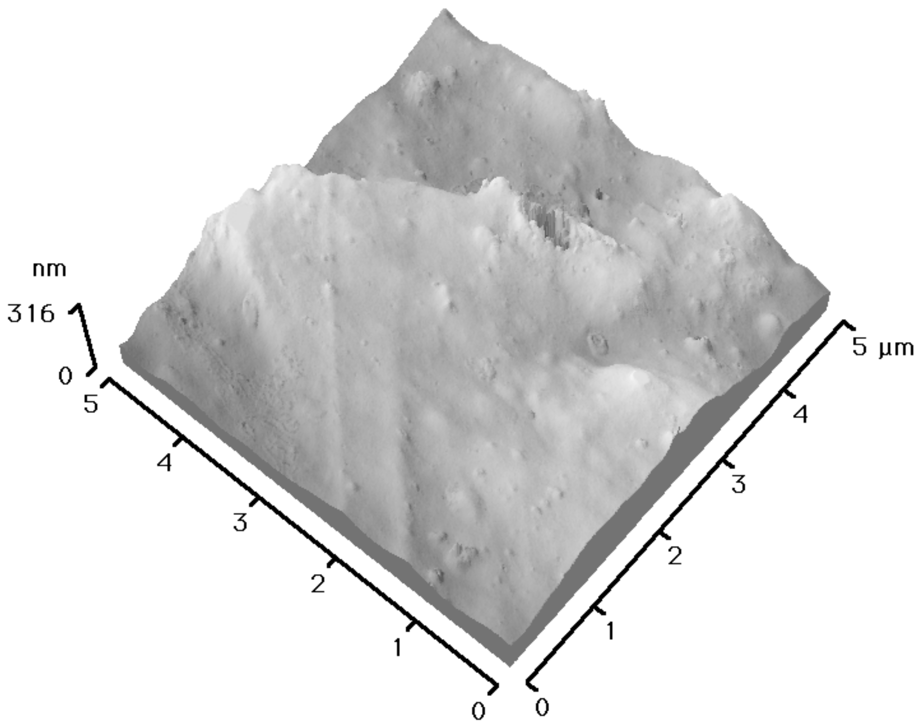

Figure 13. SAW, 90°C, Aqueous DWA051 pb990607.030 AFM Image

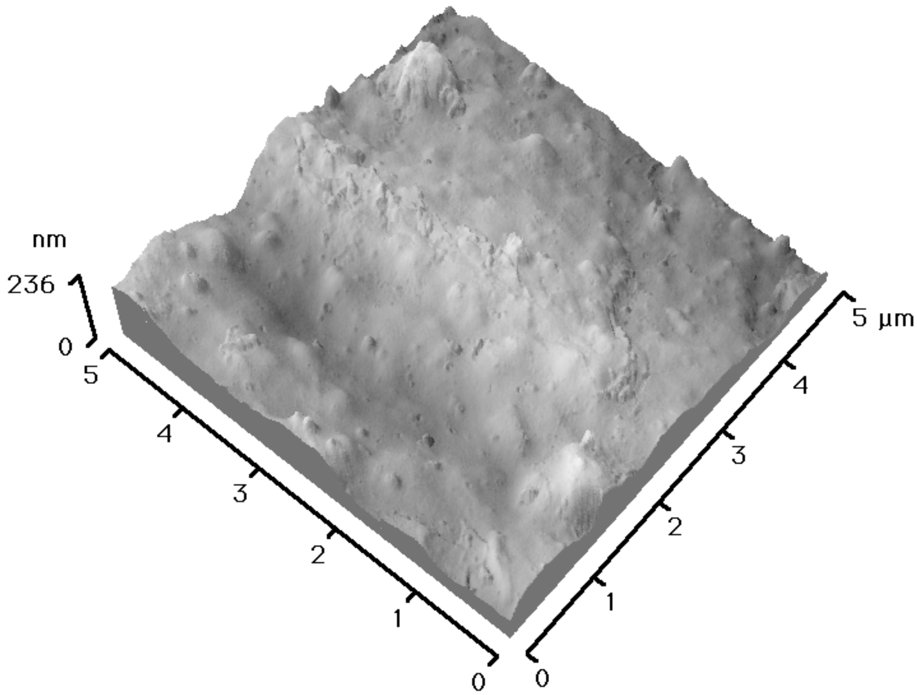

Figure 14. SAW, 90°C, Aqueous DWA051 pb990607.031 AFM Image

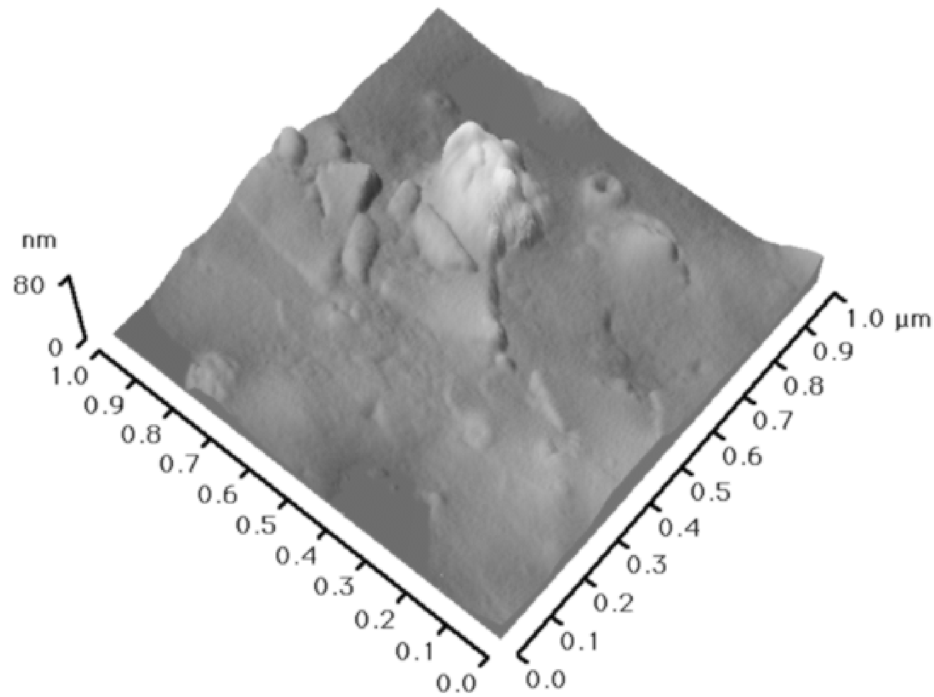

Figure 15. SAW, 90°C, Aqueous DWA051 pb990607.032 AFM Image

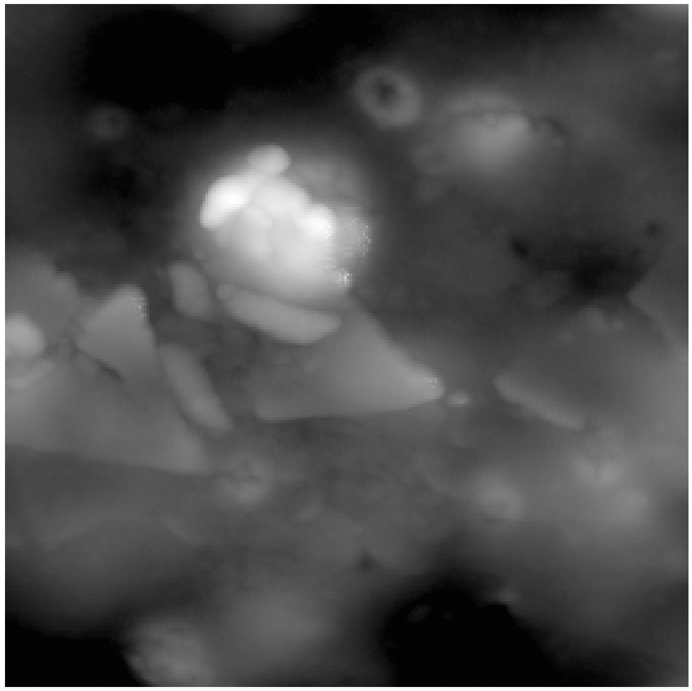

Figure 16. SAW, 90°C, Aqueous DWA051 pb990607.032 AFM Image

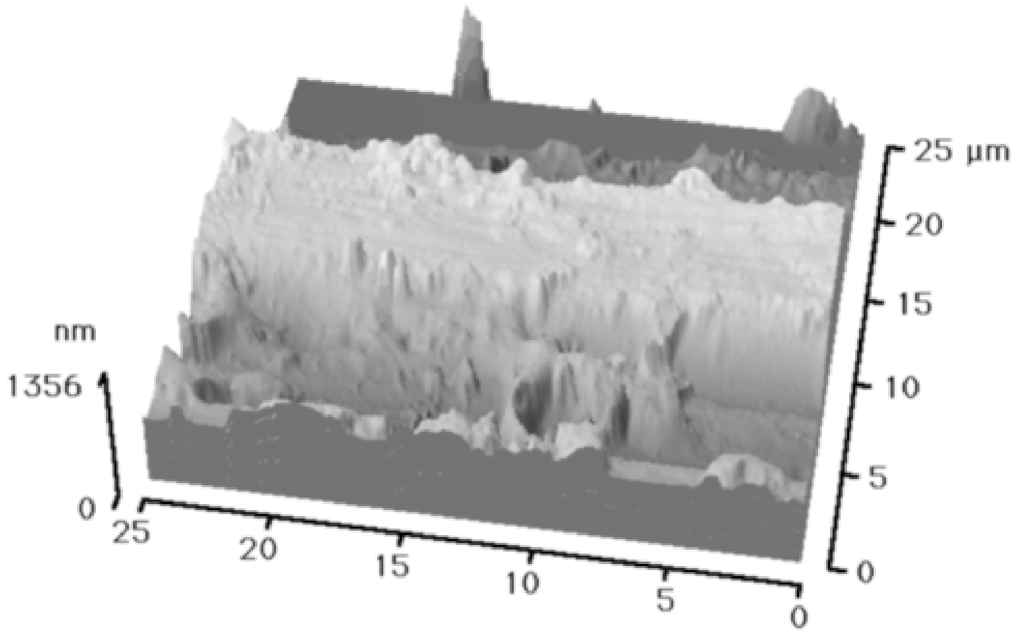

Figure 17. SAW, 90°C, Vapor DWA048 pb990607.046 AFM Image

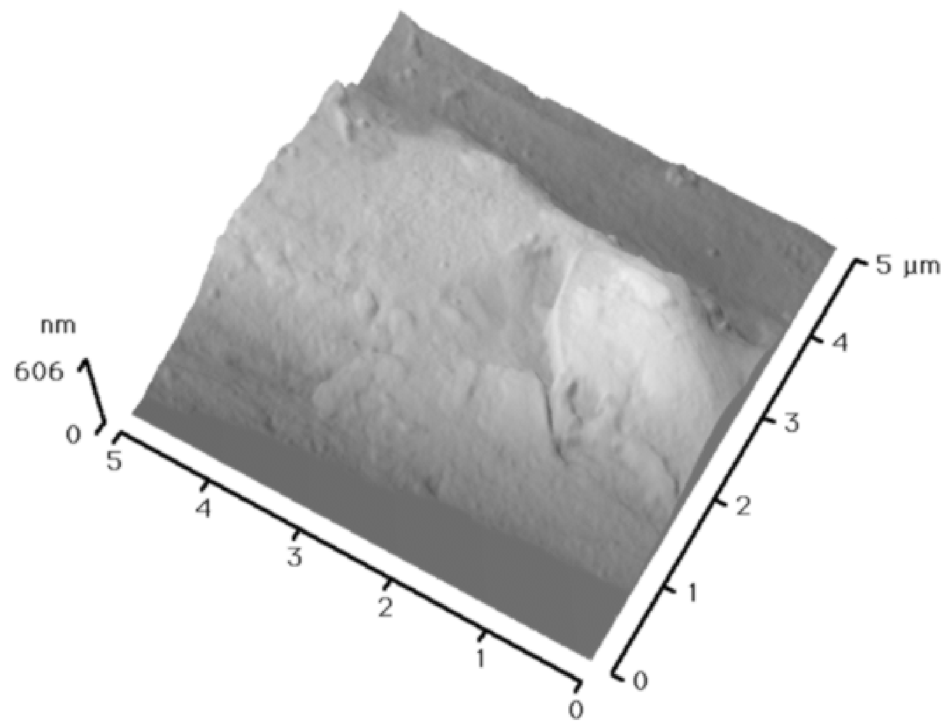

Figure 18. SAW, 90°C, Vapor DWA048 pb990607.045 AFM Image

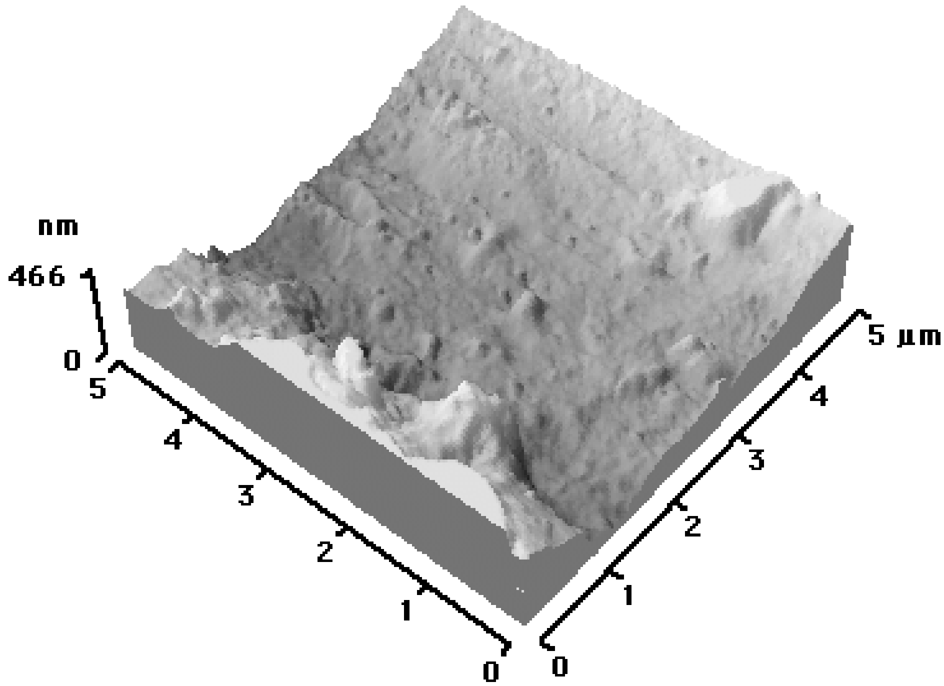

Figure 19. SAW, 90°C, Vapor DWA048 pb990607.048 AFM Image

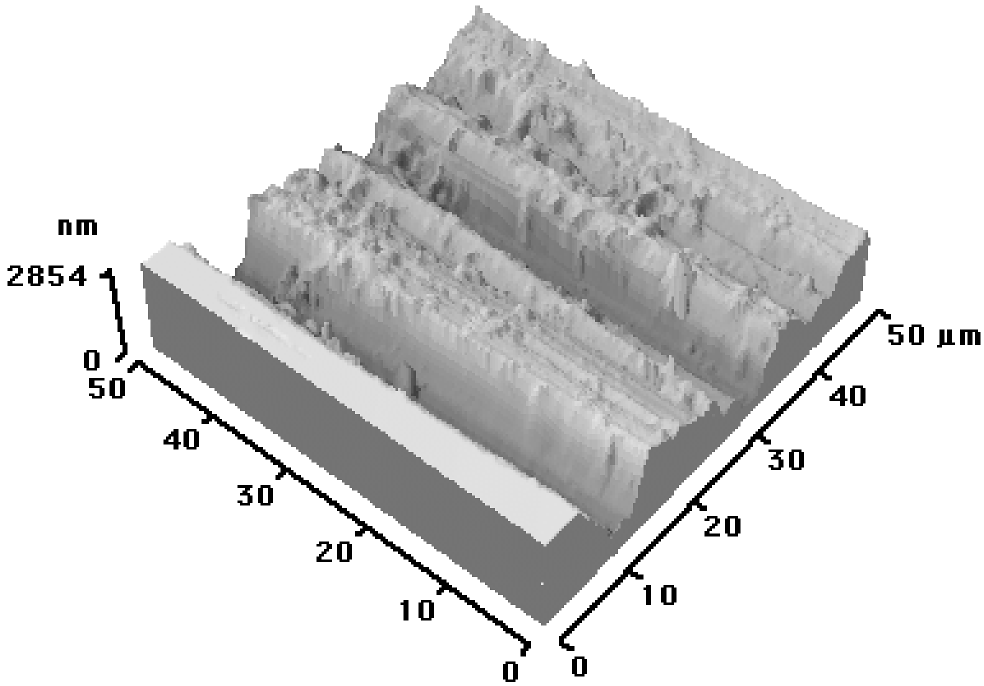

Figure 20. SAW, 90°C, Vapor DWA048 pb990607.050 AFM Image

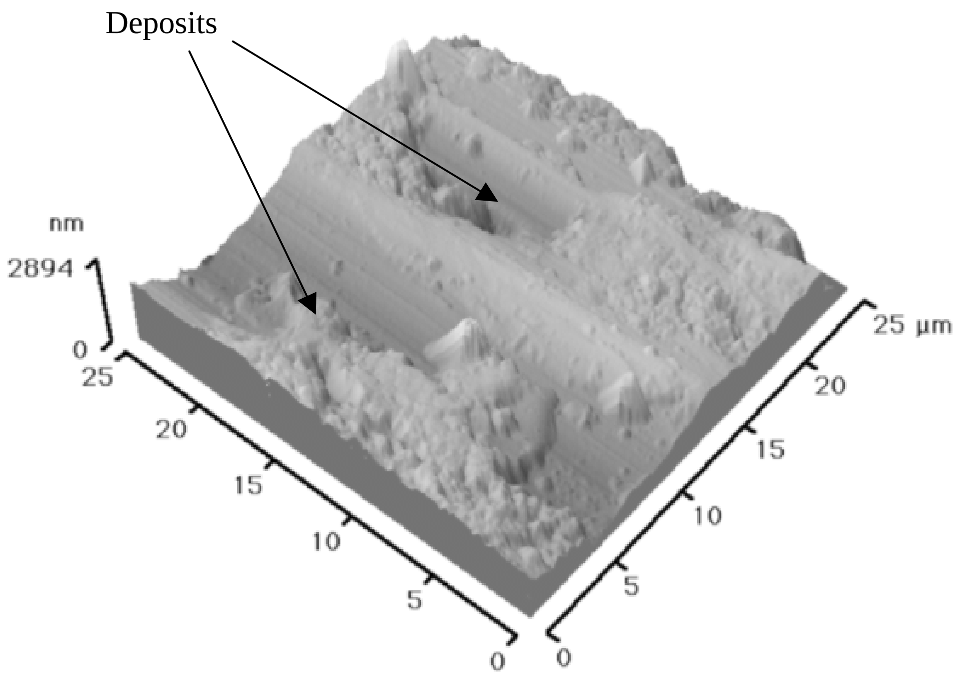

Figure 21. SAW, 90°C, Vapor DWA048 pb990607.054 AFM Image

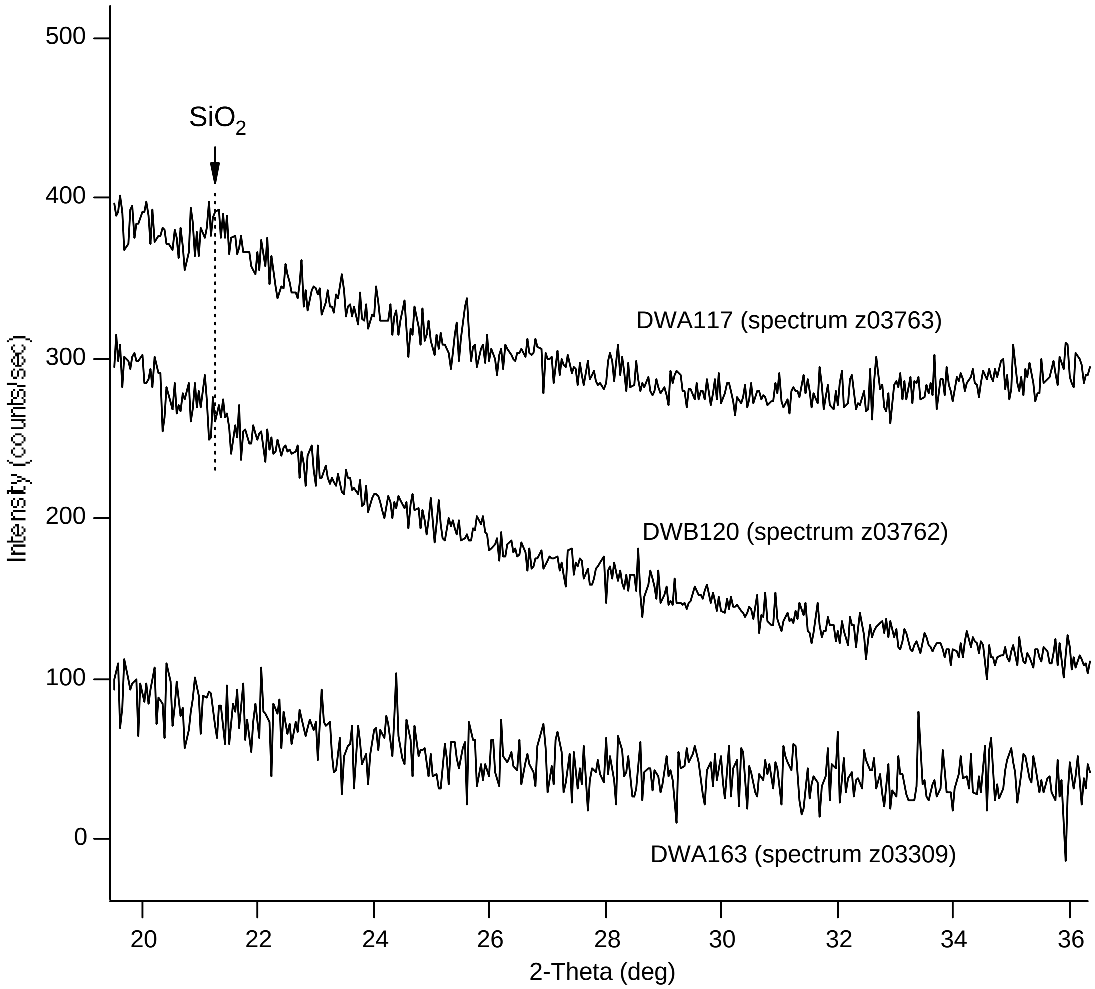

Figure 22. SCW Test Coupons: X-Ray Spectra of Scales on SCW Test Coupons

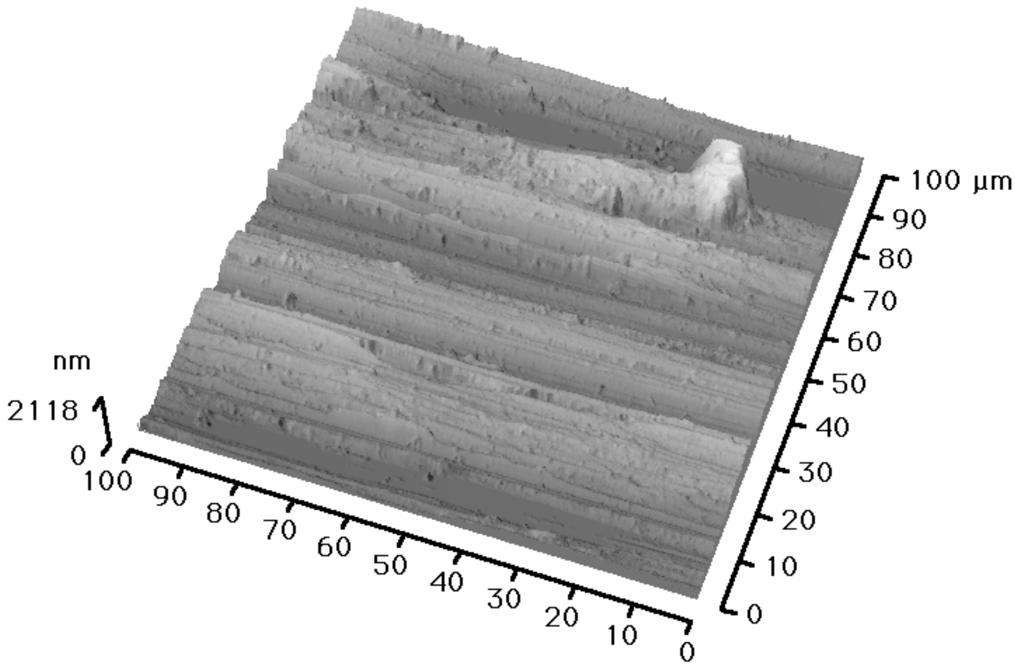

Figure 23. SCW, 90°C, Aqueous DWA 120 pb990607.001 AFM Image

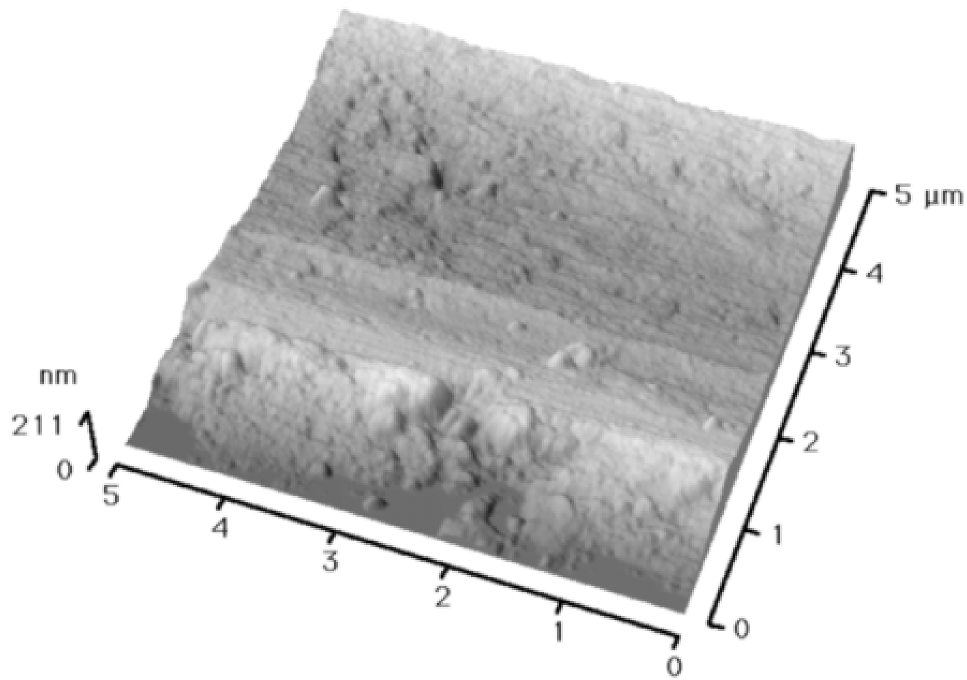

Figure 24. SCW, 90°C, Aqueous DWA 120 pb990607.005 AFM Image

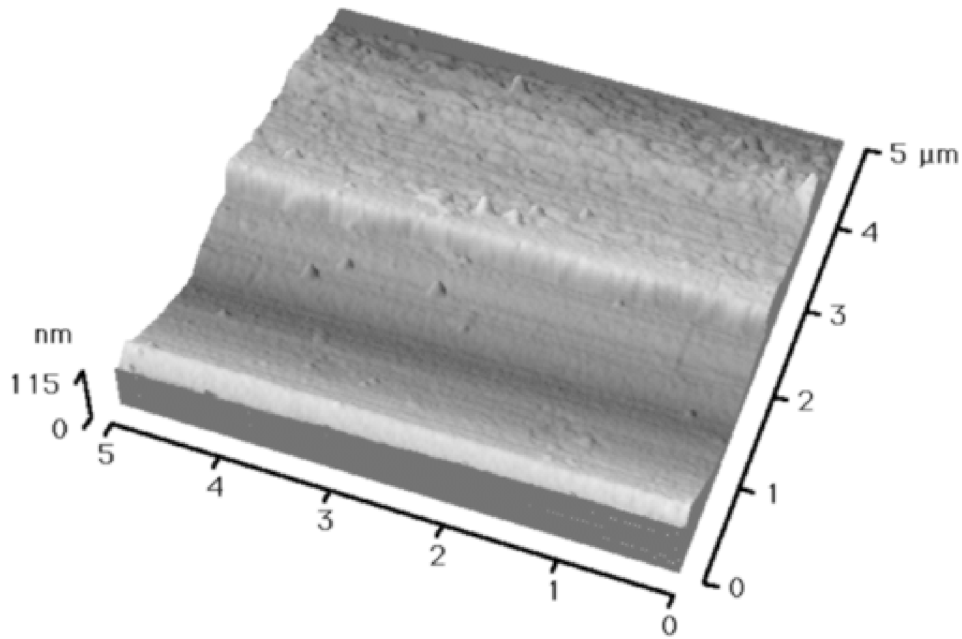

Figure 25. SCW, 90°C, Aqueous DWA 120 pb990607.015 AFM Image

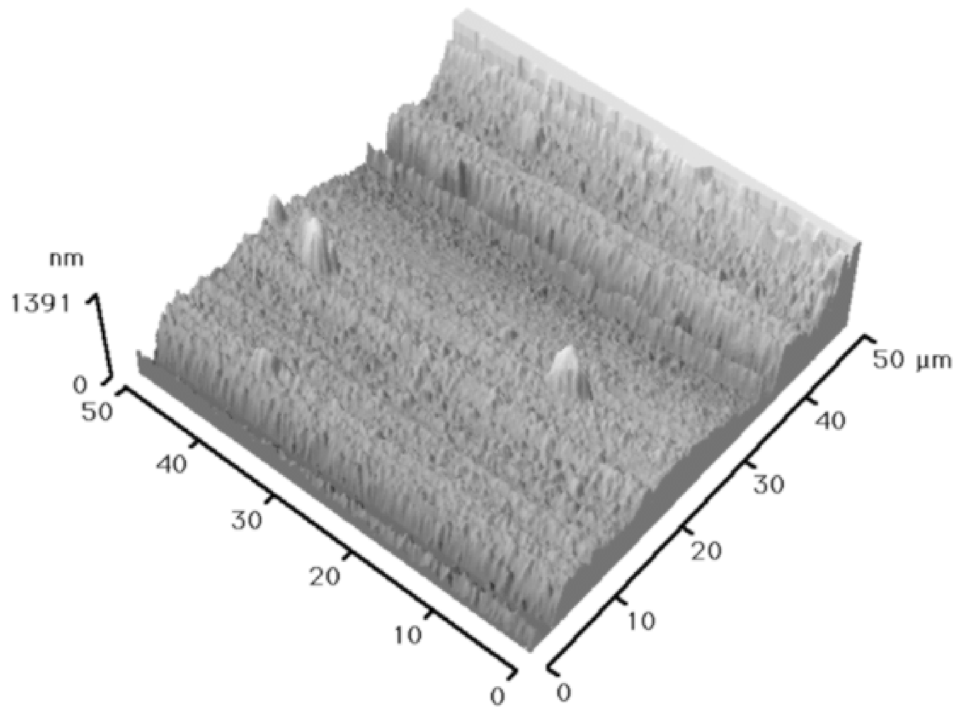

Figure 26. SCW, 90°C, Vapor DWA117 pb990607.039 AFM Image

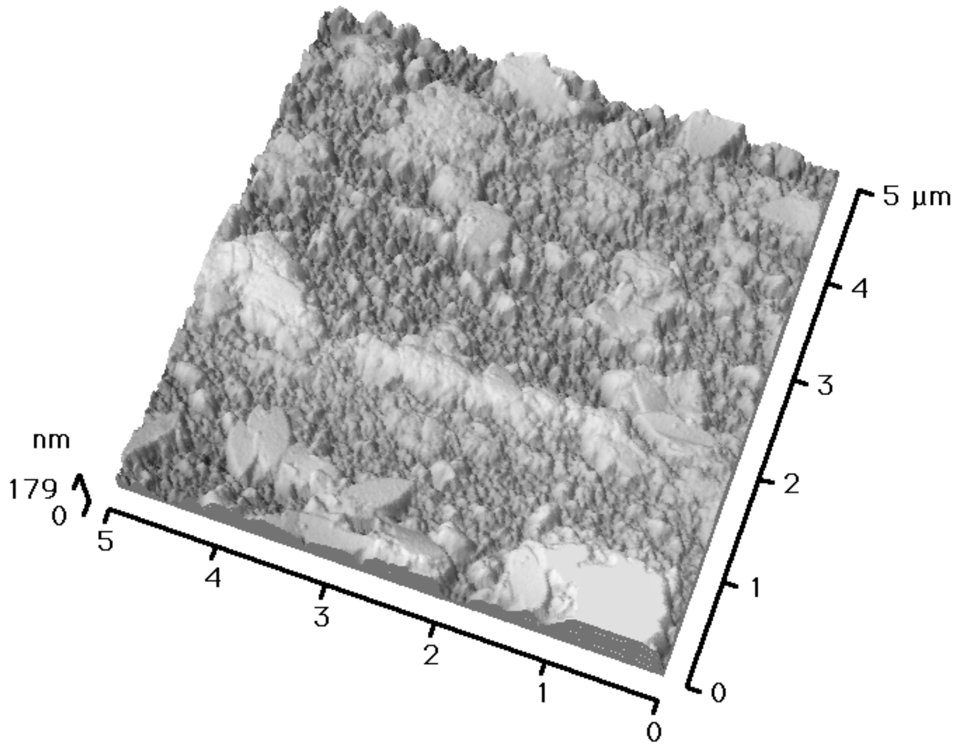

Figure 27. SCW, 90°C, Vapor DWA117 pb990607.035 AFM Image

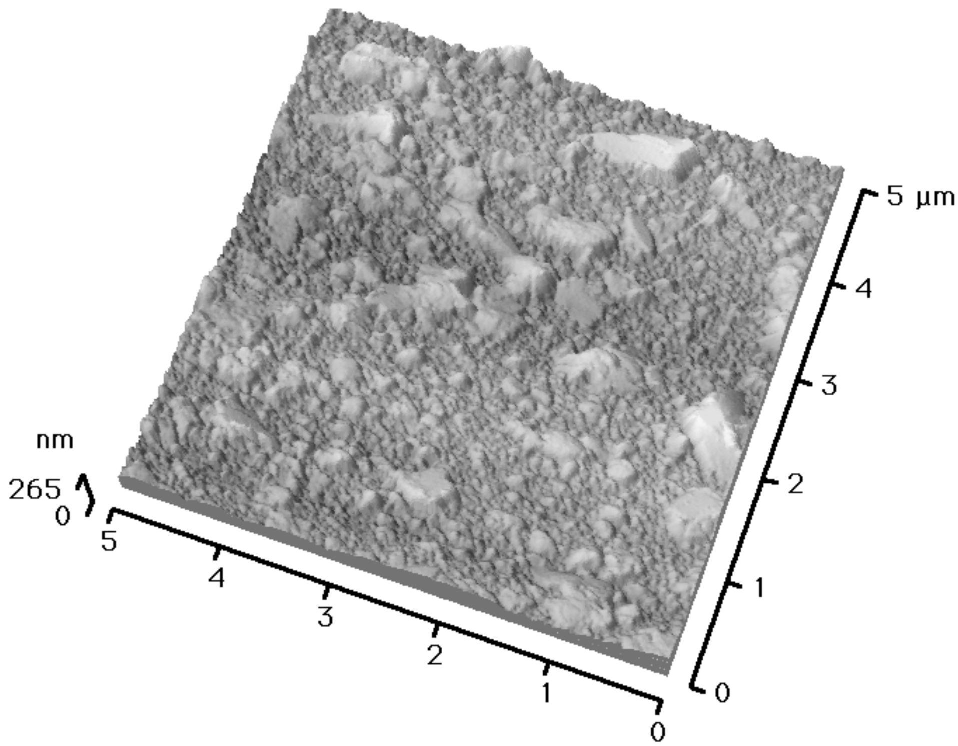

Figure 28. SCW, 90°C, Vapor DWA117 pb990607.037 AFM Image

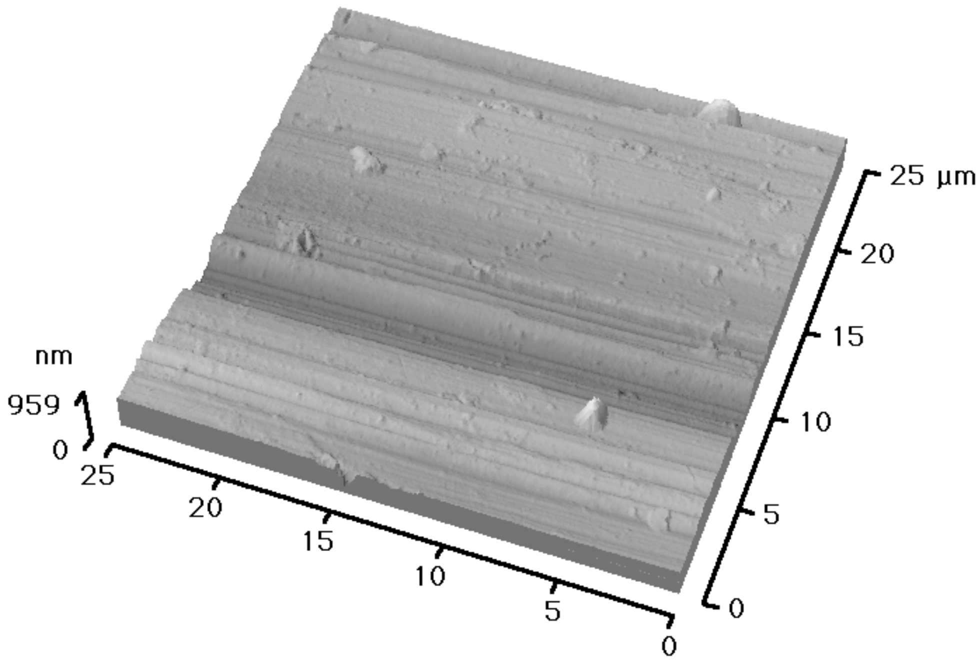

Figure 29. SCW, 90°C, Vapor DWA117 pb990607.044 AFM Image

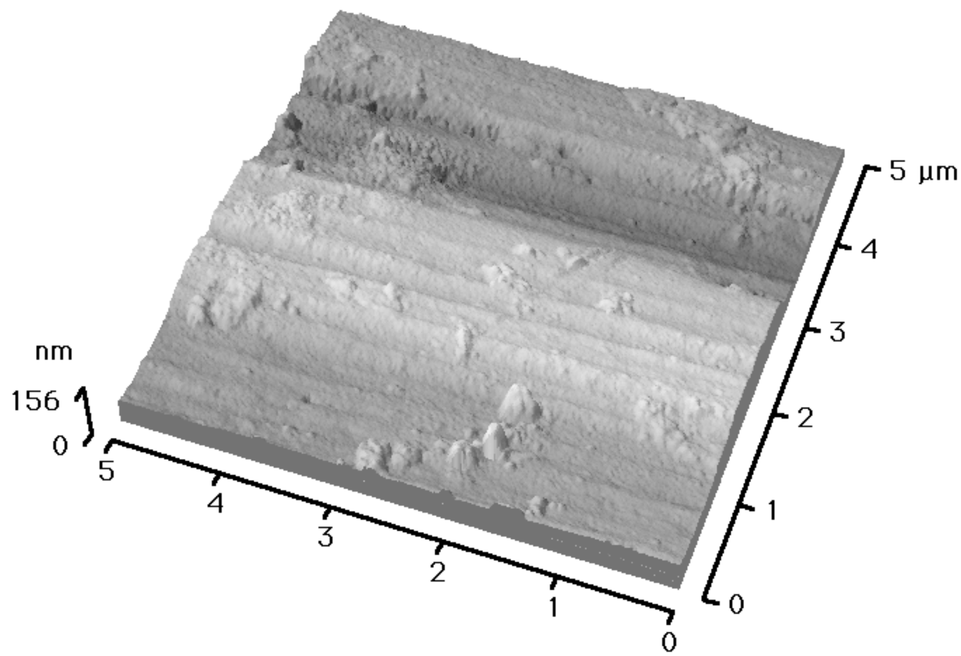

Figure 30. SCW, 90°C, Vapor DWA117 pb990607.041 AFM Image

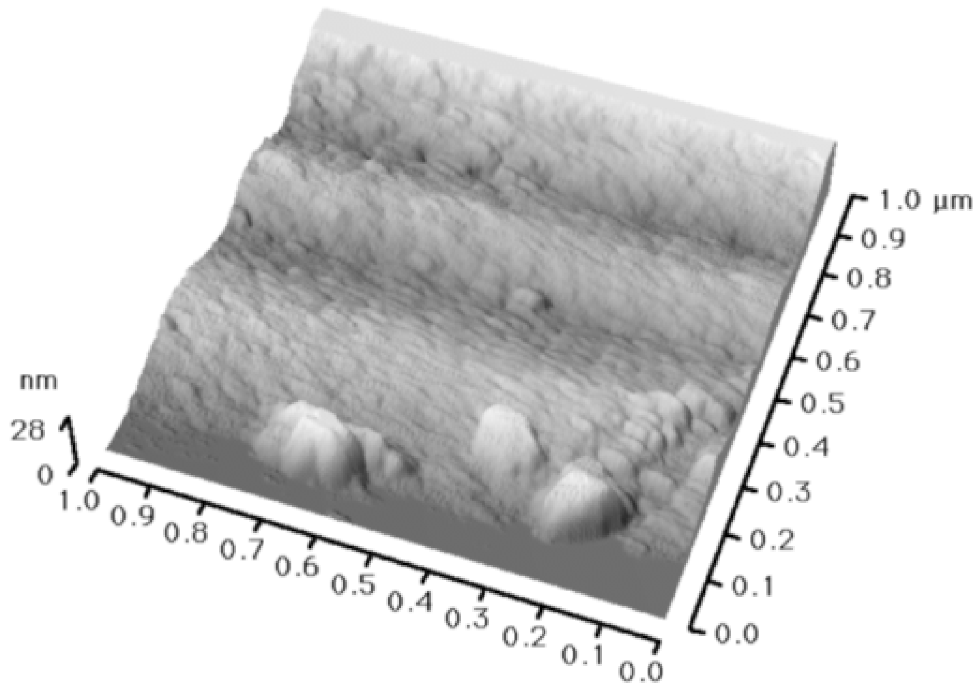

Figure 31. SCW, 90°C, Vapor DWA117 pb990607.042 AFM Image

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ATTACHMENT II

INVENTORY OF METAL SAMPLES WITH TRACEABILITY

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Specimen Composition Summary

Specimen ID	Alloy Trade Name	Base Metal MSC Lot Number	Base Metal Mill Heat Number	UNS Number	ASTM Specification	Base Metal Independent Test Report Number	Weld Filler MSC Lot Number	Weld Filler Mill Heat Number	AWS Specification	Weld Filler Independent Test Report Number	Statement of Conformity
DCA 001	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 002	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 003	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 004	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 005	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 006	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 031	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 032	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 033	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 034	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 035	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 036	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 061	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 062	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 063	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 064	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 065	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 066	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 067	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 068	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 069	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 070	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 071	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954

Specimen Composition Summary

Specimen ID	Alloy Trade Name	Base Metal MSC Lot Number	Base Metal Mill Heat Number	UNS Number	ASTM Specification	Base Metal Independent Test Report Number	Weld Filler MSC Lot Number	Weld Filler Mill Heat Number	AWS Specification	Weld Filler Independent Test Report Number	Statement of Conformity
DCA 072	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 091	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 092	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 093	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 094	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 095	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 096	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 098	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 099	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 101	Alloy 22	H157	1227703264	[illegible]06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 102	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 121	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 122	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 123	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 124	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 125	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 126	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 128	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 129	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 130	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 132	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 157	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 158	[illegible] 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of	N/A	N/A	N/A	N/A	SOC-1 PO# B313954

Specimen Composition Summary

Specimen ID	Alloy Trade Name	Base Metal MSC Lot Number	Base Metal Mill Heat Number	UNS Number	ASTM Specification	Base Metal Independent Test Report Number	Weld Filler MSC Lot Number	Weld Filler Mill Heat Number	AWS Specification	Weld Filler Independent Test Report Number	Statement of Conformity
DCA 159	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 160	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 161	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 162	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 164	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 165	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 167	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 168	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DCA 244	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DCA 245	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DCA 246	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DCA 247	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DCA 248	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DCA 249	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DCA 250	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DCA 251	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DCA 252	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DCA 253	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DCB 001	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 002	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 003	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 004	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 005	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954

Specimen Composition Summary

Specimen ID	Alloy Trade Name	Base Metal MSC Lot Number	Base Metal Mill Heat Number	UNS Number	ASTM Specification	Base Metal Independent Test Report Number	Weld Filler MSC Lot Number	Weld Filler Mill Heat Number	AWS Specification	Weld Filler Independent Test Report Number	Statement of Conformity
DCB 006	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 031	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 032	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 033	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 034	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 035	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 036	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 061	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 062	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	L098	1227743142	A5.14 ER NiCrMo-10	ASP003-97-05-09164 (Page 1 of 1)	SOC-1 & SOC-1A PO# B313954
DCB 063	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	L098	1227743142	A5.14 ER NiCrMo-10	ASP003-97-05-09164 (Page 1 of 1)	SOC-1 & SOC-1A PO# B313954
DCB 064	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 065	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 066	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 067	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 068	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 069	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 070	Alloy 22	H157	1227703264	..06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 071	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 072	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 091	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 092	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 093	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 094	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954

Specimen Composition Summary

Specimen ID	Alloy Trade Name	Base Metal MSC Lot Number	Base Metal Mill Heat Number	UNS Number	ASTM Specification	Base Metal Independent Test Report Number	Weld Filler MSC Lot Number	Weld Filler Mill Heat Number	AWS Specification	Weld Filler Independent Test Report Number	Statement of Conformity
DCB 095	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 096	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 098	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 099	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 101	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 102	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 121	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 122	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 123	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 124	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 125	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 126	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	L098	1227743142	A5.14 ER NiCrMo-10	ASP003-97-05-09164 (Page 1 of 1)	SOC-1 & SOC-1A PO# B313954
DCB 128	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 129	Alloy 22	H157	1227703264	06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 130	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 132	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 157	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 158	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 159	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	L098	1227743142	A5.14 ER NiCrMo-10	ASP003-97-05-09164 (Page 1 of 1)	SOC-1 & SOC-1A PO# B313954
DCB 160	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 161	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	L098	1227743142	A5.14 ER NiCrMo-10	ASP003-97-05-09164 (Page 1 of 1)	SOC-1 & SOC-1A PO# B313954
DCB 162	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 164	22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954

Specimen Co sition Summary

Specimen ID	Alloy Trade Name	Base Metal MSC Lot Number	Base Metal Mill Heat Number	UNS Number	ASTM Specification	Base Metal Independent Test Report Number	Weld Filler MSC Lot Number	Weld Filler Mill Heat Number	AWS Specification	Weld Filler Independent Test Report Number	Statement of Conformity
DCB 165	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 167	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DCB 168	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	L098	1227743142	A5.14 ER NiCrMo-10	ASP003-97-05-09164 (Page 1 of 1)	SOC-1 & SOC-1A PO# B313954
DEA 002	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 003	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 004	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 005	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 006	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 007	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 008	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 009	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 010	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 011	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 012	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 013	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 014	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 015	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 016	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 017	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 019	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 020	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 021	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 022	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447

Specimen Composition Summary

Specimen ID	Alloy Trade Name	Base Metal MSC Lot Number	Base Metal Mill Heat Number	UNS Number	ASTM Specification	Base Metal Independent Test Report Number	Weld Filler MSC Lot Number	Weld Filler Mill Heat Number	AWS Specification	Weld Filler Independent Test Report Number	Statement of Conformity
DEA 023	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 024	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 025	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 026	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 027	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 029	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 031	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 032	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 033	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 034	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 035	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-4 PO# B500447
DEA 159	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-5 PO# A15382YS9B Schedule 7
DEA 201	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-5 PO# A15382YS9B Schedule 7
DEA 202	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-5 PO# A15382YS9B Schedule 7
DEA 203	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-5 PO# A15382YS9B Schedule 7
DEA 209	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-5 PO# A15382YS9B Schedule 7
DWA 001	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 002	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 003	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 004	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 005	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 006	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 031	[illegible] 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 [illegible]	N/A	N/A	N/A	N/A	SOC-1 PO# B313954

Specimen Composition Summary

Specimen ID	Alloy Trade Name	Base Metal MSC Lot Number	Base Metal Mill Heat Number	UNS Number	ASTM Specification	Base Metal Independent Test Report Number	Weld Filler MSC Lot Number	Weld Filler Mill Heat Number	AWS Specification	Weld Filler Independent Test Report Number	Statement of Conformity
DWA 036	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 041	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 042	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 043	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 044	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 045	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 046	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 071	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 072	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 073	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 074	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 075	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 076	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 077	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 078	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 079	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 080	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 081	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 082	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 101	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 102	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 106	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 111	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954

Specimen Composition Summary

Specimen ID	Alloy Trade Name	Base Metal MSC Lot Number	Base Metal Mill Heat Number	UNS Number	ASTM Specification	Base Metal Independent Test Report Number	Weld Filler MSC Lot Number	Weld Filler Mill Heat Number	AWS Specification	Weld Filler Independent Test Report Number	Statement of Conformity
DWA 112	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 113	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 114	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 115	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 116	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 118	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 119	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 121	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 122	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 141	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 142	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 143	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 144	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 151	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 152	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	N/A	N/A	N/A	N/A	SOC-1 PO# B313954
DWA 164	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-3 PO# B338959
DWA 165	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-3 PO# B338959
DWA 169	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-3 PO# B338959
DWA 170	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-3 PO# B338959
DWA 171	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	N/A	N/A	N/A	N/A	SOC-3 PO# B338959
DWB 001	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 002	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 003	[illegible]y 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 [illegible])	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954

Specimen Composition Summary

Specimen ID	Alloy Trade Name	Base Metal MSC Lot Number	Base Metal Mill Heat Number	UNS Number	ASTM Specification	Base Metal Independent Test Report Number	Weld Filler MSC Lot Number	Weld Filler Mill Heat Number	AWS Specification	Weld Filler Independent Test Report Number	Statement of Conformity
DWB 004	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 005	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 006	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 031	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 036	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 041	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 042	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 043	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 044	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 045	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 046	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 072	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 073	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 074	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 075	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 076	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 077	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 078	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 079	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 080	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 081	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 082	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 101	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954

Specimen Composition Summary

Specimen ID	Alloy Trade Name	Base Metal MSC Lot Number	Base Metal Mill Heat Number	UNS Number	ASTM Specification	Base Metal Independent Test Report Number	Weld Filler MSC Lot Number	Weld Filler Mill Heat Number	AWS Specification	Weld Filler Independent Test Report Number	Statement of Conformity
DWB 102	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 106	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 111	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 112	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 113	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 114	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 115	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 116	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 118	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 119	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 121	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 122	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 141	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 142	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 144	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 151	Alloy 22	H157	1227703264	N06022	B575	ASP003-97-06-10156 (Page 7 of 13)	K926	1227743263	A5.14 ER NiCrMo-10	TRW002-99-03-05242L (Page 1 of 1)	SOC-1 PO# B313954
DWB 164	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	L098	1227743142	A5.14 ER NiCrMo-10	ASP003-97-05-09164 (Page 1 of 1)	SOC-3 PO# B338959
DWB 168	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	L098	1227743142	A5.14 ER NiCrMo-10	ASP003-97-05-09164 (Page 1 of 1)	SOC-3 PO# B338959
DWB 169	Alloy 22	K932	1227783203	N06022	B575	ASP003-97-06-10156 (Page 6 of 13)	L098	1227743142	A5.14 ER NiCrMo-10	ASP003-97-05-09164 (Page 1 of 1)	SOC-3 PO# B338959
ECA 001	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 002	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 003	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 004	T[illegible]de 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 [illegible]	N/A	N/A	N/A	N/A	SOC-2 PO# B313954

Specimen Composition Summary

Specimen ID	Alloy Trade Name	Base Metal MSC Lot Number	Base Metal Mill Heat Number	UNS Number	ASTM Specification	Base Metal Independent Test Report Number	Weld Filler MSC Lot Number	Weld Filler Mill Heat Number	AWS Specification	Weld Filler Independent Test Report Number	Statement of Conformity
ECA 005	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 006	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 031	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 032	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 033	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 034	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 035	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 036	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 061	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 062	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 063	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 064	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 065	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 066	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 067	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 068	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 069	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 070	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 071	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 072	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 091	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 092	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 093	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954

Specimen Composition Summary

Specimen ID	Alloy Trade Name	Base Metal MSC Lot Number	Base Metal Mill Heat Number	UNS Number	ASTM Specification	Base Metal Independent Test Report Number	Weld Filler MSC Lot Number	Weld Filler Mill Heat Number	AWS Specification	Weld Filler Independent Test Report Number	Statement of Conformity
ECA 094	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 096	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 098	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 099	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 101	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 102	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 121	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 122	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 123	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 124	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 125	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 126	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 128	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 129	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 130	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 132	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 157	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 158	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 159	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 160	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 161	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 162	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 164	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954

Specimen Composition Summary

Specimen ID	Alloy Trade Name	Base Metal MSC Lot Number	Base Metal Mill Heat Number	UNS Number	ASTM Specification	Base Metal Independent Test Report Number	Weld Filler MSC Lot Number	Weld Filler Mill Heat Number	AWS Specification	Weld Filler Independent Test Report Number	Statement of Conformity
ECA 165	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 167	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECA 168	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
ECD 001	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16	5001.023F	SOC-2 PO# B313954
ECD 002	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16	5001.023F	SOC-2 PO# B313954
ECD 003	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16	5001.023F	SOC-2 PO# B313954
ECD 004	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER TI-12	5001.023F	SOC-2 PO# B313954
ECD 005	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER TI-12	5001.023F	SOC-2 PO# B313954
ECD 006	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER TI-12	5001.023F	SOC-2 PO# B313954
ECD 032	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER TI-12	5001.023F	SOC-2 PO# B313954
ECD 061	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER TI-12	5001.023F	SOC-2 PO# B313954
ECD 062	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER TI-12	5001.023F	SOC-2 PO# B313954
ECD 063	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER TI-12	5001.023F	SOC-2 PO# B313954
ECD 064	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER TI-12	5001.023F	SOC-2 PO# B313954
ECD 065	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER TI-12	5001.023F	SOC-2 PO# B313954
ECD 066	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER TI-12	5001.023F	SOC-2 PO# B313954
ECD 067	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER TI-12	5001.023F	SOC-2 PO# B313954
ECD 068	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER TI-12	5001.023F	SOC-2 PO# B313954
ECD 069	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER TI-12	5001.023F	SOC-2 PO# B313954
ECD 070	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER TI-12	5001.023F	SOC-2 PO# B313954
ECD 071	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER TI-12	5001.023F	SOC-2 PO# B313954
ECD 072	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER TI-12	5001.023F	SOC-2 PO# B313954
ECD 091	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER TI-12	5001.023F	SOC-2 PO# B313954

Specimen Composition Summary

Specimen ID	Alloy Trade Name	Base Metal MSC Lot Number	Base Metal Mill Heat Number	UNS Number	ASTM Specification	Base Metal Independent Test Report Number	Weld Filler MSC Lot Number	Weld Filler Mill Heat Number	AWS Specification	Weld Filler Independent Test Report Number	Statement of Conformity
ECD 092	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 093	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 094	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 095	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 096	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 098	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 099	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 101	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 102	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 121	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 122	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 123	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 124	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 125	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 126	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 128	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 129	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 130	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 132	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 157	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 158	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 159	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 160	T[illegible]e 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 [illegible]	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954

Specimen Co[illegible]sition Summary

Specimen ID	Alloy Trade Name	Base Metal MSC Lot Number	Base Metal Mill Heat Number	UNS Number	ASTM Specification	Base Metal Independent Test Report Number	Weld Filler MSC Lot Number	Weld Filler Mill Heat Number	AWS Specification	Weld Filler Independent Test Report Number	Statement of Conformity
ECD 161	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 162	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 164	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 165	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 167	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
ECD 168	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWA 001	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 002	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 003	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 004	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 005	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 006	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 031	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 036	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 041	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 042	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 043	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 044	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 045	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 046	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 071	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 072	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 073	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954

Specimen Composition Summary

Specimen ID	Alloy Trade Name	Base Metal MSC Lot Number	Base Metal Mill Heat Number	UNS Number	ASTM Specification	Base Metal Independent Test Report Number	Weld Filler MSC Lot Number	Weld Filler Mill Heat Number	AWS Specification	Weld Filler Independent Test Report Number	Statement of Conformity
EWA 074	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 075	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 076	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 077	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 078	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 079	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 080	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 081	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 082	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 101	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 102	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 106	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 107	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 111	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 112	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 113	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 114	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 115	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 116	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 117	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 118	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 119	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 120	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954

Specimen Composition Summary

Specimen ID	Alloy Trade Name	Base Metal MSC Lot Number	Base Metal Mill Heat Number	UNS Number	ASTM Specification	Base Metal Independent Test Report Number	Weld Filler MSC Lot Number	Weld Filler Mill Heat Number	AWS Specification	Weld Filler Independent Test Report Number	Statement of Conformity
EWA 121	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 122	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 141	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 142	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 143	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 144	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 151	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 152	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	N/A	N/A	N/A	N/A	SOC-2 PO# B313954
EWA 164	Ti Grade 12	H427	T-5465	R53400	B265	ASP003-97-06-10156 (Page 8 of 13)	N/A	N/A	N/A	N/A	SOC-3 PO# B338959
EWA 165	Ti Grade 12	H427	T-5465	R53400	B265	ASP003-97-06-10156 (Page 8 of 13)	N/A	N/A	N/A	N/A	SOC-3 PO# B338959
EWA 168	Ti Grade 12	H427	T-5465	R53400	B265	ASP003-97-06-10156 (Page 8 of 13)	N/A	N/A	N/A	N/A	SOC-3 PO# B338959
EWA 169	Ti Grade 12	H427	T-5465	R53400	B265	ASP003-97-06-10156 (Page 8 of 13)	N/A	N/A	N/A	N/A	SOC-3 PO# B338959
EWA 170	Ti Grade 12	H427	T-5465	R53400	B265	ASP003-97-06-10156 (Page 8 of 13)	N/A	N/A	N/A	N/A	SOC-3 PO# B338959
EWA 171	Ti Grade 12	H427	T-5465	R53400	B265	ASP003-97-06-10156 (Page 8 of 13)	N/A	N/A	N/A	N/A	SOC-3 PO# B338959
EWD 001	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 002	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 003	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 004	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 005	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 006	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 031	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 036	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 041	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954

Specimen Composition Summary

Specimen ID	Alloy Trade Name	Base Metal MSC Lot Number	Base Metal Mill Heat Number	UNS Number	ASTM Specification	Base Metal Independent Test Report Number	Weld Filler MSC Lot Number	Weld Filler Mill Heat Number	AWS Specification	Weld Filler Independent Test Report Number	Statement of Conformity
EWD 042	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 043	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 044	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 045	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 046	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 071	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 072	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 073	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 074	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 075	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 076	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 077	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 078	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 079	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 080	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 081	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 082	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 101	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 102	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 106	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 111	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 112	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 113	T[illegible]de 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 [illegible]	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954

Specimen Composition Summary

Specimen ID	Alloy Trade Name	Base Metal MSC Lot Number	Base Metal Mill Heat Number	UNS Number	ASTM Specification	Base Metal Independent Test Report Number	Weld Filler MSC Lot Number	Weld Filler Mill Heat Number	AWS Specification	Weld Filler Independent Test Report Number	Statement of Conformity
EWD 114	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 115	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 116	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 118	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 119	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 121	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 122	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 141	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 142	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 151	Ti Grade 12	K957	BN2966	R53400	B265	ASP003-97-06-10156 (Page 9 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-2 PO# B313954
EWD 164	Ti Grade 12	H427	T-5465	R53400	B265	ASP003-97-06-10156 (Page 8 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-3 PO# B338959
EWD 168	Ti Grade 12	H427	T-5465	R53400	B265	ASP003-97-06-10156 (Page 8 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-3 PO# B338959
EWD 169	Ti Grade 12	H427	T-5465	R53400	B265	ASP003-97-06-10156 (Page 8 of 13)	L025	AT7879	A5.16 ER Ti-12	5001.023F	SOC-3 PO# B338959
PCA 003	316 L	N835	L923461	S31603	A240	TRW002-99-03-05598 (Pages 1 & 2 of 2)	N/A	N/A	N/A	N/A	SOC-4 PO# 500447
PCA 004	316 L	N835	L923461	S31603	A240	TRW002-99-03-05598 (Pages 1 & 2 of 2)	N/A	N/A	N/A	N/A	SOC-4 PO# 500447
PCA 005	316 L	N835	L923461	S31603	A240	TRW002-99-03-05598 (Pages 1 & 2 of 2)	N/A	N/A	N/A	N/A	SOC-4 PO# 500447
PCA 006	316 L	N835	L923461	S31603	A240	TRW002-99-03-05598 (Pages 1 & 2 of 2)	N/A	N/A	N/A	N/A	SOC-4 PO# 500447
PCA 007	316 L	N835	L923461	S31603	A240	TRW002-99-03-05598 (Pages 1 & 2 of 2)	N/A	N/A	N/A	N/A	SOC-4 PO# 500447
PCA 008	316 L	N835	L923461	S31603	A240	TRW002-99-03-05598 (Pages 1 & 2 of 2)	N/A	N/A	N/A	N/A	SOC-4 PO# 500447
PCA 009	316 L	N835	L923461	S31603	A240	TRW002-99-03-05598 (Pages 1 & 2 of 2)	N/A	N/A	N/A	N/A	SOC-4 PO# 500447
PCA 010	316 L	N835	L923461	S31603	A240	TRW002-99-03-05598 (Pages 1 & 2 of 2)	N/A	N/A	N/A	N/A	SOC-4 PO# 500447
PCA 011	316 L	N835	L923461	S31603	A240	TRW002-99-03-05598 (Pages 1 & 2 of 2)	N/A	N/A	N/A	N/A	SOC-4 PO# 500447
PCA 012	316 L	N835	L923461	S31603	A240	TRW002-99-03-05598 (Pages 1 & 2 of 2)	N/A	N/A	N/A	N/A	SOC-4 PO# 500447

Base Metal Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Tensile (ksi)	Yield (ksi)	% Elongation
DCA 001	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 002	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 003	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 004	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 005	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 006	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 031	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 032	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 033	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 034	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 035	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 036	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 061	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 062	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 063	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 064	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 065	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 066	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 067	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 068	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 069	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 070	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 071	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1

Base Metal Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Tensile (ksi)	Yield (ksi)	% Elongation
DCA 072	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 091	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 092	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 093	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 094	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 095	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 096	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 098	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 099	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 101	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 102	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 121	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 122	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 123	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 124	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 125	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 126	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 128	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 129	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 130	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 132	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 157	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 158	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1

Base Metal Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Tensile (ksi)	Yield (ksi)	% Elongation
DCA 159	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 160	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 161	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 162	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 164	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 165	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 167	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 168	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCA 244	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DCA 245	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DCA 246	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DCA 247	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DCA 248	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DCA 249	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DCA 250	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DCA 251	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DCA 252	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DCA 253	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DCB 001	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 002	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 003	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 004	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 005	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1

Base Metal Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Tensile (ksi)	Yield (ksi)	% Elongation
DCB 006	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 031	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 032	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 033	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 034	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 035	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 036	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 061	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 062	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 063	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 064	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 065	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 066	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 067	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 068	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 069	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 070	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 071	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 072	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 091	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 092	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 093	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 094	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1

Base Metal Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Tensile (ksi)	Yield (ksi)	% Elongation
DCB 095	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 096	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 098	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 099	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 101	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 102	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 121	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 122	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 123	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 124	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 125	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 126	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 128	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 129	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 130	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 132	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 157	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 158	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 159	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 160	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 161	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 162	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 164	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1

Base Metal Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Tensile (ksi)	Yield (ksi)	% Elongation
DCB 165	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 167	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DCB 168	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DEA 002	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 003	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 004	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 005	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 006	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 007	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 008	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 009	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 010	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 011	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 012	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 013	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 014	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 015	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 016	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 017	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 019	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 020	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 021	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 022	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0

Base Metal Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Tensile (ksi)	Yield (ksi)	% Elongation
DEA 023	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 024	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 025	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 026	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 027	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 029	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 031	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 032	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 033	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 034	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 035	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 159	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 201	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 202	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 203	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DEA 209	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DWA 001	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 002	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 003	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 004	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 005	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 006	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 031	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1

Base Metal Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Tensile (ksi)	Yield (ksi)	% Elongation
DWA 036	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 041	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 042	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 043	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 044	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 045	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 046	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 071	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 072	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 073	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 074	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 075	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 076	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 077	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 078	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 079	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 080	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 081	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 082	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 101	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 102	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 106	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 111	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1

Base Metal Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Tensile (ksi)	Yield (ksi)	% Elongation
DWA 112	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 113	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 114	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 115	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 116	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 118	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 119	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 121	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 122	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 141	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 142	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 143	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 144	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 151	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 152	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWA 164	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DWA 165	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DWA 169	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DWA 170	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DWA 171	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DWB 001	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 002	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 003	[illegible]	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Tensile (ksi)	Yield (ksi)	% Elongation
DWB 004	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 005	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 006	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 031	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 036	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 041	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 042	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 043	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 044	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 045	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 046	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 072	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 073	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 074	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 075	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 076	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 077	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 078	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 079	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 080	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 081	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 082	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 101	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1

Base Metal Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Tensile (ksi)	Yield (ksi)	% Elongation
DWB 102	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 106	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 111	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 112	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 113	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 114	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 115	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 116	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 118	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 119	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 121	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 122	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 141	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 142	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 144	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 151	0.004	0.32	0.01	<0.01	0.07	22.3	Rem	13.8			4.9			3.0	1.4	0.23	121.44	62.42	59.1
DWB 164	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DWB 168	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
DWB 169	0.005	0.22	0.01	<0.01	0.05	22.0	Rem	13.5			4.4			3.0	2.3	0.19	119.46	59.82	62.0
ECA 001	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 002	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 003	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 004	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5

Base Metal Inde[illegible]dent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Tensile (ksi)	Yield (ksi)	% Elongation
ECA 005	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 006	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 031	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 032	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 033	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 034	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 035	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 036	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 061	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 062	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 063	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 064	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 065	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 066	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 067	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 068	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 069	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 070	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 071	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 072	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 091	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 092	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 093	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5

Base Metal Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Tensile (ksi)	Yield (ksi)	% Elongation
ECA 094	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 096	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 098	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 099	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 101	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 102	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 121	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 122	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 123	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 124	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 125	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 126	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 128	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 129	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 130	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 132	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 157	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 158	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 159	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 160	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 161	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 162	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 164	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Tensile (ksi)	Yield (ksi)	% Elongation
ECA 165	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 167	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECA 168	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 001	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 002	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 003	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 004	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 005	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 006	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 032	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 061	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 062	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 063	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 064	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 065	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 066	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 067	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 068	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 069	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 070	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 071	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 072	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 091	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5

Base Metal Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Tensile (ksi)	Yield (ksi)	% Elongation
ECD 092	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 093	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 094	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 095	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 096	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 098	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 099	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 101	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 102	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 121	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 122	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 123	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 124	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 125	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 126	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 128	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 129	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 130	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 132	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 157	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 158	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 159	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 160	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5

Base Metal Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Tensile (ksi)	Yield (ksi)	% Elongation
ECD 161	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 162	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 164	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 165	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 167	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
ECD 168	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 001	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 002	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 003	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 004	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 005	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 006	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 031	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 036	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 041	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 042	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 043	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 044	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 045	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 046	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 071	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 072	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 073	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5

Base Metal Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Tensile (ksi)	Yield (ksi)	% Elongation
EWA 074	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 075	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 076	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 077	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 078	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 079	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 080	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 081	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 082	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 101	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 102	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 106	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 107	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 111	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 112	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 113	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 114	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 115	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 116	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 117	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 118	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 119	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 120	[illegible]						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5

Base Metal Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Tensile (ksi)	Yield (ksi)	% Elongation
EWA 121	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 122	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 141	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 142	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 143	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 144	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 151	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 152	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWA 164	0.02						0.8	0.3	0.01	0.005	0.13	0.14	Rem				88.41	64.7	25.1
EWA 165	0.02						0.8	0.3	0.01	0.005	0.13	0.14	Rem				88.41	64.7	25.1
EWA 168	0.02						0.8	0.3	0.01	0.005	0.13	0.14	Rem				88.41	64.7	25.1
EWA 169	0.02						0.8	0.3	0.01	0.005	0.13	0.14	Rem				88.41	64.7	25.1
EWA 170	0.02						0.8	0.3	0.01	0.005	0.13	0.14	Rem				88.41	64.7	25.1
EWA 171	0.02						0.8	0.3	0.01	0.005	0.13	0.14	Rem				88.41	64.7	25.1
EWD 001	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 002	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 003	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 004	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 005	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 006	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 031	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 036	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 041	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5

Base Metal Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Tensile (ksi)	Yield (ksi)	% Elongation
EWD 042	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 043	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 044	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 045	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 046	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 071	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 072	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 073	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 074	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 075	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 076	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 077	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 078	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 079	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 080	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 081	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 082	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 101	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 102	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 106	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 111	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 112	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 113	[illegible]						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	[illegible]	21.5

Base Metal Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Tensile (ksi)	Yield (ksi)	% Elongation
EWD 114	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 115	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 116	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 118	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 119	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 121	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 122	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 141	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 142	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 151	0.02						0.8	0.3	0.02	0.002	0.05	0.16	Rem				87.8	67.9	21.5
EWD 164	0.02						0.8	0.3	0.01	0.005	0.13	0.14	Rem				88.41	64.7	25.1
EWD 168	0.02						0.8	0.3	0.01	0.005	0.13	0.14	Rem				88.41	64.7	25.1
EWD 169	0.02						0.8	0.3	0.01	0.005	0.13	0.14	Rem				88.41	64.7	25.1
PCA 003	0.011	1.85	0.020	0.003	0.30	16.64	10.35	2.11	0.05								85.51	42.08	46.4
PCA 004	0.011	1.85	0.020	0.003	0.30	16.64	10.35	2.11	0.05								85.51	42.08	46.4
PCA 005	0.011	1.85	0.020	0.003	0.30	16.64	10.35	2.11	0.05								85.51	42.08	46.4
PCA 006	0.011	1.85	0.020	0.003	0.30	16.64	10.35	2.11	0.05								85.51	42.08	46.4
PCA 007	0.011	1.85	0.020	0.003	0.30	16.64	10.35	2.11	0.05								85.51	42.08	46.4
PCA 008	0.011	1.85	0.020	0.003	0.30	16.64	10.35	2.11	0.05								85.51	42.08	46.4
PCA 009	0.011	1.85	0.020	0.003	0.30	16.64	10.35	2.11	0.05								85.51	42.08	46.4
PCA 010	0.011	1.85	0.020	0.003	0.30	16.64	10.35	2.11	0.05								85.51	42.08	46.4
PCA 011	0.011	1.85	0.020	0.003	0.30	16.64	10.35	2.11	0.05								85.51	42.08	46.4
PCA 012	0.011	1.85	0.020	0.003	0.30	16.64	10.35	2.11	0.05								85.51	42.08	46.4

Weld Filler Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Cu	Ni + Co	Others Total
DCB 001	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 002	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 003	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 004	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 005	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 006	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 031	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 032	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 033	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 034	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 035	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 036	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 061	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 062	0.008	0.25	0.01	0.001	0.03	21.3		12.6			3.9			3.0	1.9	0.13	0.10	Rem	
DCB 063	0.006	0.25	0.01	0.001	0.03	21.3		12.6			3.9			3.0	1.9	0.13	0.10	Rem	
DCB 064	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 065	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 066	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 067	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 068	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 069	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 070	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 071	0[illegible]	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20

Weld Filler Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Cu	Ni + Co	Others Total
DCB 072	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 091	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 092	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 093	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 094	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 095	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 096	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 098	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 099	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 101	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 102	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 121	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 122	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 123	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 124	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 125	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 126	0.008	0.25	0.01	0.001	0.03	21.3		12.6			3.9			3.0	1.9	0.13	0.10	Rem	
DCB 128	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 129	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 130	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 132	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 157	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 158	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20

Weld Filler Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Cu	Ni + Co	Others Total
DCB 159	0.008	0.25	0.01	0.001	0.03	21.3		12.6			3.9			3.0	1.9	0.13	0.10	Rem	
DCB 160	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 161	0.008	0.25	0.01	0.001	0.03	21.3		12.6			3.9			3.0	1.9	0.13	0.10	Rem	
DCB 162	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 164	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 165	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 167	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DCB 168	0.008	0.25	0.01	0.001	0.03	21.3		12.6			3.9			3.0	1.9	0.13	0.10	Rem	
DWB 001	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 002	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 003	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 004	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 005	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 006	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 031	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 036	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 041	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 042	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 043	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 044	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 045	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 046	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 072	0.00[illegible]	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20

Weld Filler Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Cu	Ni + Co	Others Total
DWB 073	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 074	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 075	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 076	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 077	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 078	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 079	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 080	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 081	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 082	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 101	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 102	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 106	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 111	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 112	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 113	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 114	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 115	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 116	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 118	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 119	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 121	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 122	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20

Weld Filler Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Cu	Ni + Co	Others Total
DWB 141	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 142	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 144	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 151	0.005	0.27	0.01	0.002	0.05	20.6		13.2			3.0			2.8	1.0	0.14	0.06	Rem	0.20
DWB 164	0.008	0.25	0.01	0.001	0.03	21.3		12.6			3.9			3.0	1.9	0.13	0.10	Rem	
DWB 168	0.008	0.25	0.01	0.001	0.03	21.3		12.6			3.9			3.0	1.9	0.13	0.10	Rem	
DWB 169	0.008	0.25	0.01	0.001	0.03	21.3		12.6			3.9			3.0	1.9	0.13	0.10	Rem	
ECD 001	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 002	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 003	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 004	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 005	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 006	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 032	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 061	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 062	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 063	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 064	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 065	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 066	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 067	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 068	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 069	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						

Weld Filler Inde... .dent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Cu	Ni + Co	Others Total
ECD 070	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 071	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 072	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 091	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 092	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 093	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 094	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 095	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 096	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 096	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 099	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 101	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 102	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 121	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 122	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 123	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 124	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 125	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 126	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 128	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 129	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 130	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 132	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						

Weld Filler Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Cu	Ni + Co	Others Total
ECD 157	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 158	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 159	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 160	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 161	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 162	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 164	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 165	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 167	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
ECD 168	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 001	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 002	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 003	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 004	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 005	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 006	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 031	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 036	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 041	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 042	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 043	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 044	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 045	0.00[illegible]						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						

Weld Filler Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	Ti (%)	W (%)	Co (%)	V (%)	Cu	Ni + Co	Others Total
EWD 048	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 071	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 072	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 073	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 074	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 075	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 076	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 077	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 078	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 079	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 080	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 081	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 082	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 101	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 102	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 106	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 111	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 112	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 113	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 114	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 115	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 116	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 118	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						

Weld Filler Independent Test Results

Specimen ID	C (%)	Mn (%)	P (%)	S (%)	SI (%)	Cr (%)	NI (%)	Mo (%)	N (%)	H (%)	Fe (%)	O (%)	TI (%)	W (%)	Co (%)	V (%)	Cu	NI + Co	Others Total
EWD 119	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 121	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 122	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 141	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 142	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 151	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 164	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 166	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						
EWD 169	0.006						0.82	0.30	0.004	0.0044	0.12	0.08	Rem						

Metal Samples Co., Inc.
152 Metal Samples Road
P.O. Box 8
Munford, Alabama 36268
USA
205/358-4202
Fax: 205/358-4515

Metal Samples®
A Subsidiary of Alabama Specialty Products, Inc.

SEPTEMBER 08, 1995

STATEMENT OF CONFORMITY

SOC - 1

METAL SAMPLES QUALITY ASSURANCE CERTIFIES AND AFFIRMS THAT ALL PRODUCT SUPPLIED AGAINST P.O #B313954 HAS BEEN MANUFACTURED IN ACCORDANCE WITH ALL QUALITY REQUIREMENTS AS SET FORTH IN THE ABOVE MENTIONED PURCHASE ORDER INCLUDING THE USE OF C22 ALLOY MATERIAL (M.S. LOT #H157).

USAGE AS FOLLOWS:

LOT #H157 -- DCB 001 - DCB 243, 2"x2" WELDED CREVICE COUPONS
-- DUB 001 - DUB 163, WELDED U-BENDS
-- DWB 001 - DWB 163, 1"x2" WELDED WT. LOSS COUPONS
-- DCA 001 - DCA 243, 2"x2" CREVICE COUPONS
-- DUA 001 - DUA 163, BASE MAT'L U-BENDS
-- DWA 001 - DWA 163, 1"x2" WT. LOSS COUPONS

ALL FILLER MATERIAL FOR WELDING OF C22 ORIGINALS WAS LOT #K926.
ALL FILLER MATERIAL FOR WELDING OF C22 REMAKES WAS LOT #L098 (SEE LIST FOR REMAKE NUMBERS).

LARRY BRADEN
QUALITY CONTROL MANAGER

SUPPLEMENT TO STATEMENT OF CONFORMITY SOC - 1

PO# B313954 SEPTEMBER 08, 1995

SOC - 1A

LIST OF C22 ALLOY SPECIMENS FROM SECOND WELD FILLER LOT

C22 WELDED U-BENDS	C22 WELDED CREVICE SPECIMENS	
DUB009	DCB010	DCB168
DUB030	DCB015	DCB170
DUB036	DCB017	DCB173
DUB037	DCB021	DCB175
DUB062	DCB023	DCB188
DUB067	DCB024	DCB191
DUB068	DCB026	DCB203
DUB080	DCB027	DCB211
DUB095	DCB029	DCB221
DUB097	DCB030	DCB224
DUB098	DCB042	DCB225
DUB134	DCB043	DCB226
DUB135	DCB047	DCB227
DUB136	DCB054	DCB228
DUB138	DCB055	DCB229
DUB139	DCB058	DCB230
DUB147	DCB059	DCB231
DUB148	DCB062	DCB232
DUB149	DCB063	DCB233
DUB153	DCB076	DCB234
DUB154	DCB081	DCB235
DUB155	DCB109	DCB236
DUB158	DCB119	DCB237
	DCB120	DCB238
	DCB126	DCB239
	DCB136	DCB240
	DCB138	DCB241
	DCB159	DCB242
	DCB161	DCB243
	DCB163	

April 30, 1997

STATEMENT OF CONFORMITY
(AMENDED 08 MAY 1997)

SOC - 3

ALABAMA SPECIALTY PRODUCTS QUALITY ASSURANCE CERTIFIES AND AFFIRMS THAT ALL PRODUCT SUPPLIED AGAINST P.O.#B338959 HAS BEEN MANUFACTURED IN ACCORDANCE WITH ALL QUALITY REQUIREMENTS AS SET FORTH IN THE ABOVE MENTIONED PURCHASE ORDER.

P/N	BASE METAL ALLOY/LOT#	FILLER ALLOY/LOT#	SEQ.#
CO1296141304000	I825/J927	N/A	AWA 164 - AWA 178
CO129A161304000	G3/H230	N/A	BWA 164 - BWA 178
CO129A131304000	C4/K933	N/A	CWA 164 - CWA 178
CO129A111304000	C22/K932	N/A	DWA 164 - DWA 178
CO1298011304000	TIGR12/H427	N/A	EWA 164 - EWA 178
CO129B361304000	TIGR16/L384	N/A	FWA 164 - FWA 178
CO1296141324000	I825/J927	C22/L098	AWB 164 - AWB 178
CO129A161324000	G3/H230	G3/M176	BWC 164 - BWC 178
CO129A131324000	C4/K933	C22/L098	CWB 164 - CWB 178
CO129A111324000	C22/K932	C22/L098	DWB 164 - DWB 178
CO1298011324000	TIGR12/H427	TI-12/L025	EWD 164 - EWD 178
CO129B361324000	TIGR16/L384	TI-7/K965	FWE 164 - FWE 178

Larry Braden

LARRY BRADEN
QUALITY CONTROL MANAGER

Metal Samples

ALABAMA LASER TECHNOLOGIES
"Innovations for laser manufacturing"

ALABAMA RESEARCH AND DEVELOPMENT

April 30, 1997

STATEMENT OF CONFORMITY
(AMENDED 08 MAY 1997)

SOC - 3

ALABAMA SPECIALTY PRODUCTS QUALITY ASSURANCE CERTIFIES AND AFFIRMS THAT ALL PRODUCT SUPPLIED AGAINST P.O.#B338959 HAS BEEN MANUFACTURED IN ACCORDANCE WITH ALL QUALITY REQUIREMENTS AS SET FORTH IN THE ABOVE MENTIONED PURCHASE ORDER.

P/N	BASE METAL ALLOY/LOT#	FILLER ALLOY/LOT#	SEQ.#
CO1296141304000	I825/J927	N/A	AWA 164 - AWA 178
CO129A161304000	G3/H230	N/A	BWA 164 - BWA 178
CO129A131304000	C4/K933	N/A	CWA 164 - CWA 178
CO129A111304000	C22/K932	N/A	DWA 164 - DWA 178
CO1298011304000	TIGR12/H427	N/A	EWA 164 - EWA 178
CO129B361304000	TIGR16/L384	N/A	FWA 164 - FWA 178
CO1296141324000	I825/J927	C22/L098	AWB 164 - AWB 178
CO129A161324000	G3/H230	G3/M176	BWC 164 - BWC 178
CO129A131324000	C4/K933	C22/L098	CWB 164 - CWB 178
CO129A111324000	C22/K932	C22/L098	DWB 164 - DWB 178
CO1298011324000	TIGR12/H427	TI-12/L025	EWD 164 - EWD 178
CO129B361324000	TIGR16/L384	TI-7/K965	FWE 164 - FWE 178

LARRY BRADEN
QUALITY CONTROL MANAGER

January 11, 1999

STATEMENT OF CONFORMITY

SOC - 4

METAL SAMPLES CO. QUALITY ASSURANCE CERTIFIES AND AFFIRMS THAT PRODUCT SUPPLIED AGAINST P.O.#B500447 HAS BEEN MANUFACTURED IN ACCORDANCE WITH ALL QUALITY REQUIREMENTS AS SET FORTH IN THE ABOVE-MENTIONED PURCHASE ORDER AND/OR ENGINEERING CHANGE ORDER. MATERIALS, WORKMANSHIP AND DIMENSIONAL INTEGRITY OF THE PRODUCT SUPPLIED WERE VERIFIED IN ACCORDANCE WITH THE REQUIREMENTS OF OUR ISO 9001 CERTIFIED QUALITY SYSTEM.

MATERIAL - TI-GR7 (#N284)	SEQUENCE - NCA 184 THRU NCA 223
TI-GR16 (#L384)	FCA 244 THRU FCA 283
C22 (#K932)	DCA 244 THRU DCA 283
304 (#P384)	OCA 001 THRU OCA 040
316L (#N835)	PCA 001 THRU PCA 040

Larry Braden

LARRY BRADEN KT

QUALITY MANAGER

Metal Samples Co.

ALABAMA LASER TECHNOLOGIES "Innovations for laser manufacturing"

ALABAMA RESEARCH AND DEVELOPMENT

March 18 1998

STATEMENT OF CONFORMITY

SOC - 5

METAL SAMPLES CO QUALITY ASSURANCE CERTIFIES AND AFFIRMS THAT PRODUCT SUPPLIED AGAINST P.O #A15382YS9B HAS BEEN MANUFACTURED IN ACCORDANCE WITH ALL QUALITY REQUIREMENTS AS SET FORTH IN THE ABOVE-MENTIONED PURCHASE ORDER AND/OR ENGINEERING CHANGE ORDER. MATERIALS, WORKMANSHIP AND DIMENSIONAL INTEGRITY OF THE PRODUCT SUPPLIED WERE VERIFIED IN ACCORDANCE WITH THE REQUIREMENTS OF OUR ISO 9001 CERTIFIED QUALITY SYSTEM

LINE NUMBER	MATERIAL	SEQUENCE
06	TIGR7 (P666)	NEA 341 THRU NEA 360
07	TIGR2 (M628)	TEA 001 THRU TEA 030
08	TIGR12 (M273)	EEA 051 THRU EEA 080
09	TIGR5 (M629)	UEA 001 THRU UEA 010
10	C4 (M475)	REA 001 THRU REA 020
11	C22 (K932)	DEA 311 THRU DEA 335
12	304L (N696)	SEA 001 THRU SEA 025
13	316L (P012)	PEA 311 THRU PEA 335
14	ERNICRMO10 (P658)	E2067 WIRE 1
15	ERNICRMO10 (P657)	E2067 WIRE 2
19	316L (P463)	PEA 041 THRU PEA 060
20	C22 (P651)	DEA 041 THRU DEA 060
22	TIGR7 (P646)	NEA 071 THRU NEA 090
23	316L (P463)	PEA 061 THRU PEA 110
24	C22 (P651)	DEA 061 THRU DEA 110
26	TIGR7 (P648)	NEA 091 THRU NEA 140
27	316L (N835)	PEA 111 THRU PEA 310
28	C22 (K932)	DEA 111 THRU DEA 310
30	TIGR7 (N284)	NEA 141 THRU NEA 340

LARRY BRADEN
QUALITY MANAGER

Certificate of Conformance

LABORATORY TESTING INC.

NO. ASP003-97-06-10156

P.O. Box 249 Dublin, Pennsylvania 18917
TELE: (215) 249-0006 • FAX: (215) 249-0056

SHIPPING ADDRESS
120 MILL STREET, DUBLIN, PA 18917

SOLD TO
ALABAMA SPECIALTY PRODUCTS INC
PO BOX 8
MUNFORD, AL 36268

SHIP TO
ALABAMA SPECIALTY PRODUCTS INC.
152 METAL SAMPLES ROAD
MUNFORD, AL 36268

ATTN: LAVON CARR

CUSTOMER P.O.	CERTIFICATION DATE	SHIP VIA
34604	06/27/97	FAX AND MAIL

*CORRECTED CERTIFICATION (7/1/97)

One piece of the referenced samples was submitted to chemical content evaluation and it was found to be in conformance to ASTM B-575-94, Alloy Hastelloy C22 with the following results:

	REQUIREMENTS			
ELEMENT	MIN	MAX	LOT #H157	U/M
Molybdenum	12.5	14.5	13.8	%
Chromium	20.0	22.5	22.3	%
Iron	2.0	6.0	4.9	%
Tungsten	2.5	3.5	3.0	%
Cobalt	0.0	2.5	1.4	%
Carbon	0.000	0.015	0.004	%
Silicon	0.00	0.08	0.07	%
Manganese	0.00	0.50	0.32	%
Vanadium	0.00	0.35	0.23	%
Phosphorus	0.00	0.02	0.01	%
Sulfur	0.00	0.02	<0.01	%
Nickel	REMAINDER		REMAINDER	

A Tensile test was performed on (1) piece of the submitted Test Specimens in accordance with ASTM E-8 and (1) piece was found to be in *conformance to ASTM B-575-94, Alloy Hastelloy C22 with the following results:

LOT #	TENSILE STRENGTH	YIELD (.2%) STRENGTH	ELONGATION (IN 4D)
*REQUIRED	100,000 PSI	45,000 PSI	45.0%
H157	121,440 PSI	62,420 PSI	59.1%

The services performed above were done in accordance with LTI's Quality System Program Manual Revision 12 dated 12/2/96. These results relate only to the items tested and this report shall not be reproduced except in full, without the written approval of Laboratory Testing, Inc.

Arnold L. Horoff
Quality Assurance Manager

MERCURY CONTAMINATION - During the testing and inspection, the product did not come in direct contact with mercury or any of its compounds nor with any mercury containing devices employing a single boundary of containment.

By: Arnold L Horoff
AUTHORIZED SIGNATURE(S)

SUBJECT TO TERMS AND CONDITIONS PRINTED ON REVERSE SIDE OF THIS FORM.

Certificate of Conformance

LABORATORY TESTING INC.
P.O. Box 249 Dublin, Pennsylvania 18917
TELE: (215) 249-9898 • FAX: (215) 249-9656

NO. ASP003-97-06-10156

SHIPPING ADDRESS
120 MILL STREET, DUBLIN, PA 18917

SOLD TO
ALABAMA SPECIALTY PRODUCTS INC
PO BOX 8
MUNFORD, AL 36268

SHIP TO
ALABAMA SPECIALTY PRODUCTS INC.
152 METAL SAMPLES ROAD
MUNFORD, AL 36268

ATTN: LAVON CARR

CUSTOMER P.O.	CERTIFICATION DATE	SHIP VIA
34604	06/27/97	FAX AND MAIL

*CORRECTED CERTIFICATION (7/1/97)

One piece of the referenced samples was submitted to chemical content evaluation and it was found to be in conformance to ASTM B-575, Alloy Hastelloy C22 with the following results:

ELEMENT	REQUIREMENTS MIN	MAX	LOT #K932	U/M
Molybdenum	12.5	14.5	13.6	%
Chromium	20.0	22.5	22.0	%
Iron	2.0	6.0	4.4	%
Tungsten	2.5	3.5	3.0	%
Cobalt	0.0	2.5	2.3	%
Carbon	0.000	0.015	0.005	%
Silicon	0.00	0.08	0.05	%
Manganese	0.00	0.50	0.22	%
Vanadium	0.00	0.35	0.19	%
Phosphorus	0.00	0.02	0.01	%
Sulfur	0.00	0.02	<0.01	%
Nickel	REMAINDER		REMAINDER	

A Tensile test was performed on (1) piece of the submitted Test Specimens in accordance with ASTM E-8 and (1) piece was found to be in *conformance to ASTM B-575, Alloy Hastelloy C22 with the following results:

LOT #	TENSILE STRENGTH	YIELD (.2%) STRENGTH	ELONGATION (IN 4D)
*REQUIRED	100,000 PSI	45,000 PSI	45.0%
K932	119,460 PSI	59,820 PSI	62.0%

The services performed above were done in accordance with LTI's Quality System Program Manual Revision 12 dated 12/2/96. These results relate only to the items tested and this report shall not be reproduced except in full, without the written approval of Laboratory Testing, Inc.

Same as following page

Arnold L. Horoff
Quality Assurance Manager

By: Arnold L. Horoff
AUTHORIZED SIGNATURE

... During the testing and ... came in direct contact ... compounds nor with any ...

Certificate of Conformance

59 of 128

LABORATORY TESTING INC.
P.O. Box 249 Dublin, Pennsylvania 18917
TELE: (215) 249-8066 - FAX: (215) 249-9056

No. ASP003-97-06-10156

SHIPPING ADDRESS
120 MILL STREET, DUBLIN, PA 18917

SOLD TO
ALABAMA SPECIALTY PRODUCTS INC
PO BOX 8
MUNFORD, AL 36268

SHIP TO
ALABAMA SPECIALTY PRODUCTS INC.
152 METAL SAMPLES ROAD
MUNFORD, AL 36268

ATTN: LAVON CARR

CUSTOMER P.O.	CERTIFICATION DATE	SHIP VIA
34604	06/27/97	FAX AND MAIL

One piece of the referenced samples was submitted to chemical content evaluation and it was found to be in conformance to ASTM B-265, Alloy Titanium, Grade 12 with the following results:

ELEMENT	REQUIREMENTS MIN	MAX	LOT #K957	U/M
Nitrogen	0.00	0.03	0.02	%
Carbon	0.00	0.08	0.02	%
*Hydrogen	0.000	0.015	0.002	%
Iron	0.00	0.30	0.05	%
Oxygen	0.00	0.25	0.16	%
Molybdenum	0.2	0.4	0.3	%
Nickel	0.6	0.9	0.8	%
Titanium	REMAINDER		REMAINDER	

*Testing performed by L. Wax Inc.

A Tensile test was performed on (1) piece of the submitted Test Specimens in accordance with ASTM E-8 and (1) piece was found to be in conformance to ASTM B-265, Grade 12 with the following results:

LOT #	TENSILE STRENGTH	YIELD (.2%) STRENGTH	ELONGATION (IN 1")
REQUIRED	70,000 PSI	50,000 PSI	18.0%
K957	87,800 PSI	67,900 PSI	21.5%

The services performed above were done in accordance with LTI's Quality System Program Manual Revision 12 dated 12/2/96. These results relate only to the items tested and this report shall not be reproduced except in full, without the written approval of Laboratory Testing, Inc.

Arnold L. Horoff
Quality Assurance Manager

By: Arnold L Horoff
AUTHORIZED SIGNATURE

MERCURY CONTAMINATION - During the testing and inspection, the product did not come in direct contact with mercury or any of its compounds nor with any mercury containing devices employing a single boundary of containment.

Certificate of Conformance

LABORATORY TESTING INC.

NO. ASP003-97-06-10156

P.O. Box 249 Dublin, Pennsylvania 18917
TELE: (215) 249-0000 • FAX: (215) 249-8699

SHIPPING ADDRESS
120 MILL STREET, DUBLIN, PA 18917

SOLD TO
ALABAMA SPECIALTY PRODUCTS INC
PO BOX 8
MUNFORD, AL 36268

SHIP TO
ALABAMA SPECIALTY PRODUCTS INC.
152 METAL SAMPLES ROAD
MUNFORD, AL 36268

ATTN: LAVON CARR

CUSTOMER P.O.	CERTIFICATION DATE	SHIP VIA
34604	06/27/97	FAX AND MAIL

One piece of the referenced samples was submitted to chemical content evaluation and it was found to be in conformance to ASTM B-265, Alloy Titanium, Grade 12 with the following results:

ELEMENT	REQUIREMENTS MIN	MAX	LOT #H427	U/M
Nitrogen	0.00	0.03	0.01	%
Carbon	0.00	0.08	0.02	%
*Hydrogen	0.000	0.015	0.005	%
Iron	0.00	0.30	0.13	%
Oxygen	0.00	0.25	0.14	%
Molybdenum	0.2	0.4	0.3	%
Nickel	0.6	0.9	0.8	%
Titanium	REMAINDER		REMAINDER	%

*Testing performed by Luvak Inc.

A Tensile test was performed on (1) piece of the submitted Test Specimens in accordance with ASTM E-8 and (1) piece was found to be in conformance to ASTM B-265, Grade 12 with the following results:

LOT #	TENSILE STRENGTH	YIELD (.2%) STRENGTH	ELONGATION (IN 1")
REQUIRED	70,000 PSI	50,000 PSI	18.0%
H427	86,410 PSI	64,700 PSI	25.1%

The services performed above were done in accordance with LTI's Quality System Program Manual Revision 12 dated 12/2/96. These results relate only to the items tested and this report shall not be reproduced except in full, without the written approval of Laboratory Testing, Inc.

Arnold L. Hooff
Quality Assurance Manager

MERCURY CONTAMINATION - During the testing and inspection, the product did not come in direct contact with mercury or any of its compounds nor with any mercury containing devices employing a single boundary of containment.

By: [signature]
AUTHORIZED SIGNATURE

SUBJECT TO TERMS AND CONDITIONS PRINTED ON REVERSE SIDE OF THIS FORM.

Certified Test Report

TRW002-99-03-05598

LABORATORY TESTING INC.
PO Box 249, 120 Mill St., Dublin, PA 18917
TEL: 800-627-3966 • FAX: 215-249-9656

ACCREDITED NADCAP

SOLD TO
TRW ENVIRON.SAFETY SYSTEMS, INC.
2650 PARK TOWER DRIVE
SUITE 800
VIENNA, VA 22180
ATTN: ACCOUNTS PAYABLE

SHIP TO
NEVADA
TRW c/o Lawrence Livermore Natl Lab
7000 East Avenue
Livermore, CA 94550
ATTN: JOHN ESTILL

CUSTOMER P.O.	CERTIFICATION DATE	SHIP VIA
A15385YS9A	3/23/99	FAX & UPS

DESCRIPTION

1 pc. 1/2" x 6" x 1/8" Thick Test Piece, ASTM A-240, Alloy 316L Stainless Steel/UNS S31603, Specimen Identification PEA CHECK 1, Specimen Origin PO # /Lot #B500447/N835, Item #28

Reference: Account No. 8766-92, RFQ LV.SC.YS.2/99.012

The referenced sample was submitted to chemical content evaluation and it was found to be in conformance to ASTM A-240, UNS S31603, Alloy 316L Stainless Steel with the following results:

ELEMENT	REQUIREMENTS MIN.	MAX.	ACTUAL
C	0.000	0.030	0.011%
Mn	0.00	2.00	1.85%
P	0.000	0.045	0.020%
S	0.000	0.030	0.003%
Si	0.00	0.75	0.30%
Cr	16.00	18.00	16.64%
Ni	10.00	14.00	10.35%
Mo	2.00	3.00	2.11%
N	0.00	0.10	0.05%

Certified Test Report
TRW002-99-03-05598

LABORATORY TESTING INC.
PO Box 249, 120 Mill St., Dublin, PA 18917
TEL: 800-627-3966 • FAX: 215-249-9656

A Tensile test was performed on the submitted Test Specimen and it was found to be in conformance to ASTM A-240, UNS S31603, Alloy 316L Stainless Steel with the following results:

	TENSILE STRENGTH	YIELD (.2%) STRENGTH	ELONGATION (IN 2")
REQUIRED	**70,000 PSI**	**25,000 PSI**	**40.0%**
ACTUAL	85,510 PSI	42,080 PSI	46.4%

A Hardness test was performed on the submitted Test Specimen and it was found to be in conformance to ASTM A-240, UNS S31603, Alloy 316L Stainless Steel with the following results:

REQUIRED: RB 95 MAXIMUM

ACTUAL: RB 81.0, 81.0, 81.5, 80.5 / **AVERAGE:** RB 81.0

The services performed above were done in accordance with LTI's Quality System Program Manual Revision 13 dated 3/16/98. These results relate only to the items tested and this report shall not be reproduced, except in full, without the written approval of Laboratory Testing, Inc.

Sherri L. Lengyel
QA Coordinator

By: Sherri L. Lengyel
Authorized Signature

Certificate of Conformance

No. ASP003-97-05-09164

LABORATORY TESTING INC.
P.O. Box 249 Dublin, Pennsylvania 18917
TELE: (215) 249-8898 • FAX: (215) 249-9656

SHIPPING ADDRESS
120 MILL STREET, DUBLIN, PA 18917

SOLD TO
ALABAMA SPECIALTY PRODUCTS INC
PO BOX 8
MUNFORD, AL 36268

SHIP TO
ALABAMA SPECIALTY PRODUCTS INC.
152 METAL SAMPLES ROAD
MUNFORD, AL 36268

ATTN: LAVON CARR

CUSTOMER P.O.
34383

CERTIFICATION DATE
06/17/97

SHIP VIA
FAX AND MAIL

DESCRIPTION

1 pc. Test Piece, Weld Fill, ERNICR MO-10, Alloy C22, AWS A5.14, Lot L098'

The referanced sample was submitted to chemical content evaluation and it was found to be in conformance to ASME SFA-5.14, 1995 Edition, 1996 Addenda, ERMO10, UNS N06022, Alloy ERNiCrMo-10 Weld Rod with the following results:

ELEMENT	REQUIREMENTS MIN	REQUIREMENTS MAX	ACTUAL	U/M
Carbon	0.000	0.015	0.008	%
Manganese	0.00	0.50	0.25	%
Phosphorus	0.00	0.02	0.01	%
Sulfur	0.000	0.010	0.001	%
Silicon	0.00	0.08	0.03	%
Chromium	20.0	22.5	21.3	%
Nickel + Cobalt	REMAINDER		REMAINDER	
Molybdenum	12.5	14.5	12.6	%
Copper	0.00	0.50	0.10	%
Iron	2.0	6.0	3.9	%
Cobalt	0.0	2.5	1.9	%
Vanadium	0.00	0.35	0.13	%
Tungsten	2.5	4.5	3.0	%

The services performed above were done in accordance with LTI's Quality System Program Manual Revision 12 dated 12/2/96. These results relate only to the items tested and this report shall not be reproduced except in full, without the written approval of Laboratory Testing, Inc.

Page 1 of 1

Arnold L. Horoff
Quality Assurance Manager

MERCURY CONTAMINATION - During the testing and inspection, the product did not come in direct contact with mercury or any of its compounds nor with any mercury containing devices employing a single boundary of containment.

By: Arnold L. Horoff
AUTHORIZED SIGNATURE

Certified Test Report

TRW002-99-03-05242L

LABORATORY TESTING INC.
PO Box 249, 120 Mill St., Dublin, PA 18917
TEL: 800-627-3966 • FAX: 215-249-9656

ACCREDITED

NADCAP

SOLD TO
TRW ENVIRON.SAFETY SYSTEMS, INC.
2650 PARK TOWER DRIVE
SUITE 800
VIENNA, VA 22180
ATTN: ACCOUNTS PAYABLE

SHIP TO
NEVADA
TRW c/o Lawrence Livermore Natl Lab
7000 East Avenue
Livermore, CA 94550
ATTN: JOHN ESTILL

CUSTOMER P.O.	CERTIFICATION DATE	SHIP VIA
A15385YS9A	3/25/99	FAX & UPS

DESCRIPTION

1 pc. 2" x 2" x 1/8" Thick Test Piece, AWS A5.14, Class ER NiCrMo-10, UNS N06022, Specimen Identification DCB 223, Specimen Origin PO # /Lot #B313954/K926, Item #13

Reference: Account No. 8766-92, RFQ LV.SC.YS.2/99.012

The referenced sample was submitted to chemical content evaluation and it was found to be in conformance to AWS A5.14, UNS N06022, Class ERNiCrMo-10 with the following results:

ELEMENT	REQUIREMENTS MIN.	MAX.	ACTUAL
C	0.000	0.015	0.005%
Mn	0.00	0.50	0.27%
Fe	2.0	6.0	3.0%
P	0.00	0.02	0.01%
S	0.000	0.010	0.002%
Si	0.00	0.08	0.05%
Cu	0.00	0.50	0.06%
Ni + Co	REMAINDER		REMAINDER
Co	0.0	2.5	1.0%
Cr	20.0	22.5	20.6%
Mo	12.5	14.5	13.2%
V	0.00	0.35	0.14%
W	2.5	4.5	2.8%
Others Total	0.00	0.50	0.20%

The services performed above were done in accordance with LTI's Quality System Program Manual Revision 13 dated 3/16/98. These results relate only to the items tested and this report shall not be reproduced, except in full, without the written approval of Laboratory Testing, Inc.

Sherri L. Lengyel
QA Coordinator

By *Sherri L. Lengyel*
Authorized Signature

FTI ANAMET

3400 INVESTMENT BOULEVARD • HAYWARD, CALIFORNIA 94545-3811 • (510) 887-8811

September 10, 1997

LABORATORY NUMBER:	5001.023F
CUSTOMER AUTHORIZATION:	PO# B340085
DATE SUBMITTED:	August 1, 1997
REPORT TO:	University of California Lawrence Livermore Nat'l Lab. Attn: John Estill P.O. Box 5012 Livermore, CA 94551

SUBJECT:

One weld wire was submitted for chemical analysis. The sample was identified as Lot# L025.

CHEMICAL ANALYSIS
(Reported as Wt. %)

Requirements
AWS A5.16
Class ER Ti-12

			Min.	Max.
Carbon	(C)	0.006	-	0.03
Hydrogen	(H)	0.0044	-	0.008
Iron	(Fe)	0.12	-	0.30
Molybdenum	(Mo)	0.30	0.2	0.4
Nickel	(Ni)	0.82	0.6	0.9
Nitrogen	(N)	0.004	-	0.020
Oxygen	(O)	0.08	-	0.25
Titanium	(Ti)	Remainder	Remainder	

This testing was performed in accordance with the customer's authorization and the results meet the listed requirements.

Submitted by:

Edward C. Foreman

Edward A. Foreman
Manager, Quality Assurance

nmb

CERTIFIED REPORT OF TESTS • RAPPORT D'ESSAIS CERTIFIE • WERKSZEUGNIS

HAYNES International

Haynes International
1020 West Park Avenue
P.O. Box 9013
Kokomo, Indiana 46902

INVOICE NO / NO. DE FACTURE / RECHNUNGS NR.	B.O. SOLDE B.O.	SUP.	DATE ENTERED / DATE DE COMMANDE / BESTELLDATUM	CUSTOMER REFERENCE • REFERENCE CLIENT • KUNDENBESTELLDATEN	REPORT NO / RAPPORT NO / ZEUGNIS NR	PAGE OF PAGES / PAGE DE PAGES / ANZAHL DER SEITEN
√ 51051	00	00	012891	13665	91012939	1 1
			0000519		5681450	

SOLD TO • CLIENT • BESTELLERANSCHRIFT
519-96-816
DAVID J. HAYWOOD
*

SHIP TO • DESTINATAIRE • LIEFERANSCHRIFT
METALS SAMPLES COMPANY INC
JIM WALDROP
152 METALS SAMPLES ROAD
MUNFORD AL. 36268

PRODUCT DESCRIPTION • DESCRIPTION PRODUIT • MATERIAL BESCHREIBUNG
.12/.13 x 48 x 144
*
HASTELLOY ALLOY C-22
SHEET
H157 ... 1366
N06022 KR

SPECIFICATION • SPECIFICATION • SPEZIFIKATION	QUANTITY ORDERED / QUANTITE COMMANDEE / BESTELLMENGE	QUANTITY SHIPPED / QUANTITE EXPEDIEE / LIEFERMENGE
ASTM-B-575-86, ASME-SB-575-89ED N06022	3 PC	3 PC

CHEMICAL ANALYSIS • ANALYSE CHIMIQUE • CHEMISCHE ANALYSE

	HEAT NUMBER / NUMERO DE COULEE / CHARGE NR.	HEAT CODE	PCS	Al	B	C		Co	Cr	Cu	Fe	Mn	Mo	Ni	P	S	Si	Ti	V	W	SI
1	227703264*		2			.004		114	213		44	29	134	BAL	010	002			17	29	047
2	227703270		1			003		196	212		45	25	133	BAL	004	003			14	30	038

TENSILE TEST AT ROOM TEMPERATURE • ESSAI DE TRACTION A TEMP. AMBIANTE • ZUGVERSUCH BEI RAUM TEMP.

	ULTIMATE / ZUGFESTIGKEIT		YIELD	ELONG.		
	PSI		PSI	2IN		
1	117000		57000	580		ANLD
2	115000		53000	580		ANLD

TENSILE TEST AT ELEVATED TEMPERATURE • ESSAI DE TRACTION A HTE. TEMP. • WARM ZUGVERSUCH

STRESS RUPTURE • ESSAI A CHARGE DE RUPTURE • ZEITSTANDVERSUCH

	ANNEALED HARDNESS / DURETE RECUIT	AGED HARDNESS / DURETE VIEILLI	GRAIN SIZE / GROSSEUR DE GRAIN / KORNGROESSE
1	RB 92		6.0
2	RB 90		5.0

CERTIFIED BY • CERTIFIE PAR • BESCHEINIGT DURCH
(signature) 01-29-91

HAYNES International

Haynes International, Inc
1020 West Park Avenue
P.O. Box 9013
Kokomo, Indiana 46902-9013

CERTIFIED REPORT OF TESTS • RAPPORT D'ESSAIS CERTIFIE • WERKSZEUGNIS

Invoice No. / No. de Facture / Rechnungs Nr.	B.O. / Solde / B.O.	Sup.	Date Entered / Date de Commande / Bestelldatum	Customer Reference / Reference Client / Kundenbestelldaten	Report No. / Rapport No. / Zeugnis Nr.	Page of Pages / Page de Pages / Anzahl der Seiten
142625- 1- 1-0	00	00	950605	23292	950607372	1 1

Sold To • Client • Bestelleranschrift 5681450

METAL SAMPLES CO INC
152 METAL SAMPLES RD
MUNFORD AL 36268

Ship To • Destinataire • Lieferanschrift 5681450

METALS SAMPLES COMPANY INC
JIM WALDROP
152 METALS SAMPLES ROAD
MUNFORD AL 36268

Product Description • Description Produit • Material Beschreibung

.115/.135 x 48 x 144
HASTELLOY(R) C-22 (TM) ALLOY - SHEET

Specification • Specification • Spezifikation

ASTM-B-575-92, ASME-SB-575-89ED N06022

Quantity Ordered / Quantite Commandee / Bestellmenge	Quantity Shipped / Quantite Expediee / Liefermenge
1 PC	1 PC

Chemical Analysis • Analyse Chimique • Chemische Analyse

Heat Number / Numero de Coulee / Charge Nr.	Heat Code	PCS	Al	B	C	Cb+Ta	Co	Cr	Cu	Fe	Mn	Mo	Ni	P	S	Si	Ti	V	W	SI
227783203		1			.002		182	2130		400	19	1308	BAL	.008	.008			14	293	.026

Tensile Test at Room Temperature • Essai de Traction a Temp. Ambiante • Zugversuch bei Raum Temp.

Ultimate / Zugfestigkeit	0.1% Yield	0.2% Yield	% Elong.	% RA	
PSI		PSI	2IN		
114000		55000	590		ANLD

Tensile Test at Elevated Temperature • Essai de Traction a Hte. Temp. • Warm Zugversuch

Test / Essai / Versuch Temp.	Ultimate / Zugfestigkeit	0.1% Yield	0.2% Yield	% Elong.	% RA

Stress Rupture • Essai a Charge de Rupture • Zeitstandversuch

Test / Essai / Versuch Temp.	Stress / Contrainte / Spannung	Hours / Heures / Stunden	% Elong.	% RA

Annealed Hardness / Durete Recuit / Geglüht Haerte	Aged Hardness / Durete Vieilli / Gealtert Haerte	Grain Size / Grosseur de Grain / Korngroesse
RB 91		5.0

25932 23292
N06022 MBS
C22

Certified by • Certifie par • Bescheinigt durch

Sewell

06-07-95

THIS MATERIAL MEETS THE REQUIREMENTS OF THE LISTED SPECIFICATION, MODIFIED BY ANY EXCEPTIONS OR PURCHASE ORDER REQUIREMENTS. SPECIFICATION MARKING REQUIREMENTS MAY BE WAIVED ON ORDERS REQUIRING MULTIPLE MATERIAL SPECIFICATIONS.
MILL ORDERS USED-- 24-07246-01

TITANIUM & ALLOYS CORP.
21501 Hoover Road · Warren, Michigan 48089 · (810) 755-1900 FAX (810) 755-5100

Certificate of Tests

TO. METAL SAMPLE

DATE: 6-13-95

CUSTOMER P.O. NO: 23322

ATTN

S.O. NO:

HEAT NO.	3N2966
SPECIFICATION	CP TITKAIUM ASTM B265 GR12
DESCRIPTION	.187 X 48 X 120"

CHEMISTRY

N	.02
C	.05
O	.14
Fe	.07
H	.002
Ti	Balance
Moly	.36
Nickel	.78

Items and/or material produced under this order have not come in contact with mercury or its compounds.

MECHANICAL PROPERTIES

TENSILE	91,300/92,900
YIELD	70,200/67,900
ELONG %	20/18

X957
R53400
TIGR12

23322
MBS

BASE MATERIAL

TITANIUM & ALLOYS CORP.
21501 Hoover Road · Warren, Michigan 48089

BY [signature]

TEST REPORT

TITANIUM INDUSTRIES
.255 Lake Gray Blvd., Suite I Jacksonville, FL 32244
(904) 777-5886 FAX 777-0288

DATE	OUR ORDER NO.	CUSTOMER ORDER NO
6-7-91	46101	14300

CUSTOMER NAME

METAL SAMPLES
152 METAL SAMPLE ROAD
MUNFORD, AL 36268

MATERIAL DESCRIPTION	NO. PCS.	LINEAR FEET/WEIGHT	HEAT NO.
TITANIUM GR. 12 1/8" X 32" X 47" SHEET	2	60 LBS.	T-5465

SPECIFICATION

ASTM B265

CHEMICAL ANALYSIS

N	C	H	Fe	O_2	Al	V	Sn	Pd	Mo	Zr	Ni
.0060	.0120	.0040	.1400	.1200					.3000		.8000
RESIDUALS EACH	RESIDUALS TOTAL	Ti	Cr	Ta	Cb	Y	O PLUS Fe	Mn	Si	Mg	
		BAL									

MECHANICAL PROPERTIES

					HARDNESS / GRAIN SIZE
TENSILE STRENGTH KSi	L	87.000	L	88.000	
	T	96.000	T	91.000	
YIELD STRENGTH KSi (0.2%) OFFSET	L	61.000	L	61.000	
	T	82.000	T	74.000	
ELONGATION (INCHES)	L	20.000	L	22.000	
	T	21.000	T	21.000	
REDUCTION IN AREA	L		L		
	T		T		

HEAT NO. H427
SPEC. R53400
P.O. NO. 14300
INITIAL K.K.

		OTHER DATA
BEND TEST	RT 2.5	
STATIC NOTCH STRESS RUPTURE		
ULTRASONIC TEST		
FLARE TEST		
IMPACT TEST		
FLATTENING TEST	PASS	
HYDROSTATIC TEST	PASS	
EDDY CURRENT TEST		
PNEUMATIC TEST		
REVERSE FLATTENING TEST		
DYE PENETRANT		
RADIOGRAPHIC (X-RAY) TEST		
MICROSTRUCTURE PERFORMED		
MICROSTRUCTURE COMPLIANCE		
MACROSTRUCTURE PERFORMED		
MACROSTRUCTURE COMPLIANCE		

ANNEALED

THIS IS TO CERTIFY THAT THE ABOVE TEST RESULTS ARE CORRECT AS CONTAINED IN THE RECORDS OF THE COMPANY.

DATE 6-7-91 SIGNED Christine Rickle

WHITE-CUSTOMER COPY CANARY-MATERIALS COPY PINK -SALES COPY

TEST REPORT

DETROIT, MICHIGAN 48209

Information not critical VP 1/28/00

70 of 128

PO 801979

CODE	MILL ORDER NO.	CUSTOMER PART NO.	DESCRIPTION	SHIPPER DATE	SHIPPER NO.
30	32821	411209-0	316L 2 B	04/07/98	D54156 PAGE 1 OF 1
END USE			.1200 NOM IN MM / 48.000 IN MM / COIL COIL IN MM		

MATERIALS PRODUCED TO AND CONFORM WITH: SEE SPECS BELOW

PO NO. 801979

SOLD TO:
COPPER & BRASS SALES INC. 3/0
CORPORATE SERVICES DIVISION
ACCOUNTS PAYABLE DEPT.
17401 TEN MILE ROAD
EASTPOINTE, MI 48021-1256

SHIP TO:
COPPER & BRASS SALES INC.
4801 E. MARGARET DRIVE
TERRE HAUTE, IN 47803

LIFT NO.	HEAT NO.	COIL NO.	PIECES	NET WEIGHT LBS	NET WEIGHT KG
D08072	923461	7244377	1	13510	6128
		TOTALS	1	13510	6128

HEAT NO.	C	Mn	P	S	Si	Cr	Ni	Mo	Cu	Co	N	Al	Ti
L 923461	.015	1.81	.026	.001	0.27	16.30	10.15	2.11	0.34	.28	.049		

COIL/LIFT NO.	LOCATION	HARDNESS		YIELD PSI	YIELD MPA	TENSILE PSI	TENSILE MPA	% EL 2"	RA	OLSEN	BEND TEST ANGLE	BEND TEST FACTOR
7244377	HEAD	RB	80.0	45,900	316	85,500	590	50			180	1.0T
	TAIL	RB	82.0								180	1.0T

J&L SPECIALTY STEEL, INC. DOES NOT USE MERCURY IN THE PRODUCTION NOR IN THE TESTING OF ITS PRODUCTS.

MAT'L. I.D. NO. 11835 P.O. NO. 39184
SPEC. 531603 INITIAL MB
316L K.T.

Date 6-9-98
Customer Alabama Specialty Prods
These Tests Are For Material Shipped On
Your Order 39184
From Copper And Brass Sales, Inc.
INV/WO B53330
WGT 389 PCS 2
BENDS OK
QC

COIL/LIFT NO.	GRAIN SIZE	CORROSION
7244377		OK

ASTM A-240-96A ASME SA 240-95
TYPE 316L ONLY AMS 5507E

IT IS CERTIFIED THAT ALL ANALYSIS FIGURES ARE CORRECT AS CONTAINED IN THE RECORDS OF THE COMPANY.

M. F. MC GUIRE
V. P. - TECHNOLOGY
04/07/98

A-0003 (REV. 9/93)

S-1897-A **CERTIFIED REPORT OF TESTS • RAPPORT D'ESSAIS CERTIFIE • WERKSZEUGNIS**

HAYNES International

Haynes International
1020 West Park Aven
P.O. Box 9013
Kokomo, Indiana 469

INVOICE NO / NO DE FACTURE / RECHNUNGS NR	B O / SOLDE / B O	SUP	DATE ENTERED / DATE DE COMMANDE / BESTELLDATUM	CUSTOMER REFERENCE • REFERENCE CLIENT • KUNDENBESTELLDATEN	REPORT NO / RAPPORT NO / ZEUGNIS NR	PAGE OF PAGES / PAGE DE PAGES / ANZAHL DER SEITEN
123543- 1- 1-0	00	00	941103	37504	941107472	1 1

SOLD TO • CLIENT • BESTELLERANSCHRIFT 1573608

CORROSION MATERIALS
DIV OF SPECTRUM METALS INC
P.O. BOX 666
BAKER LA 70714

SHIP TO • DESTINATAIRE • LIEFERANSCHRIFT 1573608

CORROSION MATERIALS INC
2262 GROOM RD
BAKER LA 70714

PRODUCT DESCRIPTION • DESCRIPTION PRODUIT • MATERIAL BESCHRE

.035 x x
HASTELLOY(R) C-22 (TM) ALLO
DRAWN WIRE - LAYER WOUND
DIN 50049 3.1B(EN 10204)

SPECIFICATION • SPECIFICATION • SPEZIFIKATION	QUANTITY ORDERED / QUANTITE COMMANDEE / BESTELLMENGE	QUANTITY SHIPPED / QUANTITE EXPEDIEE / LIEFERMENGE
AWS A5.14-89 ERNICRMO-10	300 LB	304 LB

CHEMICAL ANALYSIS • ANALYSE CHIMIQUE • CHEMISCHE ANALYSE

HEAT NUMBER / NUMERO DE COULEE / CHARGE NR	HEAT CODE	LBS	Al	B	C		Co	Cr	Cu	Fe	Mn	Mo	Ni	P	S	Si	Ti	V	W	SI
1227743263		304			.002		.89	21.6	.05	3.6	.32	13.5	BAL	.009	.003			.15	2.9	.03

TENSILE TEST AT ROOM TEMPERATURE • ESSAI DE TRACTION A TEMP. AMBIANTE • ZUGVERSUCH BEI RAUM TEMP.

ULTIMATE / ZUGFESTIGKEIT	YIELD	YIELD	ELONG.	R.A.

TENSILE TEST AT ELEVATED TEMPERATURE • ESSAI DE TRACTION A HTE. TEMP. • WARM ZUGVERSUCH

TEST / ESSAI / VERSUCH TEMP°	ULTIMATE / ZUGFESTIGKEIT	YIELD	YIELD	ELONG.	R.A.

STRESS RUPTURE • ESSAI A CHARGE DE RUPTURE • ZEITSTANDVERSUCH

TEST / ESSAI / VERSUCH TEMP°	STRESS / CONTRAINTE / SPANNUNG	HOURS / HEURES / STUNDEN	ELONG.	R.A.

ANNEALED HARDNESS / DURETE RECUIT / GEGLUEHT HAERTE	AGED HARDNESS / DURETE VIEILLI / GEALTERT HAERTE	GRAIN SIZE / GROSSEUR DE GRAIN / KORNGROESSE

Material was produced in accordance with Haynes Intl's Quality Control System Manual dated 5/31/88 Rev. 6.
Total other elements analyzed do not exceed .50 percent.

X924 23312
MBS
HAST-C-22

CERTIFIED BY • CERTIFIE PAR • BESCHEINIGT DURCH

11-07-94

Same as in pg. 66

8/28/00

THIS MATERIAL MEETS THE REQUIREMENTS OF THE LISTED SPECIFICATION, MODIFIED BY EXCEPTIONS OR PURCHASE ORDER REQUIREMENTS. SPECIFICATION MARKING REQUIREMENTS BE WAIVED ON ORDERS REQUIRING MULTIPLE MATERIAL SPECIFICATIONS.
MILL ORDERS USED-- 00-00000-00

S-1 ...A **CERTIFIED REPORT OF TESTS • RAPPORT D'ESSAIS CERTIFIE • WERKSZEUGNIS**

HAYNES International
Haynes International, Inc.
1020 West Park Avenue
P.O. Box 9013
Kokomo, Indiana 46902

INVOICE NO / NO DE FACTURE / RECHNUNGS NR.	S.O. / SOLDE / S.O.	SUF.	DATE ENTERED / DATE DE COMMANDE / BESTELLDATUM	CUSTOMER REFERENCE • REFERENCE CLIENT • KUNDENBESTELLDATEN	REPORT NO / RAPPORT NO / ZEUGNIS NR	PAGE OF PAGES / PAGE DE PAGES / ANZAHL DER SEITEN	
133339- 1- 1-0	00	00	950209	38275	950302711	1	1

SOLD TO • CLIENT • BESTELLERANSCHRIFT 1573608

CORROSION MATERIALS
DIV OF SPECTRUM METALS INC
P.O. BOX 666
BAKER LA 70714

SHIP TO • DESTINATAIRE • LIEFERANSCHRIFT 1573608

CORROSION MATERIALS INC
2262 GROOM RD
BAKER LA 70714

PRODUCT DESCRIPTION • DESCRIPTION PRODUIT • MATERIAL BESCHREIBUNG

.035 x x
HASTELLOY(R) C-22 (TM) ALLOY
DRAWN WIRE - LAYER WOUND
DIN 50049 3.1B(EN 10204)

SPECIFICATION • SPECIFICATION • SPEZIFIKATION	QUANTITY ORDERED / QUANTITE COMMANDEE / BESTELLMENGE	QUANTITY SHIPPED / QUANTITE EXPEDIEE / LIEFERMENGE
AWS A5.14-89 ERNICRMO-10	100 LB	101 LB

CHEMICAL ANALYSIS • ANALYSE CHIMIQUE • CHEMISCHE ANALYSE

HEAT NUMBER / NUMERO DE COULEE / CHARGE NR.	HEAT CODE	LBS	Al	B	C		Co	Cr	Cu	Fe	Mn	Mo	Ni	P	S	Si	Ti	V	W					SI
2277 4 3142		101			003		203	21.17	09	4.24	25	13.81	BAL	009	005			13	3.01					024

TENSILE TEST AT ROOM TEMPERATURE • ESSAI DE TRACTION A TEMP. AMBIANTE • ZUGVERSUCH BEI RAUM TEMP.					TENSILE TEST AT ELEVATED TEMPERATURE • ESSAI DE TRACTION A HTE. TEMP. • WARM ZUGVERSUCH						STRESS RUPTURE • ESSAI A CHARGE DE RUPTURE • ZEITSTANDVERSUCH					
ULTIMATE				%	TEST / ESSAI / VERSUCH TEMP°	ULTIMATE				%	TEST / ESSAI / VERSUCH TEMP°	STRESS / CONTRAINTE / SPANNUNG	HOURS / HEURES / STUNDEN		%	

ANNEALED HARDNESS / DURETE RECUIT / GEGLUEHT HAERTE	AGED HARDNESS / DURETE VIEILLI / GEALTERT HAERTE	GRAIN SIZE / GROSSEUR DE GRAIN / KORNGROESSE

Material was produced in accordance with Haynes Intl's Quality Control System Manual dated 5/31/88 Rev. 6.
Total other elements analyzed do not exceed .50 percent.

L098
Tig Wire
C22

24119
MBS

CERTIFIED BY • CERTIFIE PAR • BESCHEINIGT DURCH

[signature]

03-02-95

Same as in pg. 66
JVP 1/28/00

THIS MATERIAL MEETS THE REQUIREMENTS OF THE LISTED SPECIFICATION, MODIFIED BY A[illegible]
EXCEPTIONS OR PURCHASE ORDER REQUIREMENTS. SPECIFICATION MARKING REQUIREMENTS M[illegible]
BE WAIVED ON ORDERS REQ[illegible]ING MULTIPLE MATERIAL SPECIFICATIONS.
MILL ORDERS USED-- 00-0[illegible] [illegible]0-00

T:WIRE

CERTIFICATE OF CONFORMITY
TEST CERTIFICATE TO
DIN 50049 3.1.B
EN 10204

TITANIUM WIRE CORPORATION
235 INDUSTRIAL PARK ROAD
FRACKVILLE, PA. 17931
PHONE (717) 874-0311

DATE SHIPPED	07-19-95
OUR ORDER NO.	950605
CUST. P.O. NO.	001132

PART # ____________________

CUSTOMER NAME

INWELD CORP.
P.O. BOX 460
AMBRIDGE, PA. 15003-0480

L025 23312
Ti-12 MBS
Mig-Will
Same as in pg 69 NP 1/28/00

MATERIAL DESCRIPTION	WEIGHT	HEAT NO.
.063 X 36" AS DRAWN MILL FINISH	10 LBS.	AT7879

SPECIFICATIONS:

AWS A5.16-90 ERTI 12

FILLER MATERIAL

CHEMICAL ANALYSIS

N	C	H	Fe	O_2	Al	V	Sn	Pd	Mo	Zr
0080	.086	FINAL .008	.125	.074					.29	
Ni	**Cr**	**Ta**	**Cb**	**Y**	**Mn**	**Si**	**Mg**	**Hf**		**Ti**
.755								.001		

MECHANICAL PROPERTIES

TENSILE (KSI): ____________________

YIELD (0.2%) (KSI): ____________________

ELONGATION (% & GAUGE LENGTH): ____________________

REDUCTION OF AREA: ____________________

STATIC NOTCH STRESS RUPTURE: ____________________

BETA TRANSUS TEMP. ____________________

MICROSTRUCTURE ____________________

MACROSTRUCTURE ____________________

ULTRASONIC TEST ____________________

BEND TEST ____________________

ANNEAL TEMPERATURE AND TIME

SOLUTION TREAT TEMPERATURE AND TIME

AGED TEMPERATURE AND TIME

OTHER DATA

THIS IS TO CERTIFY THAT THE ITEMS OF THIS TEST CERTIFICATE HAVE BEEN INSPECTED AND TESTED TO THE ABOVE SPECIFICATIONS AND HAVE BEEN FOUND TO CONFORM WITH YOUR ORDER.

*NOTE: The recording of false, fictitious or fraudulent statements or entries on this document may be punished as a felony under Federal Statutes including Federal Law, Title 18, Chapter 47."

Name ? critical NP 1/28/00

JULY 19, 1995

University of California
Lawrence Livermore National Laboratory
Contracting & Materiel Management Department

May 18, 1995

Metal Samples Company, Inc.
152 Metal Samples Road P.O. Box 8
Munford, Alabama 36268

Attention: Kirk Johnson

Subject: Subcontract No. B313954
Subcontract Value $267,411.00

Enclosed are two (2) copies of the subject Subcontract.

Please have an authorized representative of your company sign both copies, without alteration or conditions, and return one signed copy within five (5) days to the attention of Ann Moyle, at Mail Code L-650.

The terms and conditions of the attached Subcontract constitute the agreement between the Regents of the University of California and Metal Samples Company, Inc. in its entirety. Any exception taken to the terms and conditions will constitute a counter-offer. In that event, the University may choose to accept the counter-offer, negotiate a revised subcontract, or withdraw from negotiation.

If you have any questions, please call me at (510) 422-9296.

Sincerely,

Ann Moyle
Ann Moyle
Senior Buyer
Program Support Division

Enclosures: As noted

QUICK FAX OfficeMax
Date 11-12-99 # of Pages 21
To: JOHN ESTILL
Co./Dept. LLNL
Fax 925-422-3362
From: LARRY BRADEN
Co. METAL SAMPLES
Phone 256-358-4202

A DOE Prime Contractor • 7000 East Avenue • P.O. Box 5012 • Livermore, CA 94550/94551 • Ph. 510/422-9296 • FAX 510/423-7643

SUBCONTRACT B313954

between

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

and

METAL SAMPLES COMPANY, INC.

INTRODUCTION

This is a Fixed Price Fabrications Subcontract. The parties to this Subcontract are The Regents of the University of California, a California corporation, hereinafter called "University," and Metal Samples Company, Inc., hereinafter called "Subcontractor".

The University has entered into Prime Contract No. W-7405-ENG-48 with the United States Government, hereinafter called "Government," represented by the Department of Energy, hereinafter called "DOE," for the management and operation of the Lawrence Livermore National Laboratory and the performance of certain research and development work. This Subcontract is entered into as a subcontract in furtherance of the work provided for under the Prime Contract.

AGREEMENT

In accepting this Subcontract, the Subcontractor agrees to perform its obligations in accordance with the terms, conditions, and provisions of the following attached documents and the documents referenced or incorporated therein, which together with this Subcontract Signature Page shall collectively constitute the entire Subcontract, and supersedes all prior proposals, representations, negotiations, or agreements, whether written or oral:

SCHEDULE OF ARTICLES
GENERAL PROVISIONS FOR FIXED PRICE SUPPLIES & SERVICES (JANUARY 26, 1994)
SPECIFICATION E-20-50-ID *PROCEDURE FOR IDENTIFICATION*

METAL SAMPLES COMPANY, INC.	THE REGENTS OF THE UNIVERSITY OF CALIFORNIA
BY: ____________	BY: LeRoy M. Cordova (signature) LeRoy M. Cordova
TITLE: ____________	TITLE: Division Leader (Acting) Program Support Division Lawrence Livermore National Laboratory
DATE: ____________	DATE: June 2, 1995

University's Subcontract Administrator:
Ann Moyle, (510) 422-9296

University of California
Lawrence Livermore National Laboratory
Contracting & Material Management Department (C&MMD)
P. O. Box 5012, Livermore, California 94551

Table 2. P.v B313954

Specification E-20-50-ID

		Ref. Dwg Number AAA95-100703-00	Ref. Dwg. Number AAA95-100704-00	Ref. Dwg Number C00320 AAA95-100705-00
UNS Number	Alloy	SAMPLE IDENTIFICATION	SAMPLE IDENTIFICATION	SAMPLE IDENTIFICATION
N08825	825	AWA 001 thru AWA 163	AWB 001 thru AWB 163	ACA 001 thru ACA 243
N06985	G3	BWA 001 thru BWA 163	BWC 001 thru BWC 163	BCA 001 thru BCA 243
N06455	C4	CWA 001 thru CWA 163	CWB 001 thru CWB 163	CCA 001 thru CCA 243
N06022	C22	DWA 001 thru DWA 163	DWB 001 thru DWB 163	DCA 001 thru DCA 243
R53400	Ti Gr 12	EWA 001 thru EWA 163	EWD 001 thru EWD 163	ECA 001 thru ECA 243
N/A	Ti Gr 16	FWA 001 thru FWA 163	FWE 001 thru FWE 163	FCA 001 thru FCA 243
N04400	M400	GWA 001 thru GWA 243	GWF 001 thru GWF 243	GCA 001 thru GCA 243
C71500	CDA 715	HWA 001 thru HWA 243	HWG 001 thru HWG 243	HCA 001 thru HCA 243
K21590	A387 Gr 22	IWA 001 thru IWA 183	IWH 001 thru IWH 183	ICA 001 thru ICA 183
K01800	A516 Gr 55	JWA 001 thru JWA183	JWI 001 thru JWI 183	JCA 001 thru JCA 183
J02501	A27 Gr 70-40	KWA 001 thru KWA 183	KWI 001 thru KWI 183	KCA 001 thru KCA 183
		Ref. Dwg Number AAA95-100706-00	Ref. Dwg Number AAA95-100707-00	Ref. Dwg Number AAA95-100708-00
UNS Number	Alloy	SAMPLE IDENTIFICATION	SAMPLE IDENTIFICATION	SAMPLE IDENTIFICATION
N08825	825	ACB 001 thru ACB 243	AUA 001 thru AUA 163	AUB 001 thru AUB 163
N06985	G3	BCC 001 thru BCC 243	BUA 001 thru BUA 163	BUC 001 thru BUC 163
N06455	C4	CCB 001 thru CCB 243	CUA 001 thru CUA 163	CUB 001 thru CUB 163
N06022	C22	DCB 001 thru DCB 243	DUA 001 thru DUA 163	DUB 001 thru DUB 163
R53400	Ti Gr 12	ECD 001 thru ECD 243	EUA 001 thru EUA 163	EUD 001 thru EUD 163
N/A	Ti Gr 16	FCE 001 thru FCE 243	FUA 001 thru FUA 163	FUE 001 thru FUE 163
N04400	M400	GCF 001 thru GCF 243	GUA 001 thru GUA 243	GUF 001 thru GUF 243
C71500	CDA 715	HCG 001 thru HCG 243	HUA 001 thru HUA 243	HUG 001 thru HUG 243
K21590	A387 Gr 22	ICH 001 thru ICH 183	IUA 001 thru IUA 183	IUH 001 thru IUH 183
K01800	A516 Gr 55	JCI 001 thru JCI 183	JUA 001 thru JUA 183	JUI 001 thru JUI 183
J02501	A27 Gr 70-40	KCI 001 thru KCI 183	KUA 001 thru KUA 183	KUI 001 thru KUI 183

SCHEDULE OF ARTICLES

ARTICLE 1 – SCOPE OF WORK

A. General

The Subcontractor shall fabricate and deliver to the University the quantities of the fabricated items described in Paragraph B below, in accordance with the requirements, specifications and drawings included or referenced herein. All specifications and drawings, by their reference, are hereby incorporated as a part of this Subcontract.

B. Description, Quantities & Delivery Requirements

Item #	Description	Qty	Delivery Date
01	Spacer, Crevice Specimen, in strict accordance with Drawing AAA95-100714-OO	7380	August 28, 1995, all items except Item 07
02	Alloy 825 Consisting of the following test samples:	1 lot	
	a. Unwelded Weight Loss Specimen, in strict accordance with Drawing AAA95-100703-OO	163	
	b. Coupon, Welded Wt. Loss, in strict accordance with Drawing AAA95-100704-OO	163	
	c. Coupon, Base Mtl. Crevice, in strict accordance with Drawing AAA95-100705-OO	243	
	d. Coupon, Welded Crevice, in strict accordance with Drawing AAA95-100706-OO	243	
	e. Specimen, U-Bend, in strict accordance with Drawing AAA95-100707-OO	163	
	f. Specimen, Welded U-Bend, in strict accordance with Drawing AAA95-100708-OO, including U-Bend Assembly, in strict accordance with Drawing AAA95-100715-OO and Drawing AAA95-100855-OO	163	
03	Alloy G3 Consisting of the following test samples:	1 lot	
	a. Unwelded Weight Loss Specimen, in strict accordance with Drawing AAA95-100703-OO	163	
	b. Coupon, Welded Wt. Loss, in strict accordance with Drawing AAA95-100704-OO	163	
	c. Coupon, Base Mtl. Crevice, in strict accordance with Drawing AAA95-100705-OO	243	
	d. Coupon, Welded Crevice, in strict accordance with Drawing AAA95-100706-OO	243	
	e. Specimen, U-Bend, in strict accordance with Drawing AAA95-100707-OO	163	
	f. Specimen, Welded U-Bend, in strict accordance with Drawing AAA95-100708-OO, including U-Bend Assembly, in strict accordance with Drawing AAA95-100715-OO and Drawing AAA95-100855-OO	163	

04	Alloy C4 Consisting of the following test samples:	1 lot
	a. Unwelded Weight Loss Specimen, in strict accordance with Drawing AAA95-100703-OO	163
	b. Coupon, Welded Wt. Loss, in strict accordance with Drawing AAA95-100704-OO	163
	c. Coupon, Base Mtl. Crevice, in strict accordance with Drawing AAA95-100705-OO	243
	d. Coupon, Welded Crevice, in strict accordance with Drawing AAA95-100706-OO	243
	e. Specimen, U-Bend, in strict accordance with Drawing AAA95-100707-OO	163
	f. Specimen, Welded U-Bend, in strict accordance with Drawing AAA95-100708-OO, including U-Bend Assembly, in strict accordance with Drawing AAA95-100715-OO and Drawing AAA95-100855-OO	163
05	Alloy C22 Consisting of the following test samples:	1 lot
	a. Unwelded Weight Loss Specimen, in strict accordance with Drawing AAA95-100703-OO	163
	b. Coupon, Welded Wt. Loss, in strict accordance with Drawing AAA95-100704-OO	163
	c. Coupon, Base Mtl. Crevice, in strict accordance with Drawing AAA95-100705-OO	243
	d. Coupon, Welded Crevice, in strict accordance with Drawing AAA95-100706-OO	243
	e. Specimen, U-Bend, in strict accordance with Drawing AAA95-100707-OO	163
	f. Specimen, Welded U-Bend, in strict accordance with Drawing AAA95-100708-OO, including U-Bend Assembly, in strict accordance with Drawing AAA95-100715-OO and Drawing AAA95-100855-OO	163
06	Alloy Ti Gr 12 Consisting of the following test samples:	1 lot
	a. Unwelded Weight Loss Specimen, in strict accordance with Drawing AAA95-100703-OO	163
	b. Coupon, Welded Wt. Loss, in strict accordance with Drawing AAA95-100704-OO	163
	c. Coupon, Base Mtl. Crevice, in strict accordance with Drawing AAA95-100705-OO	243
	d. Coupon, Welded Crevice, in strict accordance with Drawing AAA95-100706-OO	243
	e. Specimen, U-Bend, in strict accordance with Drawing AAA95-100707-OO	163
	f. Specimen, Welded U-Bend, in strict accordance with Drawing AAA95-100708-OO, including U-Bend Assembly, in strict accordance with Drawing AAA95-100715-OO and Drawing AAA95-100855-OO	163

07	<u>Alloy Ti Gr 16</u> Consisting of the following test samples:	1 lot	December 22, 1995, or sooner
	a. Unwelded Weight Loss Specimen, in strict accordance with Drawing AAA95-100703-OO	163	
	b. Coupon, Welded Wt. Loss, in strict accordance with Drawing AAA95-100704-OO	163	
	c. Coupon, Base Mtl. Crevice, in strict accordance with Drawing AAA95-100705-OO	243	
	d. Coupon, Welded Crevice, in strict accordance with Drawing AAA95-100706-OO	243	
	e. Specimen, U-Bend, in strict accordance with Drawing AAA95-100707-OO	163	
	f. Specimen, Welded U-Bend, in strict accordance with Drawing AAA95-100708-OO, including U-Bend Assembly, in strict accordance with Drawing AAA95-100715-OO and Drawing AAA95-100855-OO	163	
08	<u>Alloy M400</u> Consisting of the following test samples:	1 lot	
	a. Unwelded Weight Loss Specimen, in strict accordance with Drawing AAA95-100703-OO	243	
	b. Coupon, Welded Wt. Loss, in strict accordance with Drawing AAA95-100704-OO	243	
	c. Coupon, Base Mtl. Crevice, in strict accordance with Drawing AAA95-100705-OO	243	
	d. Coupon, Welded Crevice, in strict accordance with Drawing AAA95-100706-OO	243	
	e. Specimen, U-Bend, in strict accordance with Drawing AAA95-100707-OO	243	
	f. Specimen, Welded U-Bend, in strict accordance with Drawing AAA95-100708-OO, including U-Bend Assembly, in strict accordance with Drawing AAA95-100715-OO and Drawing AAA95-100855-OO	243	
09	<u>Alloy CDA715</u> Consisting of the following test samples:	1 lot	
	a. Unwelded Weight Loss Specimen, in strict accordance with Drawing AAA95-100703-OO	243	
	b. Coupon, Welded Wt. Loss, in strict accordance with Drawing AAA95-100704-OO	243	
	c. Coupon, Base Mtl. Crevice, in strict accordance with Drawing AAA95-100705-OO	243	
	d. Coupon, Welded Crevice, in strict accordance with Drawing AAA95-100706-OO	243	
	e. Specimen, U-Bend, in strict accordance with Drawing AAA95-100707-OO	243	
	f. Specimen, Welded U-Bend, in strict accordance with Drawing AAA95-100708-OO, including U-Bend Assembly, in strict accordance with Drawing AAA95-100715-OO and AAA95-100855-OO	243	

10 Alloy A387 Gr 22 — 1 lot

Consisting of the following test samples:

a. Unwelded Weight Loss Specimen, in strict accordance with Drawing AAA95-100703-OO — 183
b. Coupon, Welded Wt. Loss, in strict accordance with Drawing AAA95-100704-OO — 183
c. Coupon, Base Mtl. Crevice, in strict accordance with Drawing AAA95-100705-OO — 183
d. Coupon, Welded Crevice, in strict accordance with Drawing AAA95-100706-OO — 183
e. Specimen, U-Bend, in strict accordance with Drawing AAA95-100707-OO — 183
f. Specimen, Welded U-Bend, in strict accordance with Drawing AAA95-100708-OO, including the U-Bend Assembly, in strict accordance with Drawing AAA95-100715-OO and Drawing AAA95-100855-OO — 183

11 Alloy A516 Gr 55 — 1 lot

Consisting of the following test samples:

a. Unwelded Weight Loss Specimen, in strict accordance with Drawing AAA95-100703-OO — 183
b. Coupon, Welded Wt. Loss, in strict accordance with Drawing AAA95-100704-OO — 183
c. Coupon, Base Mtl. Crevice, in strict accordance with Drawing AAA95-100705-OO — 183
d. Coupon, Welded Crevice, in strict accordance with Drawing AAA95-100706-OO — 183
e. Specimen, U-Bend, in strict accordance with Drawing AAA95-100707-OO — 183
f. Specimen, Welded U-Bend, in strict accordance with Drawing AAA95-100708-OO, including the U-Bend Assembly, in strict accordance with Drawing AAA95-100715-OO, and Drawing AAA95-100855-OO — 183

12 Alloy A27 Gr 70-40 — 1 lot

Consisting of the following test samples:

a. Unwelded Weight Loss Specimen, in strict accordance with Drawing AAA95-100703-OO — 183
b. Coupon, Welded Wt. Loss, in strict accordance with Drawing AAA95-100704-OO — 183
c. Coupon, Base Mtl. Crevice, in strict accordance with Drawing AAA95-100705-OO — 183
d. Coupon, Welded Crevice, in strict accordance with Drawing AAA95-100706-OO — 183
e. Specimen, U-Bend, in strict accordance with Drawing AAA95-100707-OO — 183
f. Specimen, Welded U-Bend, in strict accordance with Drawing AAA95-100708-OO, including the U-Bend Assembly, in strict accordance with Drawing AAA95-100715-OO and Drawing AAA95-100855-OO — 183

Notes:

1. Subcontractor shall furnish all materials used to machine, fabricate and weld the samples.
2. Subcontractor shall identify the samples machined to the drawings in accordance with LLNL Specification E-20-50-ID.

The delivery date(s) stipulated above are the dates on which the stipulated quantities are to be delivered at the "ship-to address" indicated in ARTICLE 4 - SHIPPING & PACKAGING INSTRUCTIONS.

C. Quantity Variance: Delivery of Excess Quantities
Unless otherwise approved by the University's Subcontract Administrator, the Subcontractor shall provide the exact quantities specified in this Subcontract. If the Subcontractor delivers and the University receives quantities of any item in excess of the quantity called for, such excess quantities will be treated as being delivered for the convenience of the Subcontractor. The University may retain such excess quantities up to $250 in value without compensating the Subcontractor therefor, and the Subcontractor waives all right, title, or interests therein. Quantities in excess of $250 will, at the option of the University, either be returned at the Subcontractor's expense or the quantity to be retained and the price for any excess material shall be negotiated between the Subcontractor and the University and the Subcontract shall be so modified.

D. Quality Assurance
The Subcontractor shall conduct its work for this procurement under its own Quality Assurance Program, which has been found acceptable to LLNL-YMP (Ref: LLLYMP 94 11006, "Pre-Award Audit Survey S94-02".

LLNL-YMP Quality Assurance personnel and their designees shall have the right of access to Subcontractor (and sub-tier suppliers) facilities and records, for the purpose of inspection or audit.

The Subcontractor shall report any nonconformances associated with this procurement to LLNL-YMP for LLNL-YMP review of their disposition.

The Subcontractor shall process the shipping, handling, and storage of all specimens in accordance with their quality assurance procedures, which have been audited and approved by LLNL-YMP Quality Assurance personnel (Ref: LLLYMP 94 11006).

Upon completion of a lot of specimens (a "lot" is described under Article 1.B. of the Schedule of Articles), the Subcontractor shall forward to LLNL-YMP copies of all Mill Certification Reports, in-process inspection reports, and final inspection reports for each lot, together with the specimens, to LLNL-YMP. Lots may be delivered and invoiced upon completion with the final shipment to be delivered on or before August 14, 1995.

Upon receipt of each lot of specimens, LLNL-YMP will perform a receiving inspection of the specimens and accompanying documentation.

ARTICLE 2 - PRICE PROVISIONS

A. Fixed Unit Prices

Item #	Description	Qty	Unit Price	Extended Price
01	Spacer, Crevice Specimen	7380	$0.95	$7,011.00
02	Alloy 825	1 Lot		$16,600.00
03	Alloy G3	1 Lot		$19,400.00
04	Alloy C4	1 Lot		$20,300.00
05	Alloy C22	1 Lot		$20,300.00
06	Alloy Ti Gr 12	1 Lot		$26,200.00
07	Alloy Ti Gr 16	1 Lot		$54,300.00
08	Alloy M400	1 Lot		$21,800.00
09	Alloy CDA715	1 Lot		$20,500.00
10	Alloy A387 Gr 22	1 Lot		$19,400.00
11	Alloy A516 Gr 55	1 Lot		$19,400.00

12	Alloy A27 Gr 70-40	1 Lot	$22,200.00

B. Pricing Terms

The total firm fixed price for the fabricated items, based on the indicated quantities and fixed unit prices indicated above, is $267,411.00.

The fixed price for the fabricated items does not include California State Sales Tax, as the University holds California Seller's State Resale Permit No. SR-CHA 21-135323.

C. Freight Charges

Freight charges shall be borne by the Subcontractor.

ARTICLE 3 – INVOICING & PAYMENT

A. Invoicing

The Subcontractor shall submit an original and one copy of an invoice for the total price for the fabricated items upon delivery of all of the fabricated items. The invoice shall reference the Subcontract number, the unit, and extended price for each item and include an item description to allow for verification.

B. Invoice Address

All invoices shall be submitted to the following address:

University of California
Lawrence Livermore National Laboratory
Attention: Accounts Payable Department, L-432
P. O. Box 5001
Livermore, CA 94551

C. Terms of Payment

The terms of payment shall be Net 30 days.

ARTICLE 4 – SHIPPING & PACKAGING INSTRUCTIONS

A. Ship To Address:

The Subcontractor shall ship the fabricated items to the following address:

University of California
Lawrence Livermore National Laboratory
for U.S. Department of Energy
Subcontract No. B313954
7000 East Avenue
Livermore, CA 94550

B. Packaging

The Subcontractor shall suitably package the fabricated items to prevent damage during handling and shipping. Any damage resulting from improper packaging, containerizing, or lack thereof shall be the liability of the Subcontractor. All packaging, permits, shipping, and related handling costs shall be borne by Subcontractor. The Subcontractor shall indicate the Subcontract number on each container or package and an itemized packing list shall be affixed to the outermost cover of each container or package.

The University encourages the use of biodegradable packaging materials. To assist in this endeavor, the Subcontractor is requested to make every reasonable effort to use biodegradable packaging materials when shipping the fabricated items to the University.

C. F. O. B. Point

The items purchased under this Subcontract shall be shipped F. O. B. LLNL.

D. Freight Carrier

Subcontractor shall ship the items via Subcontractor's choice

ARTICLE 5 – CHANGES; UNIVERSITY REPRESENTATIVES

A. Subcontract Administrator

The University's Subcontract Administrator for this Subcontract is Ann Moyle, or his/her designee, who shall represent the University in all matters relating to the non-technical interpretation, administration, and performance of this Subcontract. The Subcontractor shall direct all notices and requests for approval to the University's Subcontract Administrator, and any notices or approvals from the University to the Subcontractor shall be issued by the University's Subcontract Administrator.

B. Changes

The University's Subcontract Administrator is the only individual authorized to commit the University to make changes to the Scope of Supply, the price(s), the delivery day(s) or method of shipment, or other terms of this Subcontract. Any changes to the requirements of this Subcontract shall be effected only by a written change order or modification to this Subcontract, issued by the University's Subcontract Administrator.

ARTICLE 6 - QUALITY OF FABRICATED ITEMS

The fabricated items shall, as a minimum: (1) be new, including recycled (not used or reconditioned) and not of such age or so deteriorated as to impair their usefulness or safety; (2) be as warranted; and (3) not contain any counterfeit or suspect materials, parts, or components. Types of counterfeit or suspect materials, parts, and components include, but are not limited to: electrical components, piping, fittings, flanges, and fasteners. The University will not accept any fabricated items found by the University to not conform to these minimum requirements, notwithstanding any inspection or acceptance of delivery by the University, unless such condition is specifically approved in writing by the University's Subcontract Administrator.

ARTICLE 7 – APPROVAL OF TECHNICAL DATA

If this Subcontract requires the Subcontractor to furnish any drawings, specifications, diagrams, layouts, schematics, descriptive literature, illustrations, schedules, performance or test data, or other technical data for approval by the University prior to Subcontractor performance, the approval of the data by the University shall not relieve the Subcontractor from responsibility for any errors or omissions in such data, or from responsibility for complying with the requirements of this Subcontract, except as specified below. Any work done prior to such approval shall be at the Subcontractor's risk.

If the data includes any variations from the Subcontract requirements, the Subcontractor shall describe such variations in writing at the time of submission of the data. If the University approves any such variation(s), a change order to this Subcontract shall be issued by the University and, if appropriate, a bilateral modification to this Subcontract shall be negotiated.

ARTICLE 8 - ADDITIONAL REQUIREMENTS AND PROVISIONS

A. Required Documentation – The Subcontractor shall provide all documentation as required and set forth in this Subcontract. Subcontractor's failure to provide all the prescribed documentation may result in non-acceptance of the fabricated items and withholding of payment.

B. Final Acceptance – Final acceptance by the University of the fabricated items shall be at Lawrence Livermore National Laboratory and shall be based upon full compliance with all the requirements of this Subcontract.

C. Late Delivery; Discrepant Items – The University shall be entitled to consideration for any and all fabricated items that are delivered after the stated contractual delivery date or that are delivered but do not meet the requirements of this Subcontract. Consideration shall be negotiated before final payment is made.

D. Observation at the Subcontractor's Facilities – The University reserves the right to observe and witness all phases of the manufacturing of the Supplies, including design, fabrication, assembly, testing and inspection conducted at the Subcontractor's plant or at any of its sub-tier subcontractors' plants.

ARTICLE 9 – ACCEPTANCE OF SUBCONTRACT

A. The Subcontractor, in accepting this Subcontract, agrees to be bound by or to comply with all of its terms and conditions, in all particulars, and no other terms and conditions shall be binding upon the parties unless hereafter accepted by them in writing.

B. The signature-execution of this Subcontract or the performance of all or any portion of this Subcontract shall constitute the Subcontractor's unqualified acceptance of this Subcontract and all of the Subcontract terms and conditions. The provisions of any proposal referred to in this Subcontract are included and made a part of this Subcontract only for the purpose of specifying the nature of the materials, items, and services ordered, and then only to the extent that such provisions are consistent with this Subcontract, and any terms and conditions of such proposal shall not apply to this Subcontract.

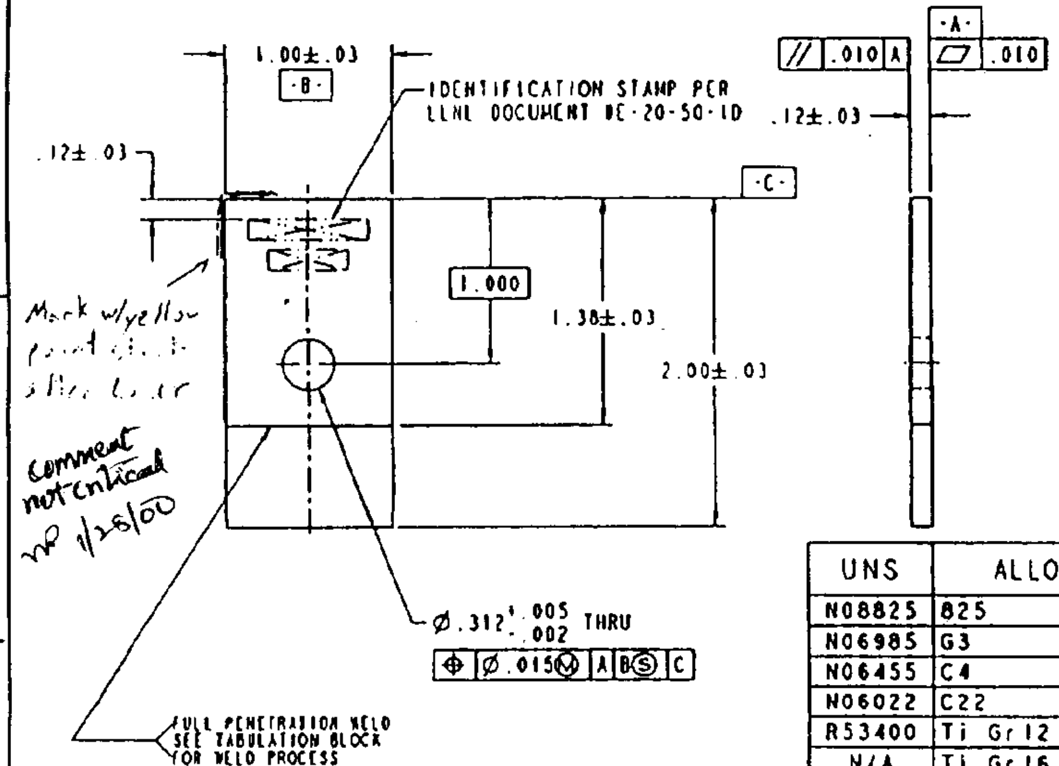
ARTICLE 10 – MODIFICATIONS TO GENERAL PROVISIONS

A. The following clauses of the GENERAL PROVISIONS FOR FIXED PRICE SUPPLIES AND SERVICES shall not be applicable to this Subcontract.

Clause 7	Security
Clause 8	Classification
Clause 9	Foreign Ownership, Control, or Influence Over Contractor
Clause 11	Organization Conflict of Interest - General
Clause 73	Commercial Computer Software - Restricted Rights
Clause 76	Classified Inventions
Clause 77	Patent Rights (Long Form)
Clause 78	Patent Rights - Small Business Firms or Nonprofit Organizations (Other than M & Os)

B. The applicability of certain other clauses of the GENERAL PROVISIONS shall be based on the value of this Subcontract, the status of the Subcontractor or the nature and location of the work, as indicated in the GENERAL PROVISIONS.

(END OF SCHEDULE)



NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1985.
4. ABBREVIATIONS PER ANSI Y1.1-1972.
5. BREAK SHARP EDGES .005 -.030.
6. DO NOT SHEAR OR PUNCH.
7. WELD SYMBOLS PER AWS A2.4-1979.
8. SURFACE FINISH OF PART AS FOLLOWS: DOUBLE DISC GRIND FACES TO A 32/ FINISH EDGES WITH 120 GRIT.

TABULATION BLOCK

UNS	ALLOY	WELD PRCS	WELD FILLER MATERIAL	QTY
N08825	825	GMAW	AWS A5.14 CLASS ER NiCrMo-10	163
N06985	G3	GMAW	AWS A5.14 CLASS ER NiCrMo-9	163
N06455	C4	GMAW	AWS A5.14 CLASS ER NiCrMo-10.	163
N06022	C22	GMAW	AWS A5.14 CLASS ER NiCrMo-10	163
R53400	Ti Gr12	GTAW	AWS A5.16 CLASS ER Ti-12	163
N/A	Ti Gr16	GTAW	AWS A5.16 CLASS ER Ti-7	163
N04400	M400	GMAW	AWS A5.14 CLASS ER NiCu-7	243
C71500	CDA715	GMAW	AWS A5.7 CLASS ER CuNi	243
K21590	A387 Gr22	GMAW	AWS A5.28 CLASS ER 90S-B3	183
K01800	A516 Gr55	GMAW	AWS A5.18 CLASS ER 70S-6	183
J02501	A27 Gr70-40	GMAW	AWS A5.18 CLASS ER 70S-6	183

FOR YUCCA MOUNTAIN PROJECT USE ONLY

NO REQD	PART / LLNL STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
		SEE TABULATION BLOCK		1

DWN S. EDSON 7-95
CHK G. GDORSKI 3-7-95
APVD C. DALDER 3-7-95

CLASSIFICATION

LAWRENCE LIVERMORE NATIONAL LABORATORY MECHANICAL ENGINEERING DEPT UNIVERSITY OF CALIFORNIA

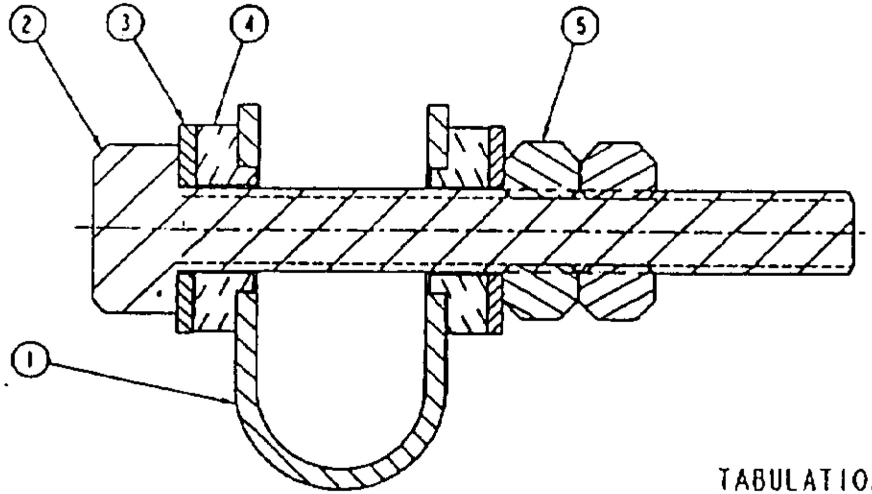
MAJOR UNIT: INTEGRATED CRSH TEST FACIL

DETAIL: COUPON, WELDED WT LOSS

DRAWING NO: AAA95-100704-00

SCALE 1 | SHEET 1 OF 1

LTR | DWN | CHK | APVD | DATE | ZONE | CHANGE



NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1985.
4. ABBREVIATIONS PER ANSI Y1.1-1972.
5. ASSEMBLE PER ASTM STANDARD G30-94.

TABULATION BLOCK

ITEM 1 UNS NUMBER	ITEM 1 SPECIMEN ALLOY	BASEMETAL SPECIMEN QTY	WELDED SPECIMEN QTY	ITEMS 2, 3, & 5 MATERIAL	ITEM 2 SCR, HEX HD .250-20 X 2.00 L QTY	ITEM 3 WASHER, FLAT .25 NOMINAL QTY	ITEM 4 LLNL DRAWING NO. AAA95-100855 QTY	ITEM 5 NUT, HEX .250-20 UNC QTY
N08825	825	163	163	C276	326	652	652	652
N06985	G3	163	163	C276	326	652	652	652
N06455	C4	163	163	C276	326	652	652	652
N06022	C22	163	163	C276	326	652	652	652
R53400	Ti Gr12	163	163	Ti Gr7	326	652	652	652
N/A	Ti Gr16	163	163	Ti Gr7	326	652	652	652
N04400	M400	243	243	C276	486	972	972	972
C71500	CDA715	243	243	C276	486	972	972	972
K21590	A387 Gr22	183	183	C276	366	732	732	732
K01800	A516 Gr55	183	183	C276	366	732	732	732
J02501	A27 Gr70-40	183	183	C276	366	732	732	732

FOR YUCCA MOUNTAIN PROJECT USE ONLY

NO REQD	PART / LLNL STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
		SEE TABULATION BLOCK		1

DWN S. EDSON 3-95
CHK G. GDETSKI 3-7-95
APVD E. BALDER 3-7-95
CLASSIFIED BY:
TITLE DATE

CLASSIFICATION

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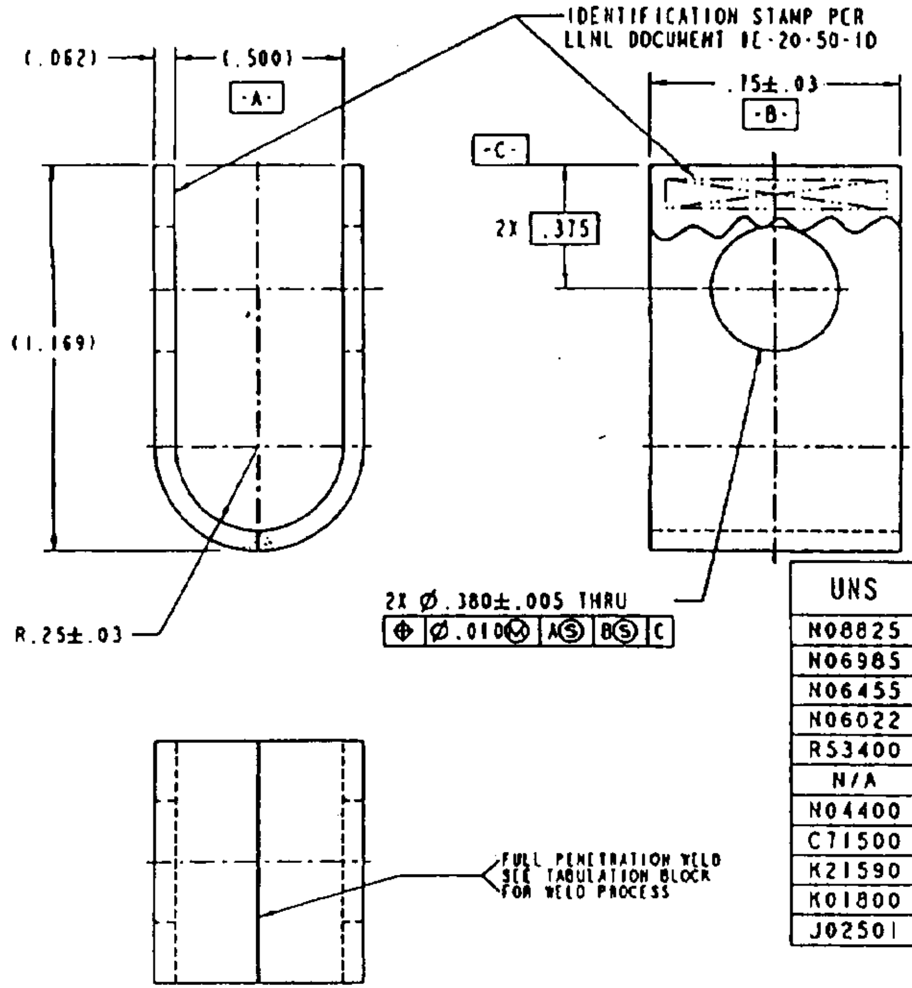
MAJOR UNIT: INTEGRATED CRSN TEST FACIL
SUBASSY: U-BEND ASSY
DETAIL:

DRAWING NO AAA95-100715-00

SCALE .5 SHEET 1 OF 1

LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

LTR | DSN | CHK | APVD | DATE | ECN | CHANGE



NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1985
4. ABBREVIATIONS PER ANSI Y1.1-1972.
5. BREAK SHARP EDGES .005 - .030.
6. DO NOT SHEAR OR PUNCH.
7. DEVELOPED LENGTH OF PART = 2.50±.03
8. WELD SYMBOLS PER AWS A2.4-1979.
9. SURFACE FINISH OF PART AS FOLLOWS: DOUBLE DISC GRIND FACES TO A 32 √. FINISH EDGES WITH 120 GRIT.
10. ASSEMBLE PER ASTM STANDARD G30-94.

TABULATION BLOCK

UNS	ALLOY	WELD PRCS	WELD FILLER MATERIAL	QTY
N08825	825	GMAW	AWS A5.14 CLASS ER NiCrMo-10	163
N06985	G3	GMAW	AWS A5.14 CLASS ER NiCrMo-9	163
N06455	C4	GMAW	AWS A5.14 CLASS ER NiCrMo-10	163
N06022	C22	GMAW	AWS A5.14 CLASS ER NiCrMo-10	163
R53400	Ti Gr12	GTAW	AWS A5.16 CLASS ER Ti-12	163
N/A	Ti Gr16	GTAW	AWS A5.16 CLASS ER Ti-7	163
N04400	M400	GMAW	AWS A5.14 CLASS ER NiCu-7	243
C71500	CDA715	GMAW	AWS A5.7 CLASS ER CuNi	243
K21590	A387 Gr22	GMAW	AWS A5.28 CLASS ER 90S-B3	183
K01800	A516 Gr55	GMAW	AWS A5.18 CLASS ER 70S-6	183
J02501	A27 Gr70-40	GMAW	AWS A5.18 CLASS ER 70S-6	183

FOR YUCCA MOUNTAIN PROJECT USE ONLY

NO REQD	PART / LLNL STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
		SEE TABULATION BLOCK		1

DWN I. IBIOR	2-95
CHK E. SDOWSKI	3-1-95
APVD C. BALBER	3-7-95
CLASSIFIED BY:	
TITLE	DATE

LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

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MAJOR UNIT: INTEGRATED CRSN TEST FACIL

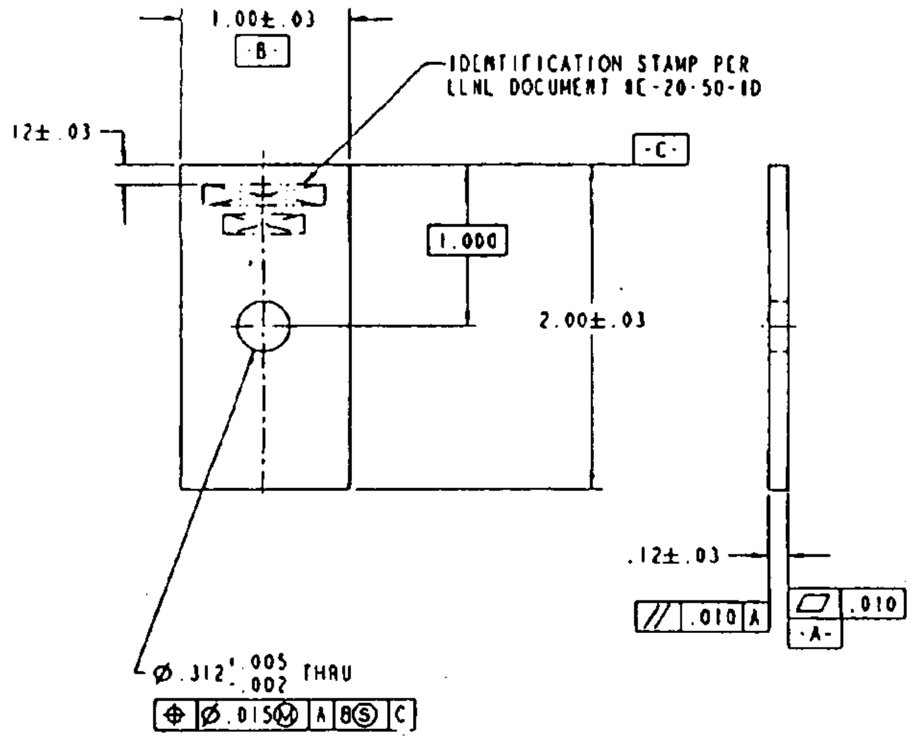
SUBASSY:

DETAIL: SPECIMEN, WELDED U-BEND

DRAWING NO: AAA95-100708-00

SCALE 1:1 | SHEET 1 OF 1

LTR	DWN	CHK	APVD	DATE	TOPE	CHANGE



NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1985.
4. ABBREVIATIONS PER ANSI Y1.1-1972.
5. BREAK SHARP EDGES .005 - .030.
6. DO NOT SHEAR OR PUNCH.
7. SURFACE FINISH OF PART AS FOLLOWS: DOUBLE DISC GRIND FACES TO A 32 √. FINISH EDGES WITH 120 GRIT.

TABULATION BLOCK

UNS	ALLOY	QTY
N08825	825	163
N06985	G3	163
N06455	C4	163
N06022	C22	163
R53400	Ti Gr12	163
N/A	Ti Gr16	163
N04400	M400	243
C71500	CDA715	243
K21590	A387 Gr22	183
K01800	A516 Gr55	183
J02501	A27 Gr70-40	183

FOR YUCCA MOUNTAIN PROJECT USE ONLY

NO REQD	PART / LLNL STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
		SEE TABULATION BLOCK		1

DWN S. EDSON 2-95
CHK G. GDOVICKI 3-1-95
APVD E. DALDER 3-1-95

CLASSIFICATION

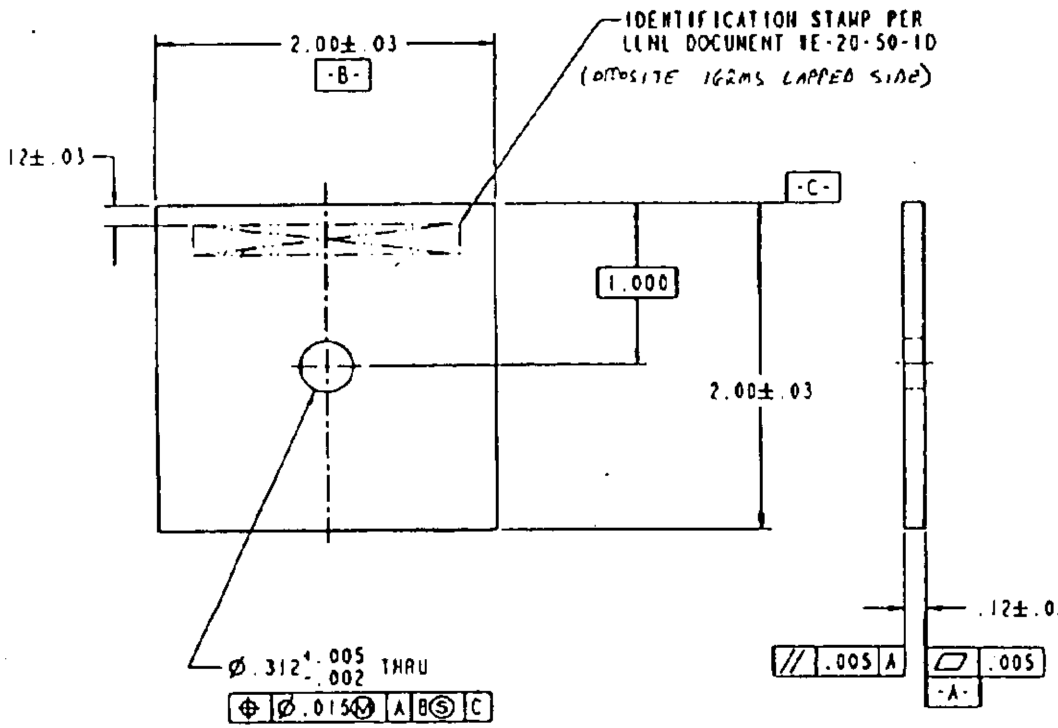
LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

MAJOR UNIT: INTEGRATED CRSH TEST FACIL
SUBASSY:
DETAIL: COUPON, BASE MTL WT LOSS

DRAWING NO AAA95-100703-00

SCALE 1 SHEET 1 OF 1

LTR	DWN	CHK	APVD	DATE	ZONE	CHANGE



NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1985.
4. ABBREVIATIONS PER ANSI Y1.1-1972.
5. BREAK SHARP EDGES .005 -.030.
6. DO NOT SHEAR OR PUNCH.
7. SURFACE FINISH OF PART AS FOLLOWS:
   LAP ONE FACE WITH 600 GRIT TO A 16.
   FINISH EDGES WITH 120 GRIT.
   OTHER FACE TO HAVE 32 RMS or BETTER

TABULATION BLOCK

UNS	ALLOY	QTY
N08825	825	243
N06985	G3	243
N06455	C4	243
N06022	C22	243
R53400	Ti Gr12	243
N/A	Ti Gr16	243
N04400	M400	243
C71500	CDA715	243
K21590	A387 Gr22	183
K01800	A516 Gr55	183
J02501	A27 Gr70-40	183

FOR YUCCA MOUNTAIN PROJECT USE ONLY

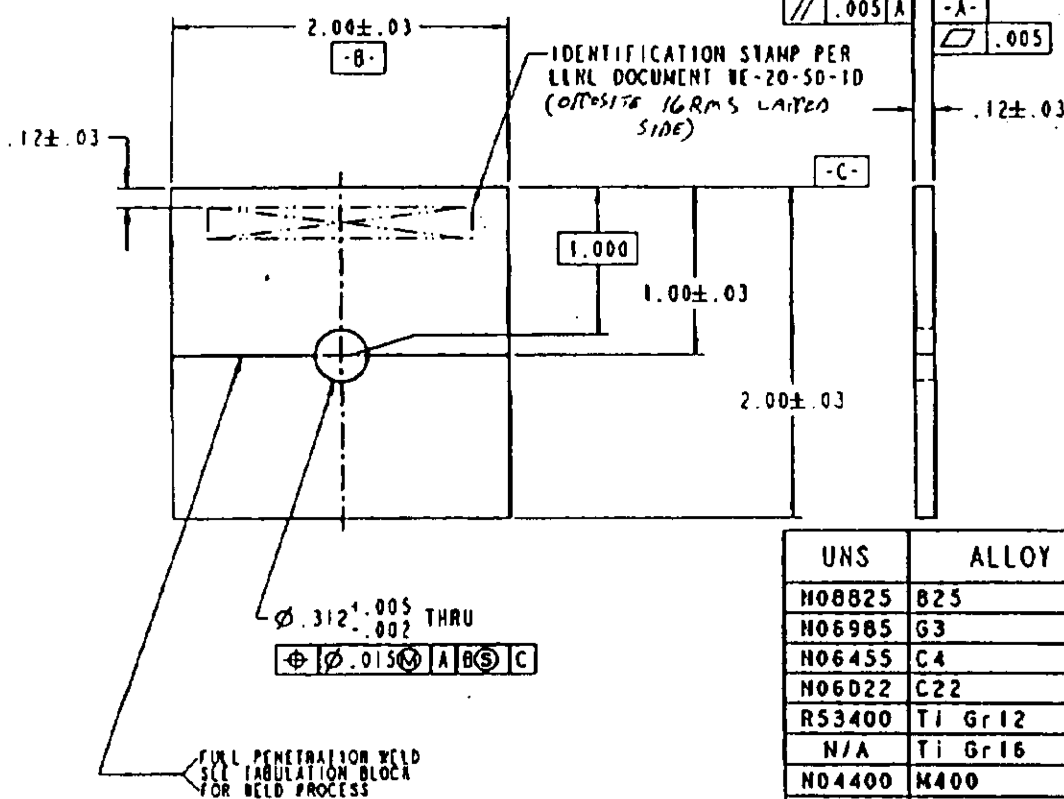
NO REQD	PART / LLNL STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
		SEE TABULATION BLOCK		1

DWN S. EDSON 2-95
CHK G. GDOWSKI 3-7-95
APVD E. DALDER 3-7-95

CLASSIFICATION

LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

MAJOR UNIT: INTEGRATED CRSN TEST FACIL
DETAIL: COUPON, BASE MTL CREVICE
DRAWING NO: AAA95-100705-00
SCALE 1 — SHEET 1 OF 1



NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1985.
4. ABBREVIATIONS PER ANSI Y1.1-1972.
5. BREAK SHARP EDGES .005 -.030.
6. DO NOT SHEAR OR PUNCH.
7. WELD SYMBOLS PER AWS A2.4-1979.
8. SURFACE FINISH OF PART AS FOLLOWS:
   LAP ONE FACE WITH 600 GRIT TO A 16 √.
   FINISH EDGES WITH 120 GRIT.
   OTHER FACE TO HAVE 32RMS OR BETTER.

TABULATION BLOCK

UNS	ALLOY	WELD PRCS	WELD FILLER MATERIAL	QTY
N08825	825	GMAW	AWS A5.14 CLASS ER NiCrMo-10	243
N06985	G3	GMAW	AWS A5.14 CLASS ER NiCrMo-9	243
N06455	C4	GMAW	AWS A5.14 CLASS ER NiCrMo-10	243
N06022	C22	GMAW	AWS A5.14 CLASS ER NiCrMo-10	243
R53400	Ti Gr12	GTAW	AWS A5.16 CLASS ER Ti-12	243
N/A	Ti Gr16	GTAW	AWS A5.16 CLASS ER Ti-7	243
N04400	M400	GMAW	AWS A5.14 CLASS ER NiCu-7	243
C71500	CDA715	GMAW	AWS A5.7 CLASS ER CuNi	243
K21590	A387 Gr22	GMAW	AWS A5.28 CLASS ER 90S-B3	183
K01800	A516 Gr55	GMAW	AWS A5.18 CLASS ER 70S-6	183
J02501	A27 Gr70-40	GMAW	AWS A5.18 CLASS ER 70S-6	183

FOR YUCCA MOUNTAIN PROJECT USE ONLY

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NO REQD	PART / LLNL STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
		SEE TABULATION BLOCK		1

DWN S. EDSON 2-95
CHK G. GDOWSKI 3-8-95
APVD C. BALDER 3-3-95

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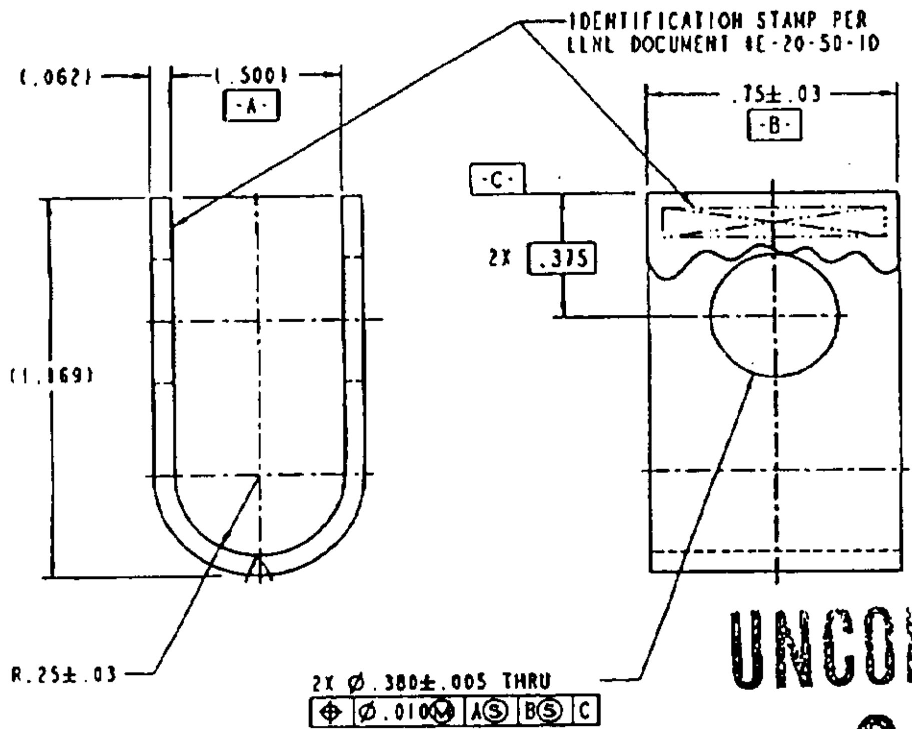
LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

MAJOR UNIT: INTEGRATED CRSN TEST FACIL

DETAIL: COUPON, WELDED CREVICE

DRAWING NO AAA95-100706-00

SCALE 1-1 SHEET 1 OF 1



NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1985.
4. ABBREVIATIONS PER ANSI Y1.1-1972.
5. BREAK SHARP EDGES .005 -.030.
6. DO NOT SHEAR OR PUNCH.
7. DEVELOPED LENGTH OF PART = 2.50±.03
8. SURFACE FINISH OF PART AS FOLLOWS:
   DOUBLE DISC GRIND FACES TO A 32.
   FINISH EDGES WITH 120 GRIT.
9. ASSEMBLE PER ASTM STANDARD G30-94.

UNCONTROLLED COPY

TABULATION BLOCK

UNS	ALLOY	QTY
N08825	825	163
N06985	G3	163
N06455	C4	163
N06022	C22	163
R53400	Ti Gr12	163
N/A	Ti Gr16	163
N04400	M400	243
C71500	CDA715	243
K21590	A387 Gr22	183
K01800	A516 Gr55	183
J02501	A27 Gr70-40	183

FOR YUCCA MOUNTAIN PROJECT USE ONLY

NO REQD	PART / LLNL STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
		SEE TABULATION BLOCK		1

DWN S. EDSON 2-95
CHK G. GIDDINGS 3-2-95
APVD E. DALDER 3-1-95
CLASSIFIED BY:
TITLE DATE

LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

CLASSIFICATION

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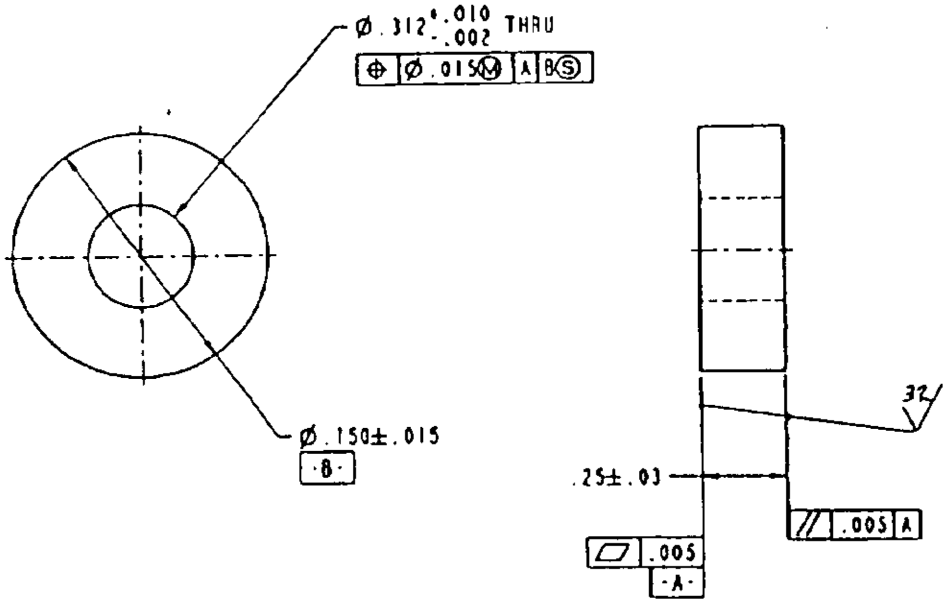
MAJOR UNIT: INTEGRATED CRSH TEST FACIL
SUBASSY:
DETAIL: SPECIMEN, U-BEND
DRAWING NO: AAA95-100707-00
SCALE 1 SHEET 1 OF 1

LTR | SYM | CHK | APVD | DATE | ZONE | CHANGE

NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1985.
4. ABBREVIATIONS PER ANSI Y1.1-1972.
5. BREAK SHARP EDGES .005 - .030.
6. 63 OR STOCK.
7. MATERIAL: VIRGIN TEFLON.



FOR YUCCA MOUNTAIN PROJECT USE ONLY

NO REQD	PART / LLNL STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
		SEE NOTE 7		1

DWN S. EDSON	1-95	CLASSIFICATION	MAJOR UNIT: INTEGRATED CRSN TEST FACIL
CHK G. GDOWSKI	3-1-95		SUBASSY
APVD C. BALDER	3-1-95		DETAIL: SPACER, CREVICE SPECIMEN
CLASSIFIED BY:			DRAWING NO AAA95-100714-00
TITLE	DATE		SCALE .1 — SHEET 1 OF 1

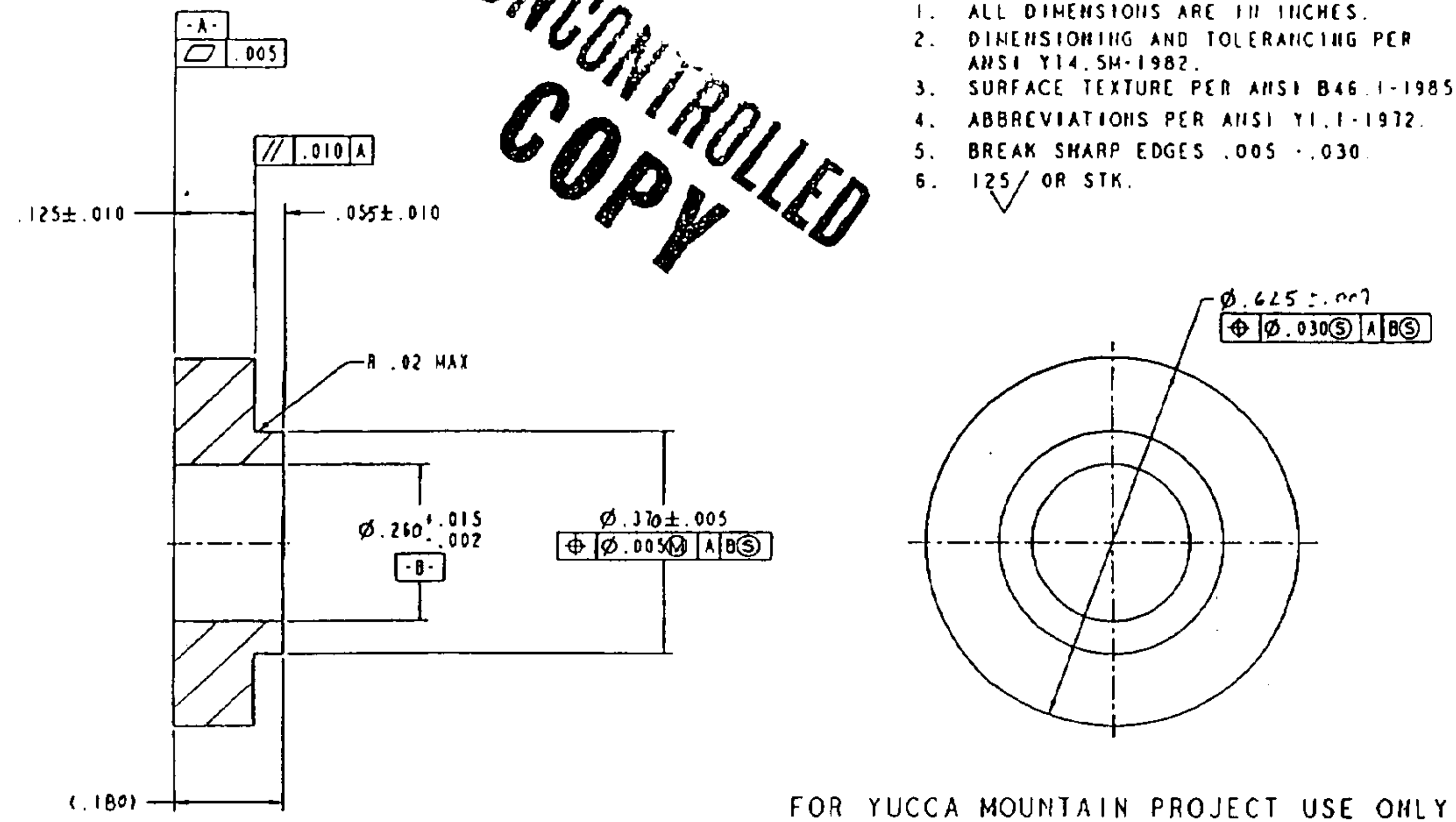
LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

LTR | DWN | CHK | APVD | DATE | ZONE | CHANGE

ST1238

NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1985.
4. ABBREVIATIONS PER ANSI Y1.1-1972.
5. BREAK SHARP EDGES .005 -.030.
6. 125/ OR STK.



FOR YUCCA MOUNTAIN PROJECT USE ONLY

NO REQD	PART / LCNL STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
		ZIRCONIA		1

DWN	S. EBSON	3-95
CHK	G. GDOWSKI	3-7-95
APVD	C. DALDER	3-7-95

CLASSIFICATION

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LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

MAJOR UNIT: INTEGRATED CRSN TEST FACIL
SUBASSY: U-BEND ASSY
DETAIL: SPACER, U-BEND
DRAWING NO: AAA95-100855-00
SCALE .75 SHEET 1 OF 1

MODIFICATION NO. 1
to
SUBCONTRACT NO. B313954
between
THE REGENTS OF THE UNIVERSITY OF CALIFORNIA
and
METAL SAMPLES COMPANY, INC.

INTRODUCTION

This is a Modification to Subcontract B313954 and is entered into by and between The Regents of the University of California, hereinafter called "University," and Metal Samples Company, Inc., hereinafter called "Subcontractor."

The Subcontract covers the procurement of metal samples. This Modification is hereby issued to add Items 13-19, change the delivery date and increase the total amount of the subcontract.

MODIFICATIONS

The following "Ordered Items," as indicated by the item number, are hereby modified to read as follows:

ITEM NO.	ITEM, SPECIFICATIONS, CATALOG REFERENCES	QTY	UNIT PRICE	TOTAL PRICE	PROMISED DEL. TO CARRIER
13	Hastelloy Plate, C22, 0.188" x 51" x 148" (455 lbs.)	1 lot		$5,587.40	August 25, 1995
14	Hastelloy Plate, G3, 0.250" x 49" x 71" (276 lbs.)	1 lot		$2,933.88	August 25, 1995
15	Hastelloy Plate, G3, 0.250" x 22" x 106" (185 lbs.)	1 lot		$1,966.55	August 25, 1995
16	Monel Plate, M400, 0.250" x 48" x 144" (574 lbs.)	1 lot		$3,818.88	August 25, 1995
17	Incoloy Plate, 1825, 0.250" x 23" x 98" (168 lbs.)	1 lot		$1,158.30	August 25, 1995
18	Incoloy Plate, 1825, 0.250" x 45" x 96" (321 lbs.)	1 lot		$2,221.29	August 25, 1995
19	Additional Engineering, Production Control, Purchasing Costs, and Freight Charges	1 lot		$17,058.76	

Order Total Prior to this Modification	**$267,411.00**
Net Increase	**$34,745.06**
New Order Total	**$302,156.06**

Delivery Date
The delivery date for Items 01-06 and 08-12 is changed to September 28, 1995.

All other terms, conditions, and provisions of the Subcontract shall remain in full force and effect.

ACCEPTANCE:	AUTHORIZATION:
METAL SAMPLES COMPANY, INC.	THE REGENTS OF THE UNIVERSITY OF CALIFORNIA
BY: Kirk Johnson	BY: L.B. Haynes
TITLE: President	TITLE: Group Leader, Lawrence Livermore National Laboratory
DATE: 08/15/95	DATE: 8/14/95

(FORM SPS-631A/5/10/95)

Procurement Representative: Ann Moylo, Senior Buyer
Phone No.: (510) 422-9296 Fax No. (510) 422-9296

Purchase Order / Confirming Order No: B338959 PAGE: 1
Do Not Duplicate.

Buyer:
E. VITZ
Ext: (510)423-7132
Fax: (510)423-7226

DATE
04/21/97

Payment Terms

Net 30 Days

To: METAL SAMPLES COMPANY, INC.
RT. 1, BOX 152

MUNFORD AL 36268
Attn: BRENDA SMITH
Phone: (205)358-4202
FAX: (205)358-4515

University of California
Lawrence Livermore National Laboratory
Purchase Order
For Contract No. W-7405-ENG.48
With Department of Energy
FOR RESALE: State Sales Tax should not be charged, as the University holds State Sales Tax Permit SR-CHA 21-135323

MAIL INVOICE IN DUPLICATE TO
UNIVERSITY OF CALIFORNIA
LAWRENCE LIVERMORE NATIONAL LABORATORY
~~Accounting Office~~ - P.O. Box 5001
LIVERMORE, CALIFORNIA 94551
ACCOUNTS PAYABLE DEPT., L-432
The Purchase Order Number shown above MUST appear prominently on your shipment, freight bill, & invoice to facilitate receiving and payment of the order.

SHIP TO:

UCLLNL
For U.S. Department of Energy
LLNL 411
7000 East Avenue (P.O. B338959)
Livermore, California 94550
RECEIVING DEPT., BLDG., NO. 411

Confirming Order 04/16/97 - DO NOT DUPLICATE

Ship Via:	Transportation Terms:	F.O.B.
FED-X Priority Ovrnt	LABORATORY Shipping Point: MUNFORD AL	SHIPPING POINT

Item No.	Model/Manufacturer Description	Qty	UOM/ UOP	Unit Price	Extended Price	Ship Date
001	N08825	15.000	EA /	9.85000	147.75	05/05/97

METAL SAMPLES CO.
1 X 2 COUPON - BASE METAL WEIGHT LOSS/ASTM B424 - COLD-ROLLED & ANNEALED SHEET - P/N C01296141304000 -

SUBJECT TO:
A. LLNL DOCUMENT E-20-50-ID4...PAGES: 1...ACCOMPANYING COPY...
B. LLNL, DRAWING, NO. AAA95-100703-00...DATE: 030195...PAGES: 1... ACCOMPANYING COPY...
C. LLNL, DRAWING, NO. AAA95-100704-00...DATE: 030195...PAGES: 1... ACCOMPANYING COPY...

REFERENCE: VENDOR-TELEFAXED QUOTATION...NO.: 12499...DATE: 041497... PAGES: 3.
SUBJECT TO: UCLLNL-PROVIDED...WEIGHT LOSS SPECIMEN PURCHASE CONTRACT REQUIREMENTS, 04-14-97...PAGES: 1...ACCOMPANYING COPY....

002 N06985 METAL SAMPLES CO. 1 X 2 COUPON - BASE METAL WEIGHT LOSS/ASTM B582 - COLD-ROLLED & ANNEALED SHEET - P/N C0129A161304000.	15.000 EA	/	12.55000	188.25	05/05/97
003 N06455 METAL SAMPLES CO. 1 X 2 COUPON - BASE METAL WEIGHT LOSS/ASTM B575 - HASTELLOY R SHEET - P/N C0129A131304000.	15.000 EA	/	12.30000	184.50	05/05/97
004 N06022 METAL SAMPLES CO. 1 X 2 COUPON - BASE METAL WEIGHT LOSS/ASTM B575 - HASTELLOY SHEET - P/N C0129A111304000.	15.000 EA	/	12.30000	184.50	05/05/97
005 R53400 METAL SAMPLES CO. 1 X 2 COUPON - BASE METAL WEIGHT LOSS/ASTM B265 - GRADE 12 - P/N C0129B361304000.	15.000 EA	/	15.20000	228.00	05/05/97
006 TITANIUM GR 16 METAL SAMPLES CO. 1 X 2 COUPON - BASE METAL WEIGHT LOSS/GRADE CP16 - P/N C0129B361304000.	15.000 EA	/	22.35000	335.25	05/05/97
007 N08825 METAL SAMPLES CO. 1 X 2 COUPON - WELDED WEIGHT LOSS/ASTM B424 - COLD-ROLLED & ANNEALED SHEET - P/N C0129B141324000.	15.000 EA	/	27.40000	411.00	05/05/97
008 N06985 METAL SAMPLES CO. 1 X 2 COUPON - WELDED WEIGHT LOSS/ASTM B585 - COLD-ROLLED & ANNEALED SHEET - P/N C0129A161324000.	15.000 EA	/		0.00	05/05/97
009 N06455 METAL SAMPLES CO. 1 X 2 COUPON - WELDED WEIGHT LOSS/ASTM B575 - 1 HASTELLOY R SHEET - P/N C0129A131324000.	15.000 EA	/	34.20000	513.00	05/05/97

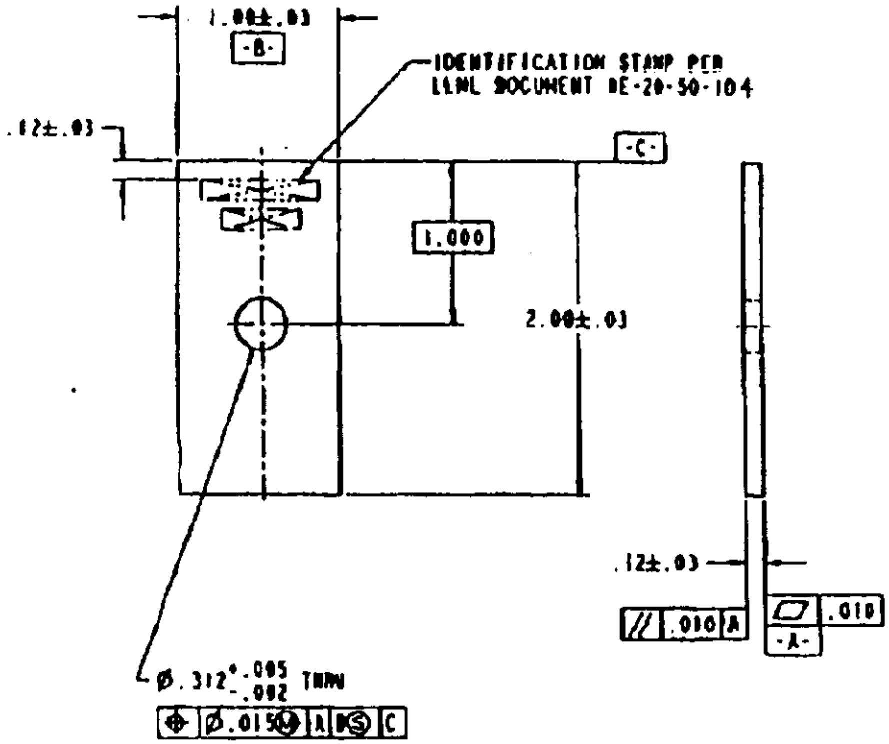
Purchase Order / Confirming Order No: B338959 PAGE: 3
Do Not Duplicate.

010	N06022 METAL SAMPLES CO. 1 X 2 COUPON - WELDED WEIGHT LOSS/ASTM B575 - HASTELLOY SHEET - P/N C0129A111324000.	15.000 EA /	34.20000	513.00	05/05/97
011	R53400 METAL SAMPLES CO. 1 X 2 COUPON - WELDED WEIGHT LOSS/ASTM B265 - GRADE 12 - P/N C0129B011324000.	15.000 EA /	49.00000	735.00	05/05/97
012	TITANIUM GR 16 METAL SAMPLES CO. 1 X 2 COUPON - WELDED WEIGHT LOSS/GRADE CP16 - P/N C0129B361324000.	15.000 EA /	63.30000	949.50	05/05/97
			Total Price:	4,389.75	

NOTE:
Ship Via Federal Express, Priority Overnight, collect.
Mark Airbill: Bill Recipient's Account 0941-0205-7.
DO NOT DECLARE VALUE!

VENDOR NOTE:

The Lawrence Livermore National Laboratory and its authorized representatives shall have the right to inspect Government property and the work and activities of the Sub-Contractor/Seller and his Subcontractor(s) under this Subcontract/Order at such time and in such manner as the University shall deem appropriate. The Subcontractor/Seller shall include in all subcontracts and purchase orders under this Subcontract/Order a similar provision making this paragraph applicable to his subcontractor or vendor.



NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1985.
4. ABBREVIATIONS PER ANSI Y1.1-1972.
5. BREAK SHARP EDGES .005 -.030.
6. DO NOT SHEAR OR PUNCH.
7. SURFACE FINISH OF PART AS FOLLOWS: DOUBLE DISC GRIND FACES TO A 32. FINISH EDGES WITH 120 GRIT.

FOR YUCCA MOUNTAIN PROJECT USE ONLY

NO REQD	PART / LLNL STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
		SEE TABULATION BLOCK		1

illegibility of names not critical to document
[illegible] 1/28/00

CLASSIFICATION

THIS DOCUMENT IS THE PROPERTY OF THE UNIVERSITY OF CALIFORNIA LAWRENCE LIVERMORE NATIONAL LABORATORY. REPRODUCTION PROHIBITED WITHOUT PERMISSION OF THE MECHANICAL ENGINEERING DEPARTMENT.

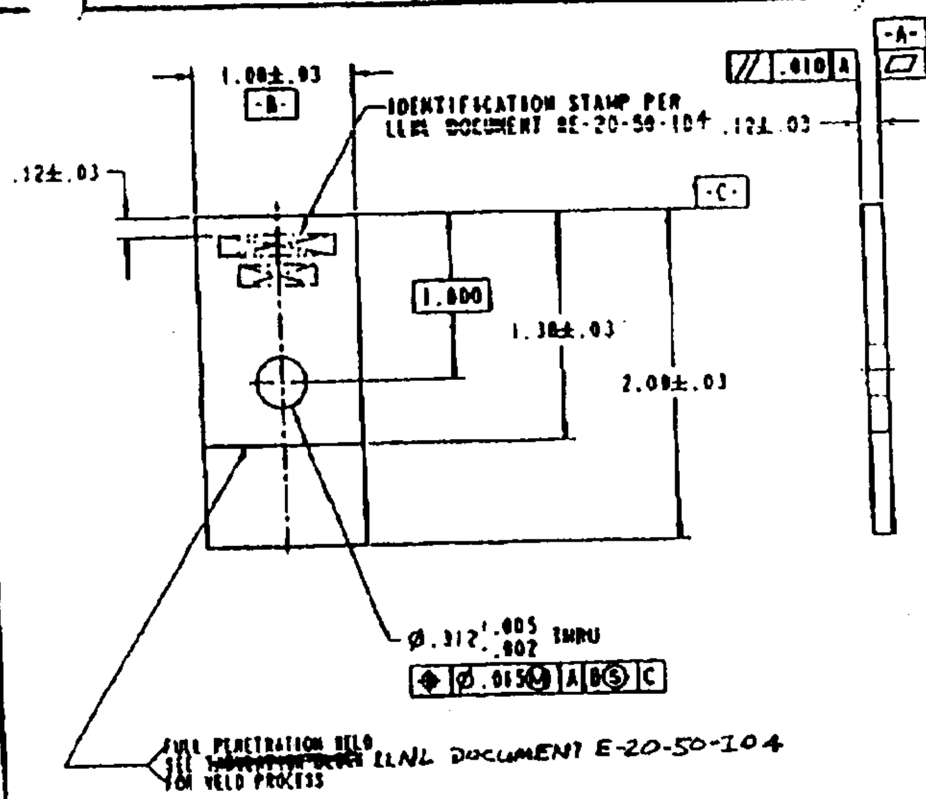
LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

MAJOR UNIT: INTEGRATED CRSN TEST FACIL

DETAIL: COUPON, BASE MTL WT LOSS

DRAWING NO: AAA95-100703-00

SCALE 1 — 1 SHEET 1 OF 1



NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1985.
4. ABBREVIATIONS PER ANSI Y1.1-1972.
5. BREAK SHARP EDGES .005 - .030.
6. DO NOT SHEAR OR PUNCH.
7. WELD SYMBOLS PER AWS A2.4-1979.
8. SURFACE FINISH OF PART AS FOLLOWS:
   DOUBLE DISC GRIND FACES TO A 32
   FINISH EDGES WITH 120 GRIT.

Illegibility of names not critical to document
1/28/00

FOR YUCCA MOUNTAIN PROJECT USE ONLY

SEE TABULATION BLOCK

DESCRIPTION / MATERIAL

NO REQD | PART / LLNL STK NO | SPEC NO | ITEM

DWN S. [illegible] 2-95
CHK [illegible] 3-1-95
APVD [illegible] 3-1-95

CLASSIFICATION

THIS DOCUMENT IS THE PROPERTY OF THE UNIVERSITY OF CALIFORNIA LAWRENCE LIVERMORE NATIONAL LABORATORY. REPRODUCTION PROHIBITED WITHOUT PERMISSION OF THE MECHANICAL ENGINEERING DEPARTMENT.

LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT

MAJOR UNIT: INTEGRATED CRSN TEST FACIL

DETAIL: COUPON, WELDED WT LOSS

DRAWING NO: AAA95-100704-00

SCALE 1 — 1 | SHEET 1 OF 1

LLNL Document E-20-50-ID4

4/14/97

Item Number	UNS Number	Alloy	Number Required	Specimen / ASTM Specification	Drawing Number	Sequential Specimen Identification	Welding Specification
1	N08825	Incoloy 825	15	1 x 2 Coupon, Base Metal Wt. Loss / ASTM B424, Cold Rolled and Annealed Sheet	AAA 95-100703-OO	AWA 164 - AWA 178	N/A
2	N06985	Hastelloy G3	15	1 x 2 Coupon, Base Metal Wt Loss / ASTM B582, Cold Rolled and Annealed Sheet	AAA 95-100703-OO	BWA 164 -BWA 178	N/A
3	N06455	Hastelloy C4	15	1 x 2 Coupon, Base Metal Wt Loss / ASTM B575, Hastelloy R sheet	AAA 95-100703-OO	CWA 164 - CWA 178	N/A
4	N06022	Hastelloy C22	15	1 x 2 Coupon, Base Metal Wt Loss / ASTM B575, Hastelloy sheet	AAA 95-100703-OO	DWA 164 - DWA 178	N/A
5	R53400	Titanium Gr 12	15	1 x 2 Coupon, Base Metal Wt Loss / ASTM B265, Grade 12	AAA 95-100703-OO	EWA 164 - EWA 178	N/A
6	Titanium Gr 16	Titanium Gr 16	15	1 x 2 Coupon, Base Metal Wt Loss / Grade CP 16	AAA 95-100703-OO	FWA 164 - FWA 178	N/A
7	N08825	Incoloy 825	15	1 x 2 Coupon, Welded Wt. Loss / ASTM B424, Cold Rolled and Annealed Sheet	AAA 95-100704-OO	AWB 164 - AWB 178	GMAW FULL PENETRATION WELD TO AWS A5.14 CLASS ER NiCrMo-10
8	N06985	Hastelloy G3	15	1 x 2 Coupon, Welded Wt Loss / ASTM B582, Cold Rolled and Annealed Sheet	AAA 95-100704-OO	BWC 164 -BWC 178	GMAW FULL PENETRATION WELD TO AWS A5.14 CLASS ER NiCrMo-9
9	N06455	Hastelloy C4	15	1 x 2 Coupon, Welded Wt Loss / ASTM B575, Hastelloy R sheet	AAA 95-100704-OO	CWB 164 - CWB 178	GMAW FULL PENETRATION WELD TO AWS A5.14 CLASS ER NiCrMo-10
10	N06022	Hastelloy C22	15	1 x 2 Coupon, Welded Wt Loss / ASTM B575, Hastelloy sheet	AAA 95-100704-OO	DWB 164 - DWB 178	GMAW FULL PENETRATION WELD TO AWS A5.14 CLASS ER NiCrMo-10
11	R53400	Titanium Gr 12	15	1 x 2 Coupon, Welded Wt Loss / ASTM B265, Grade 12	AAA 95-100704-OO	EWD 164 - EWD 178	GTAW FULL PENETRATION WELD TO AWS A5.16 CLASS ER Ti-12
12	Titanium Gr 16	Titanium Gr 16	15	1 x 2 Coupon, Welded Wt Loss / Grade CP 16	AAA 95-100704-OO	FWE 164 - FWE 178	T GMAW FULL PENETRATION WELD TO AWS A5.16 CLASS ER Ti-7

WEIGHT LOSS SPECIMEN PURCHASE CONTRACT REQUIREMENTS 4-14-97

OK 1. Specimens shall be permanently identified with ~1/8" metal die stamps or automatic type-set engraver (not hand-held vibro-scribe) in accordance with location requirements detailed in LLNL drawings AAA95-100703-OO, AAA95-100704-OO, and utilizing identification code described in LLNL document E-20-50-ID4 dated 4-14-97.

NO 2. After machining, specimens shall be cleaned in a suitable solvent. Using clean gloves or other methods which eliminate specimen contamination after cleaning, the specimens shall be placed in individual bags for shipment to LLNL. Solvents used in cleaning each of the alloys shall be identified and applicable Material Safety Data Sheets shall be supplied to LLNL.

NO 3. In-process inspection records that demonstrate specimen dimensions called out in LLNL drawings AAA95-100703-OO and AAA95-100704-OO are within tolerance, shall be provided to LLNL upon receipt of specimens.

NOT YET, SENDING VIA MAIL 4. Photocopies of the Certified Material Test Reports (CMTR) for both the base plate/sheet material and weld wire, when applicable, shall be supplied to LLNL for the plate/sheet/wire used to fabricate each of the specimens. In addition, the vendor must supply LLNL a written statement of conformity, which serves to link all specimens to the base metal and/or weld wire used in specimen fabrication by delineating the specimen identification to an applicable CMTR. Should the CMTR include multiple items or pieces, the particular piece/lot used to fabricate each specimen shall be specified in the vendor letter of conformity. This requirement shall be fulfilled upon receipt of specimens at LLNL.

NO 5. Independent chemical analysis shall be performed by vendor or qualified sub-contractor for each heat/lot of plate/sheet and weld wire used in the fabrication of the specimens. In addition, the vendor or sub-contractor shall perform physical property testing on the plate/sheet used to fabricate the specimens. The vendor shall supply LLNL a written test report of the independent chemical and physical properties analysis which shall include the identification of the heat/lot tested, including identification of any individual pieces should the CMTR include multiple pieces, and applicable test methods employed in the analysis. Physical property data derived from the independent testing shall include as a minimum the tensile strength, yield strength, and % elongation using standard methods described in ASTM E8. The chemical analysis derived from the independent testing shall include as a minimum those elemental compositions necessary to verify each heat/lot of plate/sheet/wire alloy lies within the ASTM standard requirements listed for the materials specified in LLNL document E-20-50-ID3.

NO 6. Delivery of all items to LLNL is required 2-3 weeks After Receipt of Order (ARO). Partial shipments are acceptable and encouraged as long as the supporting documentation requirements described above are met for the partial delivery.

5-9-97

ED VITZ + JOHN ESTILL SPOKE VIA SPEAKERPHONE WITH LARRY BRADEN AND HE STATED THAT METAL SAMPLES CO. DID NOT RECEIVE THIS PAGE IN ORDER. VITZ SAYS CONFIRMING COPY WAS SENT VIA TELEX CONFIRMATION. ED VITZ sent another copy that was sent 5-9-97. We expect full compliance [illegible] chemically tested independently [illegible]

PROCUREMENT & MATERIEL
INSTITUTIONAL SUPPORT.

MAIL STOP, L-650.

TEL. EXT., NO.: NO. 3-7132.

TELEFAX, NO.: 3-7226.

UNIVERSITY OF CALIFORNIA
LAWRENCE LIVERMORE NATIONAL LABORATORY
PURCHASE ORDER,
NO. B338959.

VENDOR NOTE:

(01.) (A.) SHIP VIA...FEDERAL EXPRESS...OVER-NIGHT AIR...FREIGHT COLLECT, CHARGING FREIGHT TO...ACCOUNT, NO. 0941-0205-7....
(B.) ON FEDERAL EXPRESS AIR-BILL, PLEASE ANNOTATE...UCLLNL, PURCHASE ORDER, NO. B338959.

(02.) UCLLNL, IS SELF-INSURED - PLEASE DO NOT DECLARE VALUE OF/INSURE MATERIEL WITH FREIGHT CARRIER.

Edward Otto Vaty
04/16/97

*** TX REPORT ***

TRANSMISSION OK

TX/RX NO	2189
CONNECTION TEL	812053584515
SUBADDRESS	
CONNECTION ID	
ST. TIME	04/21 13:52
USAGE T	03'19
PGS.	8
RESULT	OK

Purchase Order / Confirming Order No: B338959 PAGE: 1
Do Not Duplicate.

DATE 04/21/97

Payment Terms
Net 30 Days

Buyer:
E. VITZ
Ext: (510)423-7132
Fax: (510)423-7226

To: METAL SAMPLES COMPANY, INC.
RT. 1, BOX 152

MUNFORD AL 35268
Attn: BRENDA SMITH
Phone: (205)358-4202
FAX: (205)358-4515

University of California
Lawrence Livermore National Laboratory
Purchase Order
For Contract No. W-7405-ENG.48
With Department of Energy
FOR RESALE: State Sales Tax should not be charged, as the University holds State Sales Tax Permit SR-CHA 21-135323

SHIP TO:

UCLLNL
For U.S. Department of Energy
LLNL 411
7000 East Avenue (P.O. B338959)
Livermore, California 94550
RECEIVING DEPT, BLDG., NO. 411

MAIL INVOICE IN DUPLICATE TO
UNIVERSITY OF CALIFORNIA
LAWRENCE LIVERMORE NATIONAL LABORATORY
~~Accounting Office~~ - P.O. Box 5001
LIVERMORE, CALIFORNIA 94551
ACCOUNTS PAYABLE DEPT, L-452
The Purchase Order Number shown above MUST appear prominently on your shipment, freight bill, & invoice to facilitate receiving and payment of the order.

Confirming Order 04/16/97 - DO NOT DUPLICATE

Ship Via:	Transportation Terms:	F.O.B.
FED-X Priority Ovrnt	LABORATORY Shipping Point: MUNFORD AL	SHIPPING POINT

Item No.	Model/Manufacturer Description	Qty	UOM/ UOP	Unit Price	Extended Price	Ship Date
001	N08825	15.000	EA /	9.85000	147.75	05/05/97

METAL SAMPLES CO.
1 X 2 COUPON - BASE METAL WEIGHT LOSS/ASTM B424 - COLD-ROLLED & ANNEALED SHEET - P/N C01286141304000 -

SUBJECT TO:
A. LLNL DOCUMENT E-20-50-ID4...PAGES: 1...ACCOMPANYING COPY...
B. LLNL, DRAWING, NO. AAA95-100703-00...DATE: 030195...PAGES: 1... ACCOMPANYING COPY...
C. LLNL, DRAWING, NO. AAA95-100704-00...DATE: 030195...PAGES: 1... ACCOMPANYING COPY...

PURCHASE ORDER

Purchase Order No: B500447		Seller's Status: Small Business

University Procurement Representative:	Phone #:	Fax #:	E-Mail Address:
R. Gomez, Sr. Contract Administrator	(925) 42422-3306	(925) 42423-9559	gomez12@llnl.gov

Issued To:

METAL SAMPLES COMPANY
Attention: Brenda M. Smith
152 Metal Samples Road, P.O. Box 8
Munford, AL 36268

Ship To Address:

University of California
Lawrence Livermore National Laboratory
For the U. S. Department of Energy
Purchase Order No. B500447

Payment Terms: Net 30 Days
F.O.B. Point: Shipping Point
Shipping Point: Munford, AL
Shipping Instructions: Ship via Consolidated Freightways, freight collect. Mark Bill of Lading 'Moving Under Gov't Tender No. 10096-C.' **Deliveries are requested by 1:00 p.m. Pacific time.**
Transportation Terms: Account of University; - Do not insure

Sales Tax Exemption: This Purchase Order is exempt from State Sales & Use Tax, per the University's California State Resale Permit No. SR-CHA 21-135323.

Invoices: All invoices shall reference the Purchase Order number and be submitted to:

University of Californ[illegible]
Lawrence Livermo[illegible]onal Laboratory
Vendor Payments[illegible]32
P.O. Box 5001
Livermore, CA 94551

ORDERED ITEMS

ITEM NO.	ITEM, SPECIFICATIONS, CATALOG REFERENCES	QTY	UNIT PRICE	EXTENDED PRICE	DELIVERY DATE
1	TIGR7, 32RMS, SEQ, VCI (Titanium), Part No. CO3208081301400	40 ea	$39.50	$1,580.00	1/19/99 Or Sooner
2	TIGR16, 32RMS, SEQ, VCI (Titanium), Part No. CO320B361301400	40 ea	54.13	2,165.20	With L/I #1
3	C22, 32RMS, SEQ, VCI (Alloy), Part No. CO320A111301400	40 ea	27.40	1,096.00	With L/I #1
4	304, 32RMS, SEQ, VCI (Stainless Steel), Part No. CO3201411301400	40 ea	31.12	1,244.80	With L/I #1
5	316L, 32RMS, SEQ, VCI (Stainless Steel), Part No. CO3201591301400	40 ea	17.69	707.60	With L/I #1
6	TIGR7, LAP, ALL (Titanium), Part No. EL4058080902000	40 ea	15.00	600.00	With L/I #1
7	TIGR16, LAP, ALL (Titanium), Part No. EL405B360902000	40 ea	18.75	750.00	With L/I #1
8	C22, LAP, ALL (Alloy), Part No. EL405A110902000	40 ea	11.00	440.00	With L/I #1
9	304, LAP, ALL (Stainless Steel), Part No. EL4051410902000	40 ea	7.90	316.00	With L/I #1

ITEM NO.	ITEM, SPECIFICATIONS, CATALOG REFERENCES	QTY	UNIT PRICE	EXTENDED PRICE	DELIVERY DATE
10	316L, LAP, ALL (Stainless Steel), Part No. EL4051590902000	40 ea	4.55	182.00	With L/I #1
11	TIGR7, MILL, ALL (Titanium), Part No. CO9998080002000	1 ea	105.00	105.00	With L/I #1
12	TIGR16, MILL, ALL (Titanium), Part No. CO999B360002000	1 ea	115.00	115.00	With L/I #1
13	C22, MILL, ALL (Alloy), Part No. CO999A110002000	1 ea	65.00	65.00	With L/I #1
14	304, MILL, ALL (Stainless Steel), Part No. CO9991410002000	1 ea	55.00	55.00	With L/I #1
15	316L, MILL, ALL (Stainless Steel), Part No. CO9991590002000	1 ea	50.00	50.00	With L/I #1
16	5923HMO, 32RMS, SEQ, VCI (Alloy), Part No. CO3209371301400	40 ea	39.50	1,580.00	With L/I #1
17	5923HMO, LAP, ALL (Alloy), Part No. EL4059370902000	40 ea	15.00	600.00	With L/I #1
18	C22, LAP, ALL (Alloy), Part No. CO9999370002000 NOTE: See the Incorporated Documents in the Special Provisions of the purchase order for work requirements.	1 ea	75.00	75.00	With L/I #1

Total Firm Fixed Price: $11,726.60

TERMS & CONDITIONS: This Purchase Order includes the attached GENERAL PROVISIONS FOR COMMERCIAL SUPPLIES AND SERVICES (List 600B; Rev. 5/1/98), SPECIAL PROVISIONS and all other referenced documents. Any terms stated in Seller's acknowledgment in addition to or in conflict with the terms stated herein shall not become a part of this Purchase Order.

THE REGENTS OF
THE UNIVERSITY OF CALIFORNIA

BY: R. Gomez
R. Gomez

TITLE: Sr. Contract Administrator
General Purchasing Group
Procurement & Materiel

DATE: 12/8/98

MODIFICATION NO. 1
TO
PURCHASE ORDER NO. B500447

University Procurement Representative: R. Gomez,	Phone #: (925) 422-3306	Fax #: (925) 423-9559	E-Mail Address: gomez12@llnl.gov
Issued To: Metal Samples Company, Attention: Brenda Smith, 152 Metal Samples Road, Munford, AL 36268			

INTRODUCTION

The purpose of this No Cost Modification is to Revise Line Item #18, and the Buyer's Statement of Work, and also, Specification No. E-20-66-3.

MODIFICATIONS

1. Line Item No. 18 is deleted in its entirety and replaced with the following:

18	5923HMO, MILL, ALL (Alloy), Part No. CO9999370002000 NOTE: See the Incorporated Documents in the Special Provisions of the purchase order for work requirements.	1 ea	75.00	75.00	With L/I #1

2. In the Special Provisions, under the Incorporated Documents, the Buyer's Statement of Work, and Specification No. E-20-66-3, are hereby modified (Revision 1), to read as follows:

INCORPORATED DOCUMENTS

- BUYER'S (LLNL) - QA REQUIREMENTS FOR SUPPLIERS OF ANALYTICAL SERVICES, DATED 1/5/98
- BUYER'S (LLNL) - STATEMENT OF WORK FOR FABRICATION OF ELECTROCHEMICAL DISC SPECIMENS AND 2" X 2" CREVICE SPECIMENS, DATED 11/5/98A
- BUYER'S (LLNL) - SPECIFICATION NO. E-20-66-3, DATED 11/5/98, REV. 1
- BUYER'S (LLNL) - DRAWING OF COUPON, BASE MTL CREVICE, DATED 10/96

ALL OTHER TERMS, CONDITIONS, AND PROVISIONS OF THE PURCHASE ORDER SHALL REMAIN IN FULL FORCE AND EFFECT.

THE REGENTS OF
THE UNIVERSITY OF CALIFORNIA

BY: ______________________
R. Gomez

TITLE: Sr. Contract Administrator
General Purchasing Group
Procurement & Materiel

DATE: ______________________

 (Form #PS-621A; Rev. 10/26/98)

QA REQUIREMENTS FOR SUPPLIERS OF ANALYTICAL SERVICES (1/5/98)

I. INTRODUCTION

The services quoted upon or furnished for this procurement are for the use by the Purchaser in connection with the Civilian Radioactive Waste Management Program sponsored by the U.S. Department of Energy (DOE).

The services shall be provided in accordance with the Supplier's documented Quality Assurance (QA) program, accepted by the DOE Office of Quality Assurance (OQA) prior to the start of work. OQA acceptance of the Supplier's QA program is predicated on the degree of compliance with the QA Requirements described in Section II and the Supplier's agreement to meet the requirements described in Sections III and IV.

II. SUPPLIER'S QA PROGRAM

The Supplier=s documented QA program shall address the following topics to the degree appropriate for the nature, scope and complexity of the activity: The supplier shall provide justification for the non-applicability of a topic.

NOTE: The QA program could take the form of a QA manual that contains a QA program description and implementing documents or a series of implementing documents with a matrix that reflects how the following topics are addressed:

1.0 Organization

A description of the Supplier's organizational structure and responsibilities for the personnel verifying quality achievement must be provided. Personnel who perform verification of quality achievement must be independent from those performing the work.

2.0 QA Program

Prior to performing the work, personnel shall be evaluated to determine that they are qualified to perform the work assigned and receive documented indoctrination and training to assure suitable proficiency is achieved and maintained. The Supplier shall assure that personnel are familiar with procedures and/or instructions pertaining to the work to be performed prior to initiating the work.

3.0 Procurement Control

The approach used to assure that technical and quality requirements are incorporated into procurement documents and changes to the documents shall be described.

The methods used to document evaluation and selection of suppliers prior to the award of a contract/purchase order shall be described. Methods used to ensure that received services meet requirements shall be described.

4.0 Instructions, Procedures and Document Control

Activities shall be performed in accordance with documented approved implementing documents (e.g. procedure, instructions). The activity shall be described to a level of detail commensurate with the complexity of the activity and the need to assure consistent and acceptable results.

The process used for preparation, review, approval and control of implementing documents shall be described. This process must include: methods used for ensuring that only the latest revision is used at the work place and, methods used to ensure that documents are reviewed for applicability, correctness, adequacy, completeness, accuracy and compliance with established requirements. The review shall be performed by individuals technically competent in the subject area, and the review shall be performed by someone other than the preparer.

5.0 Control of Measuring and Test Equipment (M&TE)

QA REQUIREMENTS FOR SUPPLIERS OF ANALYTICAL SERVICES (1/5/98)

The methods used to assure that M&TE, including equipment that contains software or programmable hardware, is adjusted and maintained as a unit at prescribed intervals, or prior to use, against reference standards having traceability to nationally recognized standards shall be described. Calibration standards shall have a greater accuracy than that required of the M&TE being calibrated. If a standard with greater accuracy does not exist or is unavailable, calibration standards with equal accuracy may be used if it can be shown to be adequate for the requirements. The basis for this acceptance shall be documented.

Calibration M&TE shall be uniquely identified to provide traceability to calibration data. The use of M&TE shall be documented. Measures shall be established to prevent the use of out-of-calibration M&TE. When M&TE is found to be out-of-calibration the validity of results using that equipment since its last calibration shall be evaluated. M&TE shall be properly handled and stored to maintain accuracy.

6.0 Corrective Action

A control system for identifying and documenting deviations from technical and quality implementing documents shall be established. Adverse conditions shall be reported to appropriate management responsible for the condition, who shall determine the extent of the condition and take corrective actions. The Supplier=s QA organization or other independent organization shall have the authority and responsibility for concurring that the proposed corrective actions satisfy QA program requirements and verifying that corrective actions have been completed.

7.0 QA Records

Methods shall be established for specifying, preparing, and maintaining records that provide evidence of quality. These records shall be protected from damage, deterioration or loss. The requirements and responsibilities for record transmittal, distribution, retention, maintenance, and disposition shall be documented.

8.0 Audits

Planned and scheduled audits to verify compliance with the QA program requirements and to determine effectiveness of the QA program shall be performed at least annually. The audits shall be performed in accordance with prescribed procedures or checklists by qualified personnel who do not have direct responsibility for performing the activities being audited. Audit results shall be documented and reported to responsible management. Responsible management shall take action to correct identified deficiencies in accordance with Section 6 *Corrective Action* and follow-up action to verify corrective action shall be taken in accordance with Section 6 *Corrective Action*.

9.0 Analytical Services/Sample Control

The process for receiving, identifying, handling, analyzing, tracking and storing samples submitted by the Purchaser to the supplier shall be established. Samples that do not meet requirements specified in controlled documents shall be documented and evaluated.
The method for collecting, recording and evaluating data (analytical results) shall be described.
The method for the conduct of analyses, internal quality control, and/or analytical testing shall be established.

10.0 Scientific Investigation

When technical or other implementing documents are not utilized to perform analytical services, scientific investigation activities shall be documented in a scientific notebook that provides a description of the work as planned, performed and the results obtained. Data shall be identified in a manner that provides traceability to samples, associated documentation and computer codes. Scientific notebooks shall be review by an independent technically qualified individual to verify there is sufficient detail to 1) retrace the investigations and confirm the results, or 2) Repeat the investigation and achieve comparable results, without recourse to the original investigator.

QA REQUIREMENTS FOR SUPPLIERS OF ANALYTICAL SERVICES (1/5/98)

III. GENERAL QA REQUIREMENTS FOR THIS PURCHASE

The following general QA requirements shall apply to the supplier for this purchase but do not necessarily need to be included in the supplier=s QA program.

SUBCONTRACTING

1. The Purchaser shall be notified if the Supplier subcontracts any part of the scope of work prior to issuance of the sub-tier procurement document. Supplier procurement documents for services directly supporting this work shall incorporate appropriate portions of the QA Program requirements listed in Section II.

2. Where possible sub-tier procurements should be with suppliers that are approved by DOE/OCRWM Office of Quality Assurance.

NONCONFORMANCES/WORK CONTROL

3. The Supplier shall notify the Purchaser=s technical contact when a calibrated instrument used to calibrate and certify Purchaser equipment is found to be defective or out-of-calibration.

4. The Supplier shall notify the Purchaser (technical contact) when the Supplier identifies any nonconformances (deviations) from the procurement document. Nonconformances where the proposed disposition is Arepair≅ or Ause-as-is≅ are required to be submitted to the Purchaser (technical contact) for review and concurrence.

5. When work cannot be accomplished as described in the implementing document, or accomplishment of such work would result in an undesirable situation, the work shall be stopped until the situation is resolved by management. Work shall not resume until the implementing document is changed(in accordance with Section II, topic 4) or controlled by another appropriate process(i.e. Corrective Action/Nonconformance process).

PURCHASER AUDIT/VERIFICATION

6. The Purchaser or Purchaser=s Representative (DOE/U.S. Nuclear Regulatory Commission (NRC) or their representative) has the right to inspect and evaluate (audit/surveil) the work performed or being performed under the purchase document, and the premises where the work is being performed, at all reasonable times and in a manner that will not unduly delay the work. If the Purchaser performs inspection or evaluation on the premises of the Supplier or a subcontractor, the Supplier shall furnish and shall require subcontractors to furnish, at no increase in contract price, all reasonable facilities and assistance for the safe and convenient performance of these duties.

   NOTE: The Purchaser=s QA program is regulated by the NRC and requires that suppliers of services be audited, as a minimum every three years. It also requires an annual evaluation to determine if a more frequent audit is necessary. There should be at least one audit during the life of the activity. In other words, the Supplier can expect to be audited soon after contract award and on a three year basis after the first audit if the service is still being performed.

7. Purchaser verification activities shall not relieve the Supplier of the responsibility for verification of quality achievement.

MISCELLANEOUS

8. The Supplier shall provide the Purchaser with any revisions to their QA program documents prior to implementation.

9. The Supplier will identify any spare or replacement parts or assemblies and the appropriate technical and QA requirements/information required for ordering them.

QA REQUIREMENTS FOR SUPPLIERS OF ANALYTICAL SERVICES (1/5/98)

10. Where software is used as part of the analytical process which provides results that are not later validated, the Supplier shall identify the software version and describe the method used to verify that the software is functioning properly and produces the intended results. Software version changes shall be checked to verify that the software produces correct results. The supplier shall keep a record of the validation of the software.

11. Unless otherwise stated in the purchase document, it is not a requirement that the samples be returned to the Purchaser.

IV. REQUIRED DOCUMENTATION

The following documentation is required.

DOCUMENT DESCRIPTION	SUBMITTAL REQUIREMENT
Supplier QA Program document	Submit latest version with bid and thereafter revisions to program during the order and prior to start of work.
Analytical Results	Submit for acceptance
QA Records such as: implementing documents documentation of standards equipment calibration training qualification audit reports corrective actions software validation records notebooks logbooks	Retain by the supplier for at least 3 years or until dispositioned by Purchaser.

Analytical results shall include a statement that work was performed in accordance with the purchase order requirements and/or the suppliers QA program.

Records for this procurement shall be legible, accurate, appropriate to the work accomplished, and identifiable to the item(s) or activity(s) to which they apply and shall be stamped, initialed, or signed and dated as complete.
Corrections to completed Records for this procurement shall be made by drawing a single line through the changed or incorrect information and inserting the new or correct information. The correction shall include the initials or signature of the individual authorized to make the correction and the date the correction was made.
Correction of Records for this procurement that are incomplete or illegible shall be accomplished in one of the following ways: 1) Transcribe, regenerate, or enhance the illegible portion, or 2) Obtain a new, complete, legible record.

STATEMENT OF WORK FOR FABRICATION OF ELECTROCHEMICAL DISC SPECIMENS AND 2" x 2" CREVICE SPECIMENS

11-5-98 A

1. Specification E-20-66-3 REV.1 dated 11/5/98 is the governing document for materials and fabrication used to provide test specimens for LLNL.

2. Specimens described in **items 1-5, and 16** shall be permanently identified with ~3/32" metal die stamps or automatic type-set engraver as per requirements described in LLNL drawing AAA96-101274-00 and utilizing identification code described in specification E-20-66-3 REV. 1 dated 11/5/98.

3. Specimens described in **items 6-10, and** 17 shall be permanently identified with ~3/32" metal die stamps or automatic type-set engraver on side opposite the lap finished side (<10 RMS) utilizing identification code described in specification E-20-66-3 REV.1 dated 11/5/98.

4. Specimens described in **items 11-15 and 18** shall be permanently identified on both ends of the specimen, approximately 1/4" from ends, utilizing identification code described in specification E-20-66-3 REV.1 dated 11/5/98.

5. After machining, specimens described in **items 1-18** shall be cleaned in a suitable solvent. Using clean gloves or other methods which eliminate specimen contamination after cleaning, the specimens shall be placed in individual bags and protected from surface scratching for eventual shipment to LLNL. Solvents used in cleaning shall be identified in writing.

The following items in each group shall be fabricated from the same base metal heat/lot:

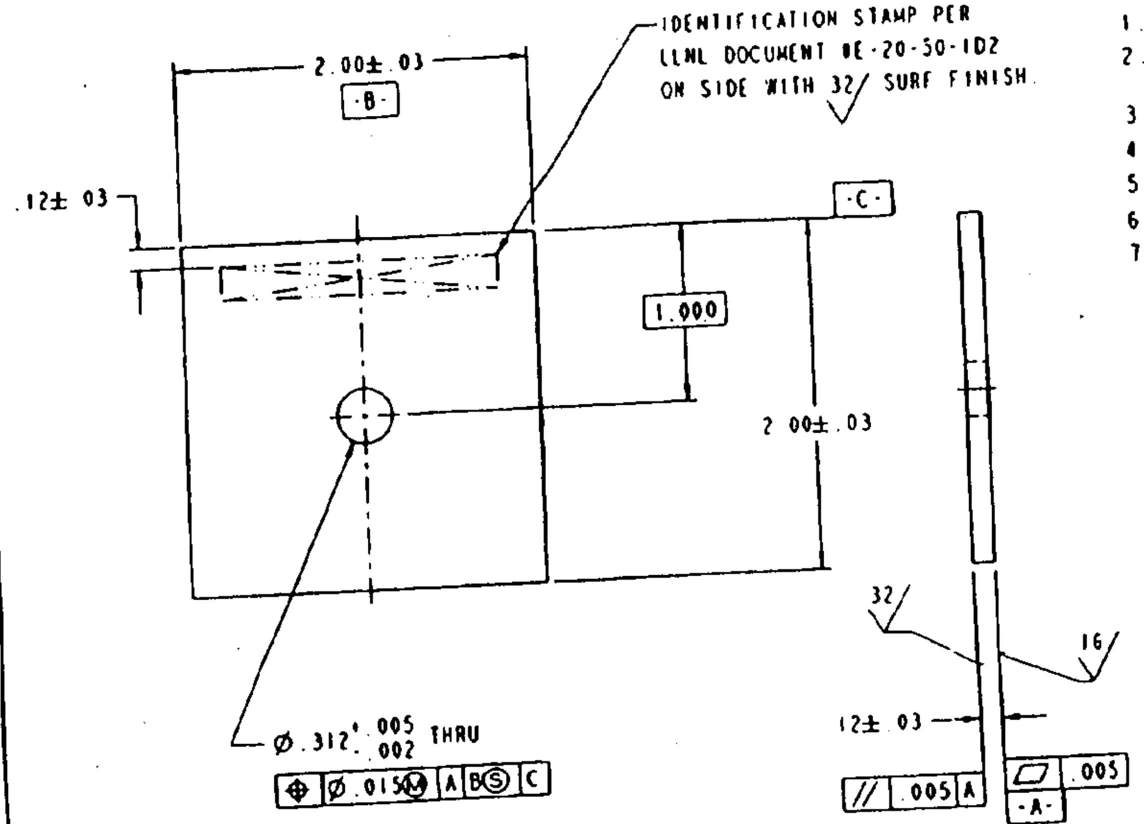
Group 1 Items 1, 6, and 11
Group 2 Items 2, 7, and 12
Group 3 Items 3, 8, and 13
Group 4 Items 4, 9, and 14
Group 5 Items 5, 10, and 15
Group 6 Items 16, 17, and 18

6. A photocopy of the Certified Material Test Reports (CMTR) used to fabricate the specimens and wire lots in items 1-18 shall be supplied to LLNL. In addition, the vendor shall supply LLNL a written statement of conformity which serves to link all specimens to the appropriate heat/lot number used to fabricate the specimens using the specimen identifiers from specification E-20-66-3 REV.1 dated 11/5/98. This requirement shall be fulfilled upon receipt of specimens at LLNL.

8. Inspection records for surface finish on a statistical sampling from items 6-10, and 17 shall be provided to LLNL upon receipt of specimens. Inspection records to verify tolerances described in LLNL DWG. AAA96-101274-00 are met based on a statistical sampling of items 1-5 and 16 shall be provided to LLNL upon receipt of specimens.

9. Delivery of all items to LLNL is required 14-21 days ARO.

112 128



NOTES
UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1985.
4. ABBREVIATIONS PER ANSI Y1.1-1972.
5. BREAK SHARP EDGES .005 - .030.
6. DO NOT SHEAR OR PUNCH.
7. 125/ OR STOCK.

Obliteration of title not critical to document - [initials] 1/25/00

~~STEEL, ALLOY 625 HOT ROLLED, UNS [illegible]~~

NO REQD	PART / LLNL STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM

DWN S. EDSON 10-96
CHK [signature] 10-96
APVD [signature] 10-96
CLASSIFIED BY
TITLE DATE

CLASSIFICATION

THIS DOCUMENT IS THE PROPERTY OF THE UNIVERSITY OF CALIFORNIA LAWRENCE LIVERMORE NATIONAL LABORATORY. REPRODUCTION PROHIBITED WITHOUT PERMISSION OF THE MECHANICAL ENGINEERING DEPARTMENT

LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

MAJOR UNIT: INTEGRATED CRSN TEST FACIL
SUBASSY
DETAIL: COUPON, BASE MTL CREVICE ~~(625)~~
DRAWING NO: AAA96-101274-OC
ACCT NO 6873-50
SCALE 1
SHEET 1 OF 1

LTR	DWN	CHK	APVD	DATE	ZONE	CHANGE

Item #	Number Specimens	Alloy UNS Number	Sequential Specimen ID	ASTM Specification	Fabrication	MSC Part Number or LLNL Dwg. No.	Surface Finish (side opposite ID)	Sample Thickness
1	40	R52400	NCA 184 thru NCA 223	B265 annealed	Non-Weld	LLNL Dwg. AAA96-101274-00	See LLNL Drawing	See LLNL Drawing
2	40	Titanium Grade 16	FCA 244 thru FCA 283	B265 annealed	Non-Weld	LLNL Dwg. AAA96-101274-00	See LLNL Drawing	See LLNL Drawing
3	40	N06022	DCA 244 thru DCA 283	B575 annealed	Non-Weld	LLNL Dwg. AAA96-101274-00	See LLNL Drawing	See LLNL Drawing
4	40	S30400	OCA 001 thru OCA 040	A240 annealed	Non-Weld	LLNL Dwg. AAA96-101274-00	See LLNL Drawing	See LLNL Drawing
5	40	S31603	PCA 001 thru PCA 040	A240 annealed	Non-Weld	LLNL Dwg. AAA96-101274-00	See LLNL Drawing	See LLNL Drawing
16	40	N06059	QCA 001 thru QCA 040	B575 Annealed	Non-Weld	LLNL Dwg. AAA96-101274-00	See LLNL Drawing	See LLNL Drawing
6	40	R52400	NEA 001 thru NEA 040	B265 annealed	Non-Weld	MSC P/N EL 405	< 10 RMS	0.125" nominal
7	40	Titanium Grade 16	FEA 001 thru FEA 040	B265 annealed	Non-Weld	MSC P/N EL 405	< 10 RMS	0.125" nominal
8	40	N06022	DEA 001 thru DEA 040	B575 annealed	Non-Weld	MSC P/N EL 405	< 10 RMS	0.125" nominal
9	40	S30400	OEA 001 thru OEA 040	A240 annealed	Non-Weld	MSC P/N EL 405	< 10 RMS	0.125" nominal
10	40	S31603	PEA 001 thru PEA 040	A240 annealed	Non-Weld	MSC P/N EL 405	< 10 RMS	0.125" nominal
17	40	N06059	QEA 001 thru QEA 040	B575 Annealed	Non-Weld	MSC P/N EL 405	< 10 RMS	0.125" nominal
11	1	R52400	NEA CHECK 1	B265 annealed	Non-Weld	1/2" x 6" (longitudinal rolling direction) x 1/8"	Mill finish	0.125" nominal
12	1	Titanium Grade 16	FEA CHECK 1	B265 annealed	Non-Weld	1/2" x 6" (longitudinal rolling direction) x 1/8"	Mill finish	0.125" nominal
13	1	N06022	DEA CHECK 1	B575 annealed	Non-Weld	1/2" x 6" (longitudinal rolling direction) x 1/8"	Mill finish	0.125" nominal
14	1	S30400	OEA CHECK 1	A240 annealed	Non-Weld	1/2" x 6" (longitudinal rolling direction) x 1/8"	Mill finish	0.125" nominal
15	1	S31603	PEACHECK 1	A240 annealed	Non-Weld	1/2" x 6" (longitudinal rolling direction) x 1/8"	Mill finish	0.125" nominal
	1	N06059	QEA CHECK 1	B575 ann	Non-Weld	1/2" x 6" (longitudinal rolling direction) x 1/8"	Mill finish	0.125" nomina

TRW Environmental Safety Systems Inc.
2650 Park Tower Drive
Suite 800
Vienna, Virginia 22180

COPY

1|2 Page of

Date Printed: 02/10/1999

115 of 128

Order To: METAL SAMPLES COMPANY
152 METAL SAMPLES RD
P.O. BOX 8
MUNFORD, AL 36268

MESACO

Ship To: NEVADA
TRW C/O LAWRENCE LIVERMORE NATL LAB
7000 EAST AVENUE
LIVERMORE, CA 94550

Contact: BRENDA SMITH Ph: (256) 358-4202 Fax: (256) 358-4515

Submit all invoices and questions on payments (in writing) to TRW Accounts Payable.
The complete P.O. number must appear on all invoices, packing slips and correspondence. Do not insure unless otherwise specified herein.

ORDER DATE	BUYER	TERMS	FOB	SALES ORDER	SHIP VIA	DELIVER TO
02/15/99	YUMI STAFFORD	NET 30	MUNFORD, AL		FEDEX	M.KNAPP,LAWANCE/L532

LINE	ITEM / DESCRIPTION	REV	U/M	DUE DATE	DESIRED DATE	ORDER QUANTITY	NEW UNIT COST	EXTENDED COST

A C K N O W L E D G M E N T R E Q U I R E D

Period of Performance: 02/15/99 To 09/30/99

1.) QUALITY AFFECTING PROCURMENT

SELLER SHALL PROVIDE TEST SPECIMENS AND ALL LABOR, MATERIAL, SUPPLIES AND EQUIPMENT TO PERFORM ALL NECESSARY SERVICES AS SPECIFIED IN THE ATTACHED PROCUREMENT REQUIREMENTS DOCUMENT OF TEST SPECIMENS REV 01, DATE 01/07/99 CONSISTING OF APPROVAL PAGE AND PAGES 2 THROUGH 7.

METAL SAMPLES COMPANY SHALL IMPLEMENT THEIR QUALITY MANUAL SECTION REVISION LEVELS, LISTING DATED 02/16/99, AND LABORATORY TESTING INC. (LTI) SHALL IMPLEMENT THEIR QUALITY SYSTEM PROGRAM MANUAL, REV. 13.

REFERENCE RFQ LV.CS.YS.01/99.003

TEST SPECIMENS AND SUPPORTING DOCUMENTS SHALL BE SHIPPED TO:

LAWRENCE LIVERMORE NATIONAL LABORATORY (LLNL)
7000 EAST AVENUE
LIVERMORE, CA 94550
ATTN: JOHN ESTILL (925)422-7139

BUYER: YUMI STAFFORD (702) 295-5437
INVOICE ADDRESS: 2650 PARK TOWER DRIVE VIENNA, VA 22180
ATTN: ACCOUNTS PAYABLE
DE-AC08-91RW00134

Purchase Order: [illegible]

1128100 [illegible]
~~Page: 2 of 2~~
Date Printed: 02/10/1999
116 of 128

TRW Environmental Safety Systems Inc.
2650 Park Tower Drive
Suite 800
Vienna, Virginia 22180

Order To: METAL SAMPLES COMPANY MESACO
152 METAL SAMPLES RD
P.O. BOX 8
MUNFORD, AL 36268

Contact: BRENDA SMITH Ph: (256) 358-4202 Fax: (256) 358-4515

Submit invoices and questions on payments (in writing) to TRW Accounts Payable.
The complete P.O. number must appear on all invoices, packing slips and correspondence. Do not insure unless otherwise specified herein.

ORDER DATE	BUYER	TERMS	FOB	SALES ORDER	SHIP VIA	DELIVER TO
02/15/99	YUMI STAFFORD	NET 30	MUNFORD, AL		FEDEX	M.KNAPP,LAWANCE/L532

LINE	ITEM / DESCRIPTION	REV	U/M	DUE DATE	DESIRED DATE	ORDER QUANTITY	NEW UNIT COST	EXTENDED COST
	*****INSIDE DELIVERY IS REQUIRED******** THIS IS CONFIRMATION ONLY. PLEASE SIGN THE ATTACHED COPY OF THIS PURCHASE ORDER AND RETURN IT BY MAIL TO: 1180 TOWN CENTER DR. LAS VEGAS, NV 89134, AS YOUR WRITTEN ACCEPTANCE. PRELIMINARY ACKNOWLEDGEMENT MAY BE FAXED TO (702) 295-2639. ALL WRITTEN CORRESPONDENCE SHOULD ALSO BE MAILED TO THE LAS VEGAS ADDRESS. ACCEPTED BY: ______________________ DATE: ______________________ THIS PO/SC IS SUBJECT TO THE SUPPLEMENTAL TERMS AND CONDITIONS OF TRW SYSTEMS FORM 2630, AS APPLICABLE. NEVADA TAX EXEMPT CERT NO: 764030400							
1	METAL TEST SPECIMENS AND INDEPENDENT TESTING SERVICE TO BE PERFORMED IN ACCORDANCE WITH THE ATTACHED PROCUREMENT REQUIREMENTS DOCUMENT (PRD) A) SCHEDULE 1 THROUGH 7 @ $72,518.20		$	02/15/99	02/15/99	100,000.0000	1.0000	$100,000.00

PO Total Amt: $100,000.00

Authorized Signatures

Q:L

PROCUREMENT REQUIREMENTS DOCUMENT APPROVAL COVER PAGE
for
Procurement Requirements Document for Test Specimens

Rev 01, Date 01/07/99

David Stahl 1/8/99
Task Manager Date
(David Stahl)

V. Pasupathi 1/8/99
Technical Reviewer Date
for (Howard Adkins)

Robert D Habbe 1-11-99
Quality Concurrence Date
(Bob Habbe)

1/11/99
Procurement Manager Date
for ~~(Rob Henderson)~~

PROCUREMENT REQUIREMENTS DOCUMENT FOR TEST SPECIMENS Rev 01, January 07, 1999

I. INTRODUCTION

This document outlines the requirements for the procurement of test specimens and independent testing services from Metal Samples Company (MSC). The item and services quoted upon or furnished for this procurement are for the use by the Purchaser in connection with the Office of Civilian Radioactive Waste Management (OCRWM) Program sponsored by the U.S. Department of Energy. This is a blanket purchase order.

II. STATEMENT OF WORK

Metal Samples Company shall provide test specimens and independent testing services by LTI in accordance with the attached technical specification. This specification describes the number, ASTM specification, material type and grade, fabrication, inspection, cleaning, marking, and packaging, and testing requirements for test specimens to be provided to LLNL.

III. TECHNICAL REQUIREMENTS

The technical requirements for each item will be identified in the **SCHEDULE OF ITEMS.** The purchaser may add additional work scope to this Procurement Requirement Document by a change notices and revised **SCHEDULE OF ITEMS.**

Metal Samples Company shall supply LLNL a records package which complies with the requirements listed in Section IV-D, Required Documentation.

Metal Samples Company shall ship the test specimens and the supporting documentation to LLNL, Attention: John Estill.

IV. QUALITY REQUIREMENTS FOR THIS PROCUREMENT

A. APPLICABLE QA PROGRAM

The test specimens shall be provided in accordance with the Alabama Specialty Products, Inc. documented Quality manual, latest revision, reviewed and accepted by the DOE Office of Quality Assurance (OQA). OQA acceptance of Alabama Specialty Products, Inc.'s QA program is predicated on the degree of compliance with the QA Requirements described in Section ~~II~~. Metal Samples Company shall comply with the general Quality requirements described in Sections ~~B~~, C and D. B
MCK 2/18/99

B. SUPPLIER'S QA PROGRAM

The Supplier's documented QA program shall address the following topics for the nature, scope and complexity of the activity. The QA program could take the form of a QA manual that contains a QA program description and implementing documents or a series of implementing documents with a matrix that reflects how the following topics are addressed:

1.0 Organization

A description of the supplier's organizational structure and responsibilities for the personnel verifying quality achievement must be provided. Personnel who perform verification of quality achievement must be independent from those performing the work.

2.0 QA Program

A documented quality assurance program shall be established, implemented, and maintained. The program shall provide control over activities affecting quality to an extent consistent with their importance.

The QA program shall provide for the planning and accomplishment of activities affecting quality under suitably controlled conditions, including the use of appropriate equipment, suitable environmental conditions for accomplishing the activity, and assurance that prerequisites for the given activity have been satisfied. The program shall provide for any special controls, processes, test equipment, tools, and skills to attain the required quality and for verification of quality.

Prior to performing the work, personnel shall be evaluated to determine that they are qualified to perform the work assigned and receive indoctrination and training to assure suitable proficiency is achieved and maintained. The supplier shall assure that personnel are familiar with the procedures and/or instructions pertaining to the work to be performed.

3.0 Procurement Control

Applicable technical and quality requirements shall be included or referenced in documents for the procurement of quality affecting items and services and such documents shall be reviewed for adequacy and ap[illegible]ed prior to issue.

The method used to document evaluation and selection of suppliers prior to the award of [illegible]act/purchase order shall be described. Methods used to ensure that received services meet requirements [illegible]e described.

4.0 Instructions, Procedures and Document Control

Quality affecting activities shall be performed in accordance with documented approved implementing documents (e.g. procedure, instructions). The activity shall be described to a level of detail commensurate with the complexity of the activity and the need to assure consistent and acceptable results.
The process used for preparation, review, approval and control of implementing documents shall be described. This process must include: methods used for ensuring that only the latest revision is used at the work place and, methods used to ensure that documents are reviewed for applicability, correctness, adequacy, completeness, accuracy and compliance with established requirements. Individuals technically competent in the subject area shall perform the review, and someone shall perform the review other than the preparer.

5.0 Identification and Control of Items

Controls shall be established to assure that only correct and accepted items are used or installed. Identification shall be maintained on the items or in documents traceable to the items, or in a manner, which assures that identification is established and maintained.

6.0 Control of Special Processes

Processes affecting quality of items or services shall be controlled. Special processes that control or verify quality, such as those used in welding, heat treating, and nondestructive examination, shall be performed by qualified personnel using qualified procedures in accordance with specified requirements.

7.0 Inspection

Inspections required verifying conformance of an item or activity to specified requirements shall be planned and executed. Characteristics to be inspected and inspection methods to be employed shall be specified. Inspection results shall be documented. Inspection for acceptance shall be performed by qualified personnel other than those who performed or directly supervised the work being inspected.

8.0 Control of Measuring and Test Equipment (M&TE)

The methods used to assure that M&TE including, equipment that contains software or programmable hardware, is adjusted and maintained as a unit at prescribed intervals, or prior to use, against reference standards having traceability to nationally recognized standards shall be described. Calibration standards shall have a greater accuracy than that required of the M&TE being calibrated. If a standard with greater accuracy does not exist or is unavailable, calibration standards with equal accuracy may be used if it can be shown to be adequate for the requirements. The basis for this acceptance shall be documented.

Calibration M&TE shall be uniquely identified to provide traceability to calibration data. The use of M&TE shall be documented. Measures shall be established to prevent the use of out-of-calibration M&TE. When M&TE is found to be out-of-calibration, the validity of results using the equipment since its last calibration shall be evaluated

M&TE shall be properly handled and stored to maintain accuracy.

9.0 Handling, Storage, and Shipping

Handling, storage, clean g, packaging, shipping, and preservation of items shall be controlled to prevent damage or loss and to minimize deterioration.

10.0 Inspection, Test, and Operating Status

The status of inspection and test activities shall be identified either on the items or in documents traceable to the items where it is necessary to assure that required inspections and tests are performed and to assure that items which have not passed the required inspections and tests are not inadvertently installed, used, or operated. Status shall be maintained through indicators, such as physical location and tags, markings, shop travelers, stamps, inspection records, or other suitable means. The authority for application and removal of tags, markings, labels, and stamps shall be specified.

11.0 Control of Nonconforming Items

Items that do not conform to specified requirements shall be controlled to prevent inadvertent installation or use. Controls shall provide for identification, documentation, evaluation, and segregation when practical and disposition of nonconforming items.

12.0 Corrective Action

A control system for identifying and documenting deviations from technical and quality implementing documents shall be established. Adverse conditions shall be reported to appropriate management responsible for the condition that shall determine the extent of the condition and take corrective actions. The Supplier's QA organization or other independent organization shall have the authority and responsibility for concurring that the proposed corrective actions satisfy QA program requirements and verifying that corrective actions have been completed.

13.0 QA Records

Methods shall be established for specifying, preparing, and maintaining records that provide evidence of quality. These records shall be protected from damage, deterioration or loss. The requirements and responsibilities for record transmittal, distribution, retention, maintenance, and disposition shall be documented.

14.0 Audits

Planned and scheduled audits to verify compliance with the QA program requirements and to determine effectiveness of the QA program shall be performed at least annually. The audits shall be performed in accordance with prescribed procedures or checklists by qualified personnel who do not have direct responsibility for performing the activities being audited. Audit results shall be documented and reported to responsible management. Responsible management shall take action to correct identified deficiencies and verify corrective action has been accomplished.

C. GENERAL QA REQUIREMENTS FOR THIS PURCHASE

The following general QA requirements shall apply to the supplier for this purchase but do not necessarily need to be included in the supplier's QA program.

SUBCONTRACTING

1. The Purchaser shall be notified if Metal Samples Company or LTI subcontracts an[illegible] the scope of work prior to issuance of the sub-tier procurement document. Supplier procurement d[illegible]ents for services directly supporting this work shall incorporate appropriate portions of the QA Pr[illegible]irements listed in Section II. MSC procurement documents to LTI shall require LTI to implement [illegible] Q[illegible]y program as approved by OCRWM. The Metal Samples Company procurement document issued to [illegible] also require: chemical and mechanical testing to be performed and accepted in accordance with the specific ASTM standards referenced in Section III.

2. Where possible sub-tier procurements should be with suppliers that are approved by DOE/OCRWM Office of Quality Assurance.

NONCONFORMANCES/WORK CONTROL

3. The Supplier shall notify the Purchaser's technical contact when a calibrated instrument used to calibrate and certify Purchaser equipment is found to be defective or out-of-calibration.
4. The Supplier shall notify the Purchaser (technical contact) when the Supplier identifies any nonconformances (deviations) from the procurement document. Nonconformances where the proposed disposition is "repair" or "use-as-is" are required to be submitted to the Purchaser (technical contact) for review and concurrence.

PURCHASER AUDIT/VERIFICATION

5. The Purchaser or Purchaser's Representative (DOE or their representative) has the right to inspect and evaluate (audit/surveil) the work performed or being performed under the purchase document, and the premises where the work is being performed, at all reasonable times and in a manner that will not unduly delay the work. If the Purchaser performs inspection or evaluation on the premises of the Supplier or a subcontractor, the Supplier shall furnish and shall require subcontractors to furnish, at no increase in contract price, all reasonable facilities and assistance for the safe and convenient performance of these duties.

NOTE: The Purchaser's QA program is regulated by the NRC and requires that suppliers of services be audited, as a minimum every three years. It also requires an annual evaluation to determine if a more frequent audit is necessary. In other words, the Supplier can expect to be audited soon after contract award and on a three-year basis after the first audit if the service is still being performed.

6. Purchaser verification activities shall not relieve the Supplier of the responsibility for verification of quality achievement.

MISCELLANEOUS

7. The Supplier shall provide the Purchaser with any revisions to their QA program documents prior to implementation.

8. Where software is used as part of the calibration process which provides results that are not later validated, the Supplier shall identify the software version and describe the method used to verify that the software is functioning properly and produces the intended results. Software version changes shall be checked to verify that the software produces correct results. The supplier shall keep a record of the validation of the software.

9. There are no purchaser hold points for this purchase order

D. REQUIRED DOCUMENTATION

The following documentation is required

DOCUMENT DESCRIPTION	SUBMITTAL REQUIREMENT
The supplier shall provide a documentation package that includes the following documents: 1. Certificate of Conformance (by the supplier) 2. A copy of LTI's Material Test Reports for each heat and lot of material. LTI shall make a statement that work was performed in accordance with the purchase order requirements and the suppliers QA program including revision level in effect. 3. MSDS for cleaning solvents used 4. A photocopy of the Manufacturers Certified Material Test Reports (CMTR) for each heat and lot of material 5. Inspection and test records of dimensions and surface finish	Submit for acceptance with the metal samples.
QA Records such as: • implementing documents • documentation of calibration standards • equipment calibration records • training records • qualification of personnel records • evaluation or audit reports • corrective action records • software validation records (as applicable) • inspection and test records • traceability records	Retain by the supplier for a minimum of 3 years unless dispositioned by purchaser before that time

The supplier's Certificate of Conformance and Inspection results shall include the following:

A. This Purchase Order number.
B. Name of the organization (company) performing the testing or certification.
C. Identification of sample/coupon submitted to LTI for independent testing using heat or lot number or other unique identifier.
D. Identification of the solvent used in the cleaning process.
E. A statement that work was performed in accordance with the purchase order requirements and the suppliers QA program including revision level in effect.
F. All the LLNL specimens identified in Attachment 1 tied to the heat or lot number of material used in fabrication.

A copy of the certificate of conformance shall be sent with the samples to the attention of John Estill at LLNL and the purchase buyer.

Records for this procurement shall be legible, accurate, appropriate to the work accomplished, and identifiable to the item(s) or activity(s) to which they apply and shall be stamped, initialed, or signed and dated as complete.
Corrections to completed Records for this procurement shall be made by drawing a single line through the changed or incorrect information and inserting the new or correct information. The correction shall include the initials or signature of the individual authorized to make the correction and the date the correction was made. Correction of Records for this procurement that is incomplete or illegible shall be accomplished in one of the following ways: 1) Transcribe, regenerate, or enhance the illegible portion, or 2) Obtain a new, complete, legible record.

PROCUREMENT REQUIREMENTS DOCUMENT FOR TEST SPECIMENS - SCHEDULE OF ITEMS - TECHNICAL SPECIFICATION FW-1: REV 00, January 7, 1999

Item	Number Specimens	UNS Number (Alloy)	Specimen Type	Sequential Specimen ID	ASTM Specification	Fabrication	Sample Description or Part Number	Surface Finish	Specimen Thickness	Unit Price	Extended Amount
1	20	S31603 (316L Stainless Steel)	Electrochemical	Rec'd [illegible] ✓ PEA 041 thru PEA 060	A276 annealed	Non-Weld	Saw-cut and deburred 1/4-inch diameter rod x 36-inch long	Mill	1/4-inch nominal diameter	14.65	293.00
2	20	N06022 (Alloy 22)	Electrochemical	Rec'd 11-23-99 ✓ DEA 041 thru DEA 060	B574 annealed	Non-Weld	Saw-cut and deburred 1/4-inch diameter rod x 36-inch long	Mill	1/4-inch nominal diameter	49.55	991.00
3	20	N06059 (Alloy 59)	Electrochemical	Rec'd 11-21-99 ✓ QEA 041 thru QEA 060	B574 annealed	Non-Weld	Saw-cut and deburred 1/4-inch diameter rod x 36-inch long	Mill	1/4-inch nominal diameter	42.45	849.00
4	20	R52400 (Titanium Grade 7)	Electrochemical	Rec'd [illegible] ✓ NEA 071 thru NEA 090	B348 annealed	Non-Weld	Saw-cut and deburred 1/4-inch diameter rod x 36-inch long	Mill	1/4-inch nominal diameter	54.95	1,099.00
5	50	S31603 (316L Stainless Steel)	Electrochemical	[illegible] ✓ PEA 061 thru PEA 110	A276 annealed	Non-Weld	Saw-cut and deburred 1/4-inch diameter rod x 10-inch long	Mill	1/4-inch nominal diameter	12.55	627.50
6	50	N06022 (Alloy 22)	Electrochemical	[illegible] DEA 061 thru DEA 110	B574 annealed	Non-Weld	Saw-cut and deburred 1/4-inch diameter rod x 10-inch long	Mill	1/4-inch nominal diameter	22.25	1,112.50
7	50	N06059 (Alloy 59)	Electrochemical	Rec'd 4-21-99 ✓ QEA 061 thru QEA 110	B574 annealed	Non-Weld	Saw-cut and deburred 1/4-inch diameter rod x 10-inch long	Mill	1/4-inch nominal diameter	20.35	1,017.50
8	50	R52400 (Titanium Grade 7)	Electrochemical	Rec'd [illegible] ✓ NEA 091 thru NEA 140	B348 annealed	Non-Weld	Saw-cut and deburred 1/4-inch diameter rod x 10-inch long	Mill	1/4-inch nominal diameter	23.75	1,187.50
9	200	S31603 (316L Stainless Steel)	Electrochemical	[illegible] ✓ PEA 111 thru PEA 310	A240 annealed	Non-Weld	Modified MSC P/N EL 405 *	* One side polished < or = 1 RMS	1/8-inch nominal	36.15	7,230.00
10	200	N06022 (Alloy 22)	Electrochemical	[illegible] ✓ DEA 111 thru DEA 310	B575 annealed	Non-Weld	Modified MSC P/N EL 405	* One side polished < or = 1 RMS	1/8-inch nominal	37.10	7,420.0

11	200	N06059 (Alloy 59)	Electrochemical	QEA 111 thru QEA 310	B575 annealed	Non-Weld	Modified MSC P/N EL 405 *	* One side polished < or = 1 RMS	1/8-inch nominal	37.60	7,520.00
12	200	R52400 (Titanium Grade 7)	Electrochemical	NEA 141 thru NEA 340	B265 annealed	Non-Weld	Modified MSC P/N EL 405 *	* One side polished < or = 1 RMS	1/8-inch nominal	37.60	7,520.00

Additional Technical Requirements

Cleaning. Specimens shall be cleaned in a suitable solvent which does not degrade the chemical and physical characteristics of the material.

Packaging. After cleaning, samples shall be handled with cotton gloves and placed in individual bags to protect from surface scratching during shipment.

Marking:

Items 1-8. Specimens shall be permanently identified on one end only with ~1/16-inch metal die stamps or automatic type-set engraver starting about ¼-inch from one end of rod with the identification extending ~1-inch in length down the rod. To facilitate ease of identif[illegible] flat surface versus the surface of the round rod, a flat may be ground in the area of identification extending the length of the identification (~1-inch).

Items 9-12. specimens shall be permanently identified with metal die stamps or automatic type-set eng[illegible] side opposite the polished surface (< or = 1 RMS) utilizing identification code described specification FW-1.

All specimens in each line item shall be fabricated from the same metal heat and lot.

Items 1 and 5 shall be fabricated from the same heat or lot

Items 2 and 6 shall be fabricated from the same heat or lot

Items 3 and 7 sha[illegible] [illegible]bricated from the same heat or lot

8 Items 4 and 8 shall be fabricated from the same heat or lot								
9 Metal Samples Company shall contract with LTI, Dublin, PA, for chemical and mechanical testing, and provide LTI requisite test specimens from the same heat and lot used to fabricate the specimens described in items 1-12. The following chemical and mechanical testing shall be conducted at LTI:								
Chemical: Testing to determine chemical composition consistent with the requirements in applicable ASTM requirements.								
Mechanical: Testing consistent with all the mechanical testing requirements in applicable ASTM mechanical property requirements								
10 Surface Finish Inspection in items 9-12. Polished surface shall be inspected using established MSC sampling method.								
11 Delivery of all items is require 30 days ARO								

Alabama Specialty Products, Inc.

Inspection and Test Report S/O 3445?

	Part Number	Rev.	Job	155905	Operation
Customer	EL405A113502400		Customer	TRW Procurement / 09484	
ASPI	EL0405	A2	ASPI Insp.	[illegible]	Date Insp. 3/12/99
Description	5/8" dia. PAR DISC		Cust. Insp.		Date Insp.

Order Quantity	Sample Size	Quantity Accepted	Quantity Rejected
200	6	200	

Inspection Equipment ID	Characteristic	Findings					
	1 Ø .624 +.000/-.005	622	.623	.621	.621	.622	.622
	2 1/8 or 1/16 Thick	.125	.125	.125	.125	.125	.125
97-122	3 Finish < / = 1 RMS	✓	✓	✓	✓	✓	✓
	4 ID STAMP DEA111-DEA310	✓	✓	✓	✓	✓	✓
X068-03	5 1/8 OR 1/16	.123	.121	.123	.124	.122	.121
	6						
96-58	7 Ø .624	.624	.624	.624	.624	.622	.624
96-58	8 1/8	.124	.125	.12	[illegible]	.125	.123
96-87	9 1 RMS *	4	4	2	[illegible]	3	2
	10 ID	DEA 181	DEA 149	DE[illegible]	[illegible]A 256	DEA 193	DEA 272
	11						
	12						
	13						
	14						
	15						

Comments

GAGE TOL. +/- 4RA

Top part not critical to content.

[initials] 1/28/00.

LINE 28

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