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DWPF Materials Evaluation Summary Report (U)

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EXECUTIVE SUMMARY

To better ensure the reliability of DWPF remote canyon process equipment, a materials evaluation program was performed as part of the overall startup test program. Specific test programs included FA-04 ("Process Vessels Erosion/Corrosion Studies") and FA-05 (melter inspection). At the conclusion of field testing, Test Results Reports were issued to cover the various test phases. While these reports completed the startup test requirements, DWPF-Engineering agreed to compile a more detailed report which would include essentially all of the materials testing programs performed at DWPF.

The scope of the materials evaluation programs included selected equipment from the Salt Process Cell (SPC), Chemical Process Cell (CPC), Melt Cell, Canister Decon Cell (CDC), and supporting facilities. The program consisted of performing pre-service baseline inspections (work completed in 1992) and follow-up inspections after completion of the DWPF cold chemical runs. Process equipment inspected included: process vessels, pumps, agitators, coils, jumpers, and melter top head components. Various NDE (non-destructive examination) techniques were used during the inspection program, including: ultrasonic testing (UT), visual (direct or video probe), radiography, penetrant testing (PT), and dimensional analyses. Finally, coupon racks were placed in selected tanks in 1992 for subsequent removal and corrosion evaluation after chemical runs.

Test results and conclusions were numerous, so only general highlights will be reported in this section. Predicted equipment life estimates were made and it was concluded that with few exceptions (discussed later), all of the equipment will meet or exceed its design basis (i.e. twenty years for major vessels; five years for vessel components such as pumps, agitators, and coils; and one year for easily replaceable jumpers and melter top head components. Of primary significance, UT and coupon data clearly demonstrates that the major CPC vessels and permanent sample lines will last the life of the DWPF facility (about forty years). Further, coupon evaluation and corrosion assessments were used to conclude that the insulated SPC tanks would also last the life of the DWPF facility. Significant erosion/corrosion to a degree such that the equipment life would be below design life was observed only in the slurry mix evaporator (SME) process equipment (i.e. agitator and coil) and selected melter top head components (i.e. film cooler brush, borescope housing, and melter feed tubes).

Erosion of the SME agitator as a result of the glass frit slurry was expected based on inspection of similar equipment at the TNX pilot facilities. Examination of the DWPF SME agitator confirmed severe erosion on the backside of the lower blades. Since this erosion was expected, a spare unit with a new blade design (i.e. increased use of Stellite hard-face overlay coating to mitigate erosion) had been procured and were installed prior to radioactive operations. Significant localized erosion was also observed on the SME coil assembly. Areas of particular attack included the bottom inner coil near supports, the

lower support structure and the cooling water downcomer pipe. Damaged areas of the SME coil were repaired to extend the life and the coil was reinstalled. The repaired SME coil is expected to provide an additional two years of service.

Oxidation/corrosion was observed on several of the melter top head components (i.e. film cooler brush, borescope housing, and melter feed tubes) which would limit equipment life. The film cooler brush bristles were severely oxidized and the bristles could be broken off. The problem was thought to be related to the choice of material which was clearly inadequate for the service conditions. The failed film cooler brush was removed from service and a spare unit will be installed when, and if, required (NOTE: The film cooler brush has never been used and no plugging of the offgas line has been experienced at DWPF). Severe localized pitting occurred on the borescope housings as a result of corrosive salt condensation. The lower (i.e. exposed) portion of two spare borescope housing assemblies were subsequently coated with a diffusion based Al/Cr coating to improve oxidation resistance and the units were installed. Inspection of the melter feed tubes revealed apparent end grain corrosion at the very tip of the tube assembly. The damaged end was repaired using I690 weld metal (i.e. "buttering") to reduce risk of end grain corrosion. After the repair strategy was implemented, one unit was reinstalled in the melter. Both a borescope housing and a melter feed tube with the noted repairs were pulled for visual inspection after 2-3 months service. Results of these inspections confirmed the suitability of the repair strategies.

Performance of the materials testing programs led to the discovery of mechanical fatigue at welds in several jumper dip-tubes, two SPC sample pumps (cross bracing on dip tubes), and the sludge receipt adjustment tank (SRAT) coil assembly. The design adequacy of the attachment welds was evaluated by Structural Mechanics personnel, which led to subsequent design changes. The failed equipment was repaired as well as equipment with similar design features. Based on these repairs, the equipment is now considered suitable for radioactive service.

1.0 INTRODUCTION AND BACKGROUND

1.1 Abbreviations Used in Report

Many acronyms and abbreviations are commonly used at DWPF when referring to equipment, NDE inspections and groups. For convenience, a listing of these abbreviations is provided in Table I provided below.

Table I Abbreviations Commonly Used in Summary Report

Abbreviation	Proper Designation
CPC	Chemical Process Cell
SPC	Salt Process Cell
LPPP	Low Point Pump Pit
PR	Precipitate Reactor
PRFT	Process Reactor Feed Tank
PRCD	Process Reactor Condenser Decanter
OE	Organic Evaporator
OECT	Organic Evaporator Condensate Tank
OECD	Organic Evaporator Condenser Decanter
PRBT	Precipitate Reactor Bottoms Tank
SRAT	Sludge Receipt Adjustment Tank
SMECT	Slurry Mix Evaporator Condensate Tank
SME	Slurry Mix Evaporator
MFT	Melter Feed Tank
RCT	Recycle Collection Tank
MOG	Melter Offgas
OGCT	Offgas Condensate Tank
SAS	Steam Atomized Scrubber
HEME	High Efficiency Mist Eliminator
CDC	Canister Decon Chamber
A&IQ	Administration and Infrastructure Division - Quality Control
NDE	Non-destructive Examination
UT	Ultrasonic Thickness Measurement
PT	Liquid Penetrant

1.2 Background and Basis

The purpose of the DWPF Startup Test Program FA-04 was to evaluate the material degradation mechanisms in remote process equipment. The scope of the FA-04 study included selected critical equipment located in the DWPF canyon facilities other than the Melter. The Melter and related top head components were to be covered under a parallel DWPF Startup Test Program FA-05. Due to problems with the Melter inspection device, much of the FA-05 test program was not completed. The only exception was that visual inspections were performed on the removable Melter top head components. At the request of the JTG, it was agreed that all materials evaluation testing for DWPF would be compiled into one final report. Thus, the subject report will consist of the FA-04 test program results, supplemented by inspection data from the Melter top head components.

DWPF process equipment will be subjected to two basic wear phenomena, chemical corrosion and abrasion due to glass frit particles. For process slurries, particularly those with glass frit particles (e.g. SME, MFT), the overall wear rate will be determined by the combined effects of both abrasion and corrosion. The technical term for this phenomena is "erosion." Wear associated with erosion is characterized by the localized removal of the protective oxide layers by abrasion. Since such oxide layers on the material surfaces provide corrosion protection, their continuous removal would open up the material structure to chemical corrosion. Given the harsh chemical environment encountered in the DWPF process (e.g. halides, mercury, elevated temperatures, etc.), corrosion was also thought to be of considerable concern.

1.3 Development of the FA-04 Startup Test Program

SRTC provided comments and recommendations to DWPF concerning development of an erosion/corrosion test program.[1] SRTC personnel felt that such a materials evaluation effort was essential to the final decision to introduce radioactivity into the DWPF process equipment, since repair of contaminated equipment is more expensive, requires longer repair times (i.e. lead times for replacement equipment), and increases the radiation and health risk to inspection and repair crews.

The referenced SRTC document formed the basis for the DWPF-FA-04, Process Vessels Erosion/Corrosion Study, test plan which was approved by JTG on 06/20/90. The test plan was revised on 10/17/95 (i.e. Revision 1) to include a test matrix to provide a scope of inspection activities to be performed. The test matrix is provided as Table II.

The FA-04 test program was originally developed as a three part test program, baseline of equipment, erosion study (primarily frit particle impact), and a final erosion/corrosion evaluation after mercury runs. The baseline portion of this test program (FA-04.01)[2] was completed in 1992 and a considerable amount of equipment was baselined (e.g., tanks, agitators, coils, pumps, jumpers, etc.). Portions 2 and 3 of the test program were combined together and performed after mercury runs. Due to schedule advantages, the later erosion/corrosion evaluations were performed at different times. All selected DWPF process equipment other than for the SPC (i.e., CPC, etc.) were inspected in August-October, 1995 and are reported under field completion report FA-04.02. The SPC equipment was inspected in December, 1995 and January, 1996 and are reported under field completion report FA-04.03.

REFERENCES

1. S. M. Nordwick and D. F. Bickford, " Initial Comments and Recommendations for the DWPF Process Vessels Erosion and Corrosion Studies," DWP-GTG-90-0005, May 15, 1990.

2. J. L. Ramsey, "Process Vessels Erosion/Corrosion - Baseline," WSRC SW4-3-2 (DWPF-FA-04.01), Revision 0, 1/30/92.

BLE II

EQUIPMENT	INSPECTION ACTIVITIES TO SUPPORT FA-04						
	Visual Direct	Visual Video Probe	Radiography	Dimensional Analysis	UT	PT	Coupon Rack Removal
LPPP Sludge Tank		1			1		
LPPP Precipitate Tank		1			1		
PR Vessel / Fixed Coil		1					
PR Agitator (in-place)		3					
PR Sample Pump	2				2	2	2
- Sample Discharge Jumper					3		
PRFT Vessel							
PRCD Vessel		1					
PR to PRCD Jumper		3			3		
PRCD to SCVC Vent Jumper		3			3		
OE Vessel		1					
OECT Vessel		1					
OECD Vessel		1					
PRBT Vessel					1		
PRBT to SRAT Jumper - orifice	1			1			
SRAT Vessel		1			1		
SRAT Sample Pump	2			2	2	2	2
- Sample Discharge Jumper					3		
SRAT Coil Assembly	2				2		
SRAT Agitator	2			2			
SRAT Condenser		2					
SRAT Condenser to MWWT Jumper		3			3		
SRAT Condenser to FAVC Vent Jumper		3			3		
SRAT Ammonia Scrubber (or)		3			3		
or SME Ammonia Scrubber (or)		3			3		
or RCT/MFT Ammonia Scrubber		3			3		
SMECT Vessel		2			2		
SMECT Coil Assembly (in-place)		2					

TA E II (Cont.)

INSPECTION ACTIVITIES TO SUPPORT FA-04

EQUIPMENT	Visual Direct	Visual Video Probe	Radiography	Dimensional Analysis	UT	PT	Coupon Rack Removal
SME Vessel	1				1		
SME Sample Pump	2		2	2	2	2	
- Sample Discharge Jumper					3		
SME Coil Assembly	2				2		
SME Condenser		2					
SME Agitator	2			2			
MFT Vessel					1		
MFT Sample Pump	2		2	2	2	2	
- Sample Discharge Jumper					2		
Melter Feed Pump No. 1	2					2	
MFT Coil Assembly	2				2		
MFT Feed Pump #2 / Recirculation Jumper					3		
MFT Feed Pump #1 / Dip Tube Assembly	2			2			
MFT Agitator	2			2			
Formic Acid Vent Condenser		3			3		
Process Vessel Vent (PVV) Header	3						
RCT Vessel					3		
MOG Line Melter End / Isolation Valve	2	2					
MOG Line Quencher End	2	2					
Primary Quencher Vessel	2	2			2		
OGCT Vessel		2			2		
OGCT Sample Pump	2				2	2	2
- Sample Discharge Jumper					3		
SAS Vessel		3					
HEME Vessel		3					

INSPECTION ACTIVITIES TO SUPPORT FA-04

EQUIPMENT	Visual Direct	Visual Video Probe	Radiography	Dimensional Analysis	UT	PT	Coupon Rack Removal
CDC #1 Recirculation Pump	2				3	2	
CDC #1 Spray Nozzle Rack	2						
CDC #1 Frit Feed Jumpers - Ribbon					2		
CDC #1 Nozzle Feed Lines					2		
SRAT Permanent Sample Line					2		
SME Permanent Sample Line					2		
MFT Permanent Sample Line					2		
OGCT Permanent Sample Line					2		
PR Permanent Sample Line					2		
SME Hydragard Liquid Sampler	2		2	2			
MFT Hydragard Liquid Sampler			2				
Testing and Evaluation/SME Sample Station	2						
Inspect C-276/304L Gavanic Couplings	2						

Ranking Criteria for Inspection Activities (i.e. Priority)

- 1 Must Do to Support Structural Integrity Basis
- 2 Should Do to Support Operational Issues
- 3 Desirable Data if Time Permits and Equipment Available

* - NOTE: The ranking system described above will define the test requirements. Inspection activities ranked "1" or "2" are considered a test requirement. Any deletion of these inspection activities is considered an intent change to the scope and must be approved by JTG. Those inspection activities ranked as a "3" can be modified as a non-intent change.

1.4 Limitations on Field Completion Reports

Preliminary field completion reports were issued for the FA-04.02 (CPC) and FA-04.03 (SPC) equipment shortly after completion of the inspections. These reports are provided in their entirety in Appendix 1. While these reports addressed major findings from the inspections, they did not include a complete evaluation of the test results. This report will provide information and data interpretation that was not available at the time the field completion reports were issued.

1.5 DWPF Cold Chemical Runs

DWPF performed a series of cold chemical runs over a period of about eighteen months to confirm the suitability of the process prior to radioactive operation. During this period, sixteen batches of material were processed through the Melter in five test campaigns as outlined below.

DWPF-FA-13, Melter Characterization with Composite Feed (Batches 2-5)
The initial charge to the Melter was a glass frit specially formulated for melter startup. This run was used to flush the initial startup frit from the Melter and achieve stable operation (16 canisters produced).

DWPF-WP-14, Melter Characterization with Doped Feed (Batch 6)
This test constitutes the beginning of Waste Qualification Runs. A non-radioactive composition doped with Nd was used to study melter mixing behavior (7 canisters produced, corresponding to almost 1.5 melter turnovers).

DWPF-WP-15, Melter Characterization with Low Viscosity Glass (Batches 7-10)
A low viscosity (high iron) composition was used to simulate an extreme change in feed composition (20 canisters produced, corresponding to 5 melter turnovers).

DWPF-WP-16, Melter Characterization with High Viscosity Glass (Batches 11-14)
A high viscosity (high aluminum) composition was used to simulate another extreme change in feed composition (19 canisters produced, corresponding to 5 melter turnovers). The last batch of this campaign also contained mercury.

DWPF-WP-17, Melter Characterization with Mercury in Initial Feed (Batches 15 & 16)
A composite feed was used to simulate return to a composite feed from high aluminum feed (9 canisters produced, corresponding to two melter turnovers). This run demonstrated mercury removal and the feed contained noble metals.

1.6 Report Format / Location of Reference Documents

The FA-04.01 baseline document referenced above is a large (i.e. three-inch binder) self contained document. A second three-inch binder contains the field inspection reports completed under FA-04.02 or FA-04.03, the latest revision of the test plan, a test implementing document (i.e. procedure) and complete copies of data collected during the DWPF cold chemical runs. This document, entitled "FA-04 Materials Evaluation / Field Reports," will be submitted to document control (WSRC-TR-96-0197). Copies of remaining DWPF test reports, pertinent files, data, pictures of equipment and video tapes will be placed in "boxed storage" in document control for permanent retrieval.

The subject DWPF Materials Evaluation Summary Report will be issued as a separate stand alone document with references to the supporting documents noted above. To facilitate discussions, this report will be further broken down by equipment grouping (e.g., pumps, agitators, etc.). Each of these subsections will be written to be largely self supporting with references to the appropriate tables, figures, appendices and reference documents.

2.0 TECHNICAL SUPPORT

2.1 Inspection Personnel - NDE

A& IQ NDE personnel performed inspections to support the DWPF materials evaluation programs. Inspections included ultrasonic thickness (UT), liquid penetrant (PT), and visual (both direct and remote using video equipment). In addition, non-destructive examination (NDE) personnel assisted in interpretation of radiography results which had been performed by Raytheon. Their inspection reports are issued as Quality Control Condition Reports. Two Quality Control Condition Reports were issued, one for the CPC inspections (FA-04.02) and one for the SPC inspections (FA-04.03) as outlined below. Note that each of the Quality Control Condition Reports contained specific inspection reports for each type of inspection performed for a given piece of equipment.

1) FA-04.02 - CPC Inspections:

Quality Control Condition Report: AID-QCM-950127 (JOB No. S950513)

2) FA-04.03 - SPC Inspections:

Quality Control Condition Reports: AID-QCM-960011 (JOB No. S950807)

The summary sections for the referenced Quality Control Condition Reports are provided in their entirety in Appendix 2 of this report. Complete copies of the individual inspection reports are contained in "FA-04 Materials Evaluation / Field Reports" (WSRC-TR-96-0197). The following A&IQ NDE personnel were heavily involved in the materials evaluation programs at DWPF:

Jim Dickinson
Jim Elder
Pat Gibbons
Bob Holmes
Judy McCall

2.2 Materials Evaluations / Inspection Support

Personnel from the Materials Technology Section of SRTC assisted DWPF in field inspections, data interpretation and reporting during the DWPF materials evaluation programs. Each piece of equipment had a field inspection report which is provided in "FA-04 Materials Evaluations / Field Reports," (WSRC-TR-96-0197) of the material evaluation records. In most cases, one or more materials (or welding) personnel performed direct inspection of the equipment. Some equipment could not be directly inspected (i.e. due to access or scheduling problems) and their review was based on review of inspection documents, photographs and video footage. The SRTC materials personnel provided direct input into this report, and their assessment of the material condition of the equipment is provided in the following report sections and/or appendices. The following SRTC materials personnel were heavily involved in the inspections.

Bill Daugherty	Materials Consultation Group
Charlie Jenkins	Materials Consultation Group
Glenn McKinney	Materials Consultation Group (welding)
Greg Chandler	Materials Technology Section
Ken Imrich	Materials Technology Section

3.0 EQUIPMENT INSPECTIONS

3.1 General:

Results from the equipment inspections and/or evaluations are discussed in the following sections. An overall summary of the equipment inspected and the results obtained are provided in Appendix 3. These summary sections provide details on types of inspections performed, the materials reviewer and method of review. Also, these tables provide equipment numbers for inspected equipment which will not be repeated in the text.

3.2 Process Tanks

3.2.1 Salt Process Cell (SPC) - Reported by J. T. Gee

All of the process vessels in the SPC have insulated walls which precludes the use of external UT measurements to monitor vessel wall thinning. The internal surfaces of the SPC tanks, listed below, were visually inspected and documented using remote videophotography.

SPC Vessel	Inspection Report (WSRC-TR-96-0197)
PR	95-IR-06-VT-1177
PRFT	95-IR-06-VT-1181
PRCD	95-IR-06-VT-1186
OE	95-IR-06-VT-1178
OECT	95-IR-06-VT-1179
OECD	95-IR-06-VT-1185

In addition, the condition of the vessel wall was inferred by indirect means, such as direct inspection of components (e.g., coils, pumps, etc.) removed from the tanks and/or results from corrosion coupon testing. All of the tanks with the exception of the OECT are fabricated from alloy C-276. This alloy is very resistant to general and localized corrosion. The OECT is fabricated from 304L stainless steel, which is more than adequate for the expected chemistry for the condensate.

Results and Conclusions:

Based on the subject inspections and evaluation, it was concluded that none of the SPC process vessels would have experienced significant erosion/corrosion during the cold run testing period. None of the internal vessel walls showed evidence of localized corrosion, as would be expected for the nickel based C-276 alloy.

For these reasons, it was concluded that the SPC vessels would last the life of the DWPF facility (i.e. 20 years).

3.2.2 Chemical Process Cell (CPC) - Reported by J. T. Gee

The CPC vessels were examined through the use of visual observations and external UT measurements. The general condition of the tank interiors was documented by videophotography. The following CPC vessels were inspected by NDE personnel and documented in the referenced inspection reports contained in the "FA-04 Materials Evaluations / Field Reports," (WSRC-TR-96-0197) of the material evaluation records.

CPC Vessel	Inspection Report (contained in WSRC-TR-96-0197)
PRBT	95-IR-06-UT-0892 / 95-IR-06-VT-0893
SRAT	95-IR-06-UT-0842 / 95-IR-06-VT-0843 & 0844
SMECT	95-IR-06-UT-0868 / 95-IR-06-VT-0869 & 0870
SME	95-IR-06-UT-0855 / 95-IR-06-VT-0856, 0857, & 1051
MFT	95-IR-06-UT-0874 / 95-IR-06-VT-0875
OGCT	95-IR-06-UT-0886 / 95-IR-06-VT-0887
RCT	95-IR-06-UT-0888 / 95-IR-06-VT-0889 & 1047

NDE personnel provided statistical and graphical presentations of the UT data comparing wall thickness between the original baseline and post cold run inspections. These results are provided in Figures 1-7.

A note of caution is provided in interpretation of the UT data in the noted inspection reports. The UT measurements (i.e. baseline and post cold chemical run condition) were performed using different ultrasonic equipment. Also, while the location of prior UT measurements were marked, a small change in location of the UT probe can account for considerable difference in the reading. This is particularly true for the bottom head of the vessels, given the physical limitations (i.e. respirator required, etc.) when accessing the bottom and the limited lighting. Thus, the UT data can best be used to evaluate trends. With the exception of the SMECT, all of the CPC process tanks (listed above) are fabricated from alloy C-276. This nickel based alloy is highly resistant to localized corrosion such as pitting. The SMECT, fabricated from 316L stainless steel, would also be highly unlikely to pit given a basically dilute nitric acid chemistry of the process fluid. For these reasons, random scatter in the UT data is not considered significant.

Results and Conclusions:

Based on comparison of UT data between the baseline and post cold run test condition, none of the referenced CPC process tanks were thought to have experienced a significant reduction in wall thickness as a result of erosion/corrosion.

Results of remote visual (or direct visual for SME) inspections of the vessel interior surfaces did not indicate localized areas of erosion/corrosion. This was also confirmed (as reported in later discussions) by direct inspections of components (i.e. pumps, coils, etc.) removed from the process vessels.

3.2.3 Internal Inspection of SME Tank - Reported by C. F. Jenkins

Due to concerns about localized erosion from frit particles in the SME tank (e.g., supports for coils, agitator bumper guides, tank bottom, etc.), the tank was entered to perform a visual inspection. Inspection results are documented in an NDE inspection report, 95-IR-06-VT-0857, which is contained in “FA-04 Materials Evaluation / Field Reports” (WSRC-TR-96-0197). A separate report, “Inspection: Interior of SME Tank (SRT-MTS-96-5106) was issued by the Materials Consultation Group to formally report this inspection. A copy of this report is provided in Appendix 4.

3.2.4 Low Point Pump Pit Tanks (LPPP) - Reported by J. T. Gee

The LPPP Precipitate and LPPP Sludge tanks were belatedly added to the FA-04 materials evaluation program due to their Safety Class (“SC”) designation. For this reason, no initial baseline evaluation had been performed on these tanks prior to cold run processing to support the erosion/corrosion study.

The LPPP process tanks are fabricated from 304L stainless steel. This alloy is very unlikely to corrode if the process fluid is not acidified (See discussion in Appendix 7.). The expected condition of these tanks (i.e. pH 10, etc.) should therefore preclude corrosion.

The LPPP vessels were examined through the use of visual observations and external UT measurements. The general condition of the tank interiors was documented by videophotography. The following LPPP vessels were inspected by NDE personnel and documented in the referenced inspection reports contained in “FA-04 Materials Evaluations / Field Reports,” (WSRC-TR-96-0197) of the material evaluation records.

LPPP Vessel	Inspection Report (contained in WSRC-TR-96-0197)
LPPP Precipitate Tank	95-IR-06-UT-0890 / 95-IR-06-VT-0891
LPPP Sludge Tank	95-IR-06-UT-0986 / 95-IR-06-VT-1069

Results and Conclusions:

Neither of the LPPP process tanks showed any evidence of erosion/corrosion based on visual inspections. (UT data was not available to support this conclusion because of the noted lack of pre-test baseline data.)

3.2.5 Potential for Erosion/Corrosion - General (all tanks)
- Reported by J. T.

3.2.5.1 Laboratory Corrosion Data (See Section 3.17.)

The potential for degradation of the major process vessels was considered under the DWPF Structural Integrity Program. Concerns related to possible erosion/corrosion were evaluated in this study. A document, "Evaluation of Potential for Materials Degradation of DWPF Safety Class and Safety Significant Components," was issued to report these evaluations. This document is provided in Appendix 7 in its entirety.

Results and Conclusions:

In most cases, this study predicted that the vessels of interest in the FA-04 program would last up to sixty years.

3.2.5.2 Corrosion Coupon Data from FA-04 Test (See Section 3.16.)

Corrosion coupon racks were placed in the PR, SRAT and OGCT prior to cold runs and evaluated upon completion of testing. Results for the C-276 alloy coupons, which is the material of construction for most process equipment, indicated very low corrosion rates (i.e. less than 0.05 mils/year).

Results and Conclusion:

Corrosion coupons recovered from the PR, SRAT and OGCT, which are equivalent to the materials of construction for these vessels, predicted very low corrosion rates and indicated that corrosion was not a significant issue.

PRBT TANK
Tank Bottom

	Bottom (Old)	Bottom (New)	Change
Ave	0.7651	0.7593	-0.0058
min	0.7620	0.7520	-0.0110
max	0.7680	0.7670	0.0010
Ave Dev.	0.0016	0.0028	0.0023
Stnd Dev.	0.0019	0.0038	0.0032
	Bottom (Old)	Bottom (New)	Change
0	0.762	0.760	-0.002
	0.764	0.757	-0.007
	0.763	0.752	-0.011
90	0.766	0.767	0.001
	0.765	0.760	-0.005
	0.768	0.763	-0.005
180	0.767	0.762	-0.005
	0.767	0.760	-0.007
	0.763	0.758	-0.005
270	0.765	0.758	-0.007
	0.767	0.758	-0.009
	0.764	0.756	-0.008

PRBT TANK
Tank Shell, No baseline on shell

	Shell (Old)	Shell (New)	Change
Ave	#DIV/0!	0.4973	#VALUE!
min	0.0000	0.4930	#VALUE!
max	0.0000	0.5020	#VALUE!
Ave Dev.	#NUM!	0.0023	#VALUE!
Stnd Dev.	#DIV/0!	0.0027	#VALUE!
	Shell (Old)	Shell (New)	Change
0	none	0.502	#VALUE!
	none	0.495	#VALUE!
	none	0.499	#VALUE!
90	none	0.500	#VALUE!
	none	0.496	#VALUE!
	none	0.496	#VALUE!
180	none	0.499	#VALUE!
	none	0.493	#VALUE!
	none	0.494	#VALUE!
270	none	0.500	#VALUE!
	none	0.497	#VALUE!
	none	0.496	#VALUE!

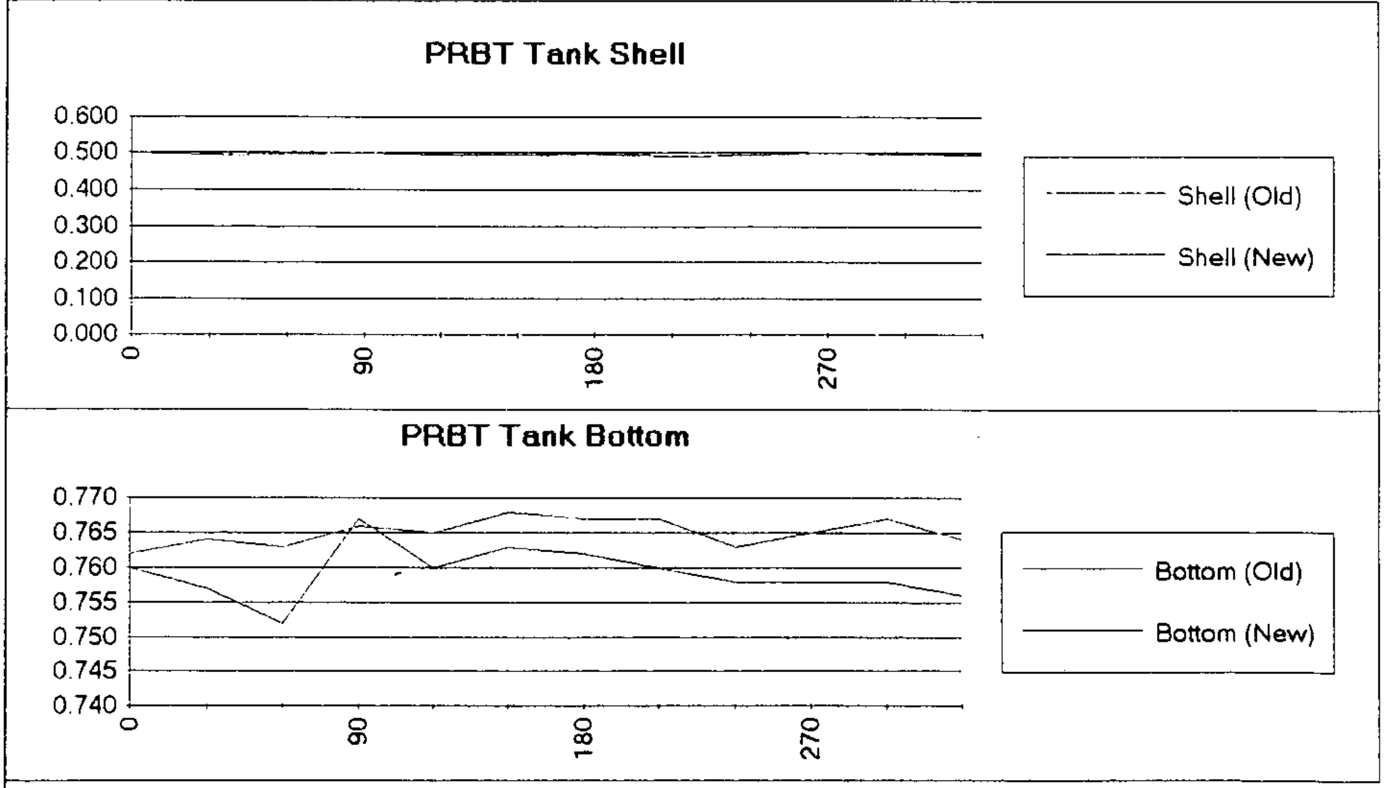


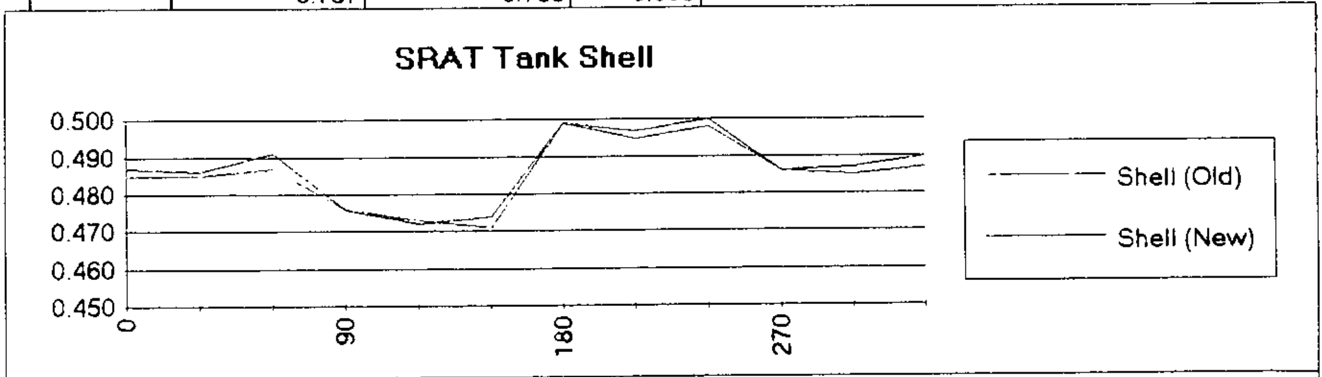
Figure 1. Comparison of UT wall thickness data for PRBT tank shell and bottom before (i.e. "old") and after (i.e. "new") DWPF cold chemical runs.

SRAT TANK
Tank Bottom

	Bottom (Old)	Bottom (New)	Change
Ave	0.7586	0.7614	0.0028
min	0.7540	0.7580	0.0000
max	0.7640	0.7650	0.0060
Ave Dev.	0.0016	0.0015	0.0014
Stnd Dev.	0.0022	0.0018	0.0017
	Bottom (Old)	Bottom (New)	Change
0	0.760	0.762	0.002
	0.764	0.765	0.001
	0.759	0.759	0.000
	0.760	0.762	0.002
	0.759	0.760	0.001
90	0.758	0.759	0.001
	0.757	0.760	0.003
	0.757	0.762	0.005
	0.758	0.763	0.005
	0.754	0.758	0.004
180	0.760	0.761	0.001
	0.759	0.763	0.004
	0.759	0.762	0.003
	0.761	0.763	0.002
	0.755	0.760	0.005
270	0.760	0.763	0.003
	0.759	0.760	0.001
	0.757	0.760	0.003
	0.759	0.762	0.003
	0.757	0.763	0.006

SRAT TANK
Tank Shell

	Shell (Old)	Shell (New)	Change
Ave	0.4856	0.4871	0.0015
min	0.4710	0.4720	-0.0010
max	0.4990	0.5000	0.0040
Ave Dev.	0.0064	0.0069	0.0013
Stnd Dev.	0.0090	0.0093	0.0015
	Shell (Old)	Shell (New)	Change
0	0.485	0.487	0.002
	0.485	0.486	0.001
	0.487	0.491	0.004
90	0.476	0.476	0.000
	0.473	0.472	-0.001
	0.471	0.474	0.003
180	0.499	0.499	0.000
	0.495	0.497	0.002
	0.498	0.500	0.002
270	0.486	0.486	0.000
	0.485	0.487	0.002
	0.487	0.490	0.003



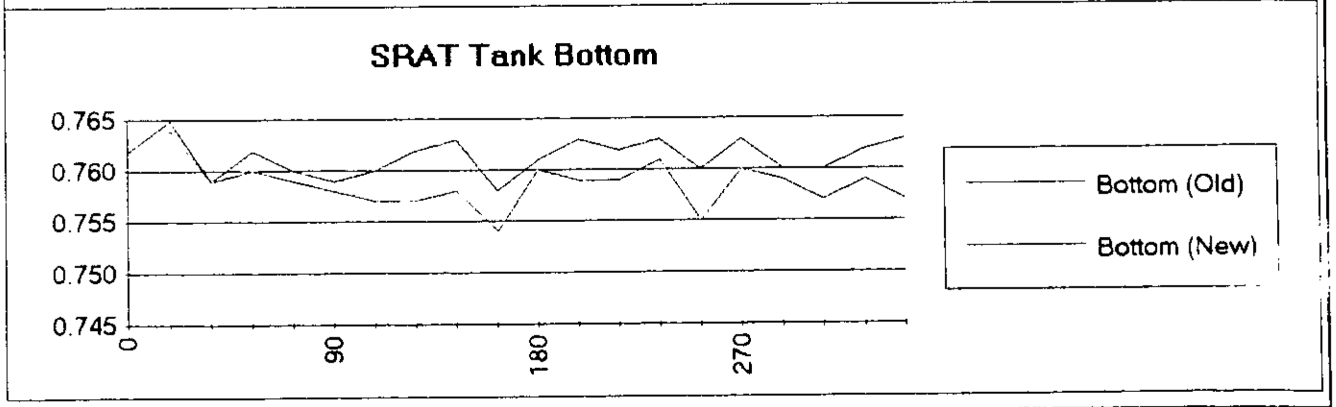


Figure 2. Comparison of UT wall thickness data for SRAT tank shell and bottom before (i.e. "old") and after (i.e. "new") DWPF cold chemical runs.

SME TANK
Tank Bottom

	Bottom (Old)	Bottom (New)	Change
Ave	0.7469	0.7502	0.0033
min	0.7400	0.7450	-0.0020
max	0.7540	0.7600	0.0060
Ave Dev.	0.0038	0.0039	0.0019
Stnd Dev.	0.0045	0.0046	0.0024
	Bottom (Old)	Bottom (New)	Change
0	0.747	0.745	-0.002
	0.743	0.746	0.003
	0.741	0.746	0.005
	0.744	0.747	0.003
	0.753	0.751	-0.002
90	0.751	0.753	0.002
	0.748	0.751	0.003
	0.740	0.745	0.005
	0.740	0.746	0.006
	0.743	0.748	0.005
180	0.754	0.757	0.003
	0.754	0.760	0.006
	0.749	0.755	0.006
	0.744	0.749	0.005
	0.749	0.752	0.003
270	0.749	0.751	0.002
	0.744	0.745	0.001
	0.745	0.746	0.001
	0.748	0.752	0.004
	0.752	0.758	0.006

SME TANK
Tank Shell

	Shell (Old)	Shell (New)	Change
Ave	0.5034	0.5044	0.0010
min	0.4890	0.4910	-0.0010
max	0.5150	0.5160	0.0040
Ave Dev.	0.0077	0.0076	0.0011
Stnd Dev.	0.0089	0.0088	0.0014
	Shell (Old)	Shell (New)	Change
0	0.494	0.496	0.002
	0.500	0.504	0.004
	0.492	0.493	0.001
	0.492	0.491	-0.001
	0.489	0.491	0.002
90	0.505	0.505	0.000
	0.514	0.514	0.000
	0.512	0.515	0.003
	0.513	0.513	0.000
	0.512	0.512	0.000
180	0.502	0.502	0.000
	0.513	0.513	0.000
	0.515	0.516	0.001
	0.515	0.515	0.000
	0.513	0.515	0.002
270	0.500	0.500	0.000
	0.501	0.502	0.001
	0.496	0.496	0.000
	0.496	0.496	0.000
	0.495	0.498	0.003
	0.503	0.506	0.003

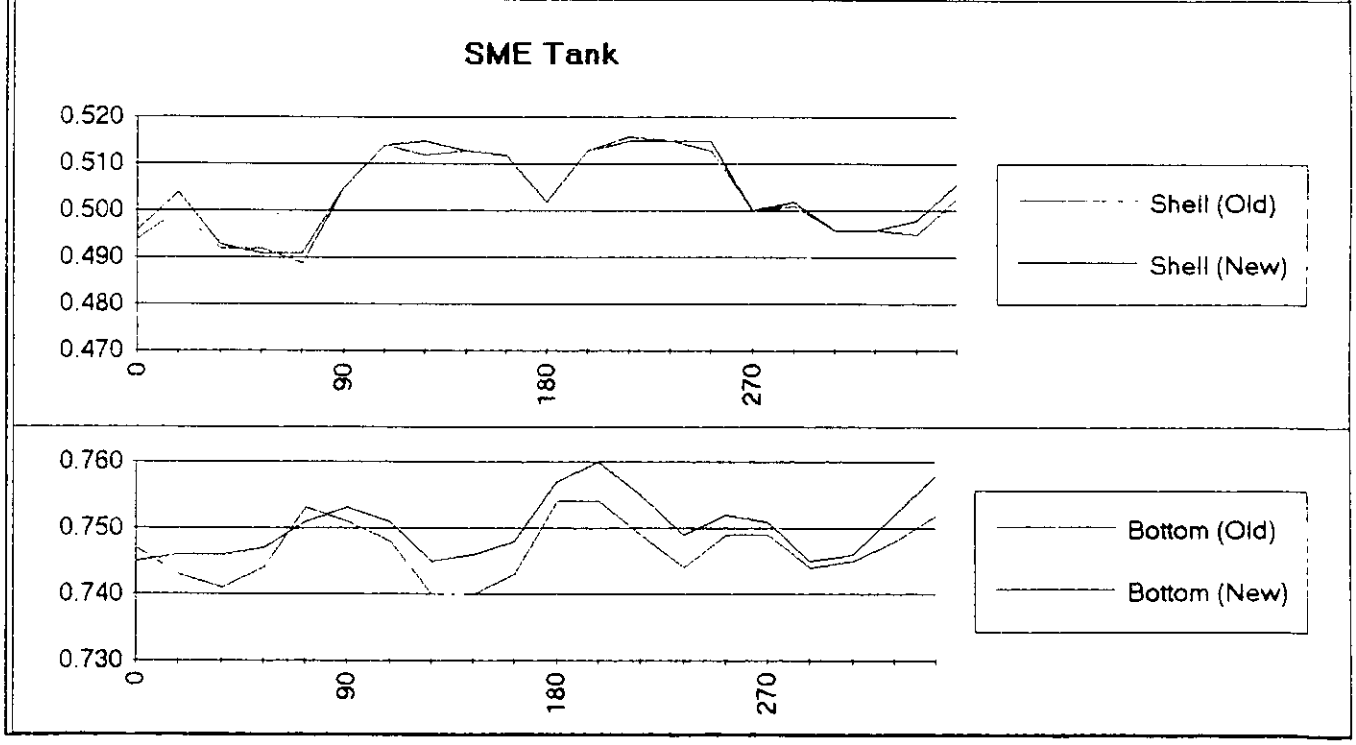


Figure 3. Comparison of UT wall thickness data for SME tank shell and bottom before (i.e. "old") and after (i.e. "new") DWPF cold chemical runs.

SMECT TANK
Tank Bottom

	Bottom (Old)	Bottom (New)	Change
Ave	0.8900	0.8869	-0.0032
min	0.8650	0.8620	-0.0140
max	0.9020	0.9020	0.0010
Ave Dev	0.0085	0.0090	0.0025
Stnd Dev.	0.0109	0.0114	0.0035
	Bottom (Old)	Bottom (New)	Change
0	0.880	0.874	-0.006
	0.865	0.864	-0.001
	0.870	0.862	-0.008
	0.879	0.874	-0.005
	0.877	0.876	-0.001
90	0.902	0.898	-0.004
	0.902	0.898	-0.004
	0.900	0.896	-0.004
	0.897	0.894	-0.003
	0.896	0.891	-0.005
180	0.893	0.891	-0.002
	0.888	0.888	0.000
	0.895	0.896	0.001
	0.902	0.902	0.000
	0.901	0.898	-0.003
270	0.897	0.883	-0.014
	0.887	0.886	-0.001
	0.889	0.886	-0.003
	0.890	0.889	-0.001
	0.890	0.891	0.001

SMECT TANK
Tank Shell

	Shell (Old)	Shell (New)	Change
Ave	0.5229	0.5224	-0.0005
min	0.5110	0.5110	-0.0020
max	0.5350	0.5330	0.0030
Ave Dev.	0.0074	0.0071	0.0010
Stnd Dev.	0.0084	0.0079	0.0014
	Shell (Old)	Shell (New)	Change
0	0.530	0.529	-0.001
	0.530	0.530	0.000
	0.526	0.526	0.000
90	0.519	0.517	-0.002
	0.515	0.514	-0.001
	0.511	0.511	0.000
180	0.519	0.519	0.000
	0.518	0.517	-0.001
	0.511	0.514	0.003
270	0.533	0.533	0.000
	0.535	0.533	-0.002
	0.528	0.526	-0.002

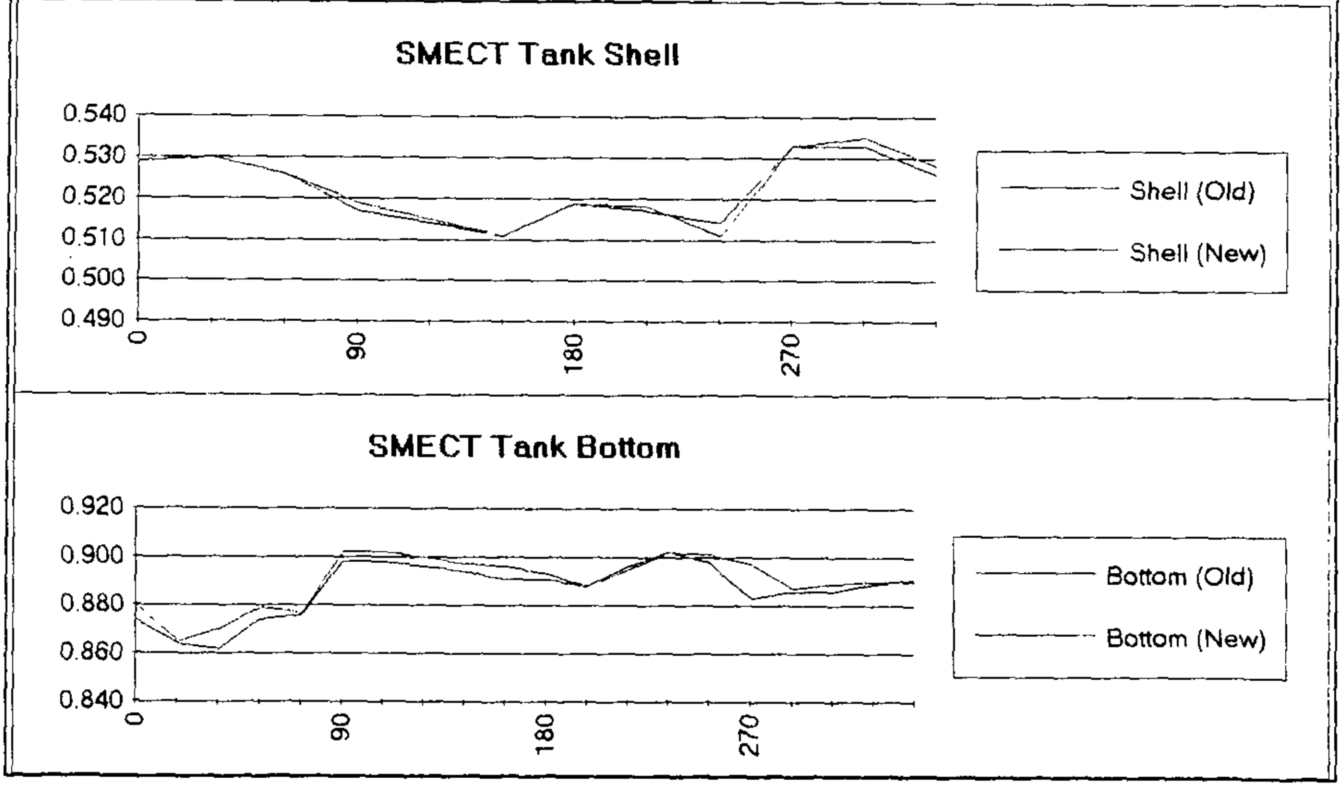


Figure 4. Comparison of UT wall thickness data for SMECT tank shell and bottom before (i.e. "old") and after (i.e. "new") DWPF cold chemical runs.

MFT TANK
Tank Bottom

	Bottom (Old)	Bottom (New)	Change
Ave	0.7470	0.7536	0.0066
min	0.7410	0.7470	-0.0010
max	0.7530	0.7630	0.0110
Ave Dev.	0.0032	0.0041	0.0024
Stnd Dev.	0.0037	0.0049	0.0031
	Bottom (Old)	Bottom (New)	Change
0	0.753	0.763	0.010
	0.749	0.760	0.011
	0.743	0.752	0.009
	0.753	0.763	0.010
	0.750	0.749	-0.001
90	0.745	0.747	0.002
	0.742	0.747	0.005
	0.748	0.752	0.004
	0.742	0.750	0.008
	0.750	0.756	0.006
180	0.746	0.747	0.001
	0.745	0.752	0.007
	0.751	0.757	0.006
	0.742	0.749	0.007
	0.749	0.756	0.007
270	0.750	0.756	0.006
	0.748	0.756	0.008
	0.747	0.756	0.009
	0.741	0.750	0.009
	0.745	0.753	0.008

MFT TANK
Tank Shell

	Shell (Old)	Shell (New)	Change
Ave	0.4966	0.5030	0.0064
min	0.4880	0.4950	0.0020
max	0.5040	0.5110	0.0110
Ave Dev.	0.0029	0.0028	0.0021
Stnd Dev.	0.0037	0.0038	0.0026
	Shell (Old)	Shell (New)	Change
0	0.494	0.503	0.009
	0.501	0.511	0.010
	0.499	0.509	0.010
	0.495	0.503	0.008
	0.496	0.501	0.005
90	0.498	0.502	0.004
	0.494	0.500	0.006
	0.499	0.504	0.005
	0.496	0.503	0.007
	0.501	0.509	0.008
180	0.500	0.502	0.002
	0.494	0.500	0.006
	0.493	0.500	0.007
	0.492	0.503	0.011
	0.496	0.499	0.003
270	0.488	0.495	0.007
	0.497	0.505	0.008
	0.504	0.506	0.002
	0.499	0.507	0.008
	0.494	0.500	0.006
	0.499	0.502	0.003

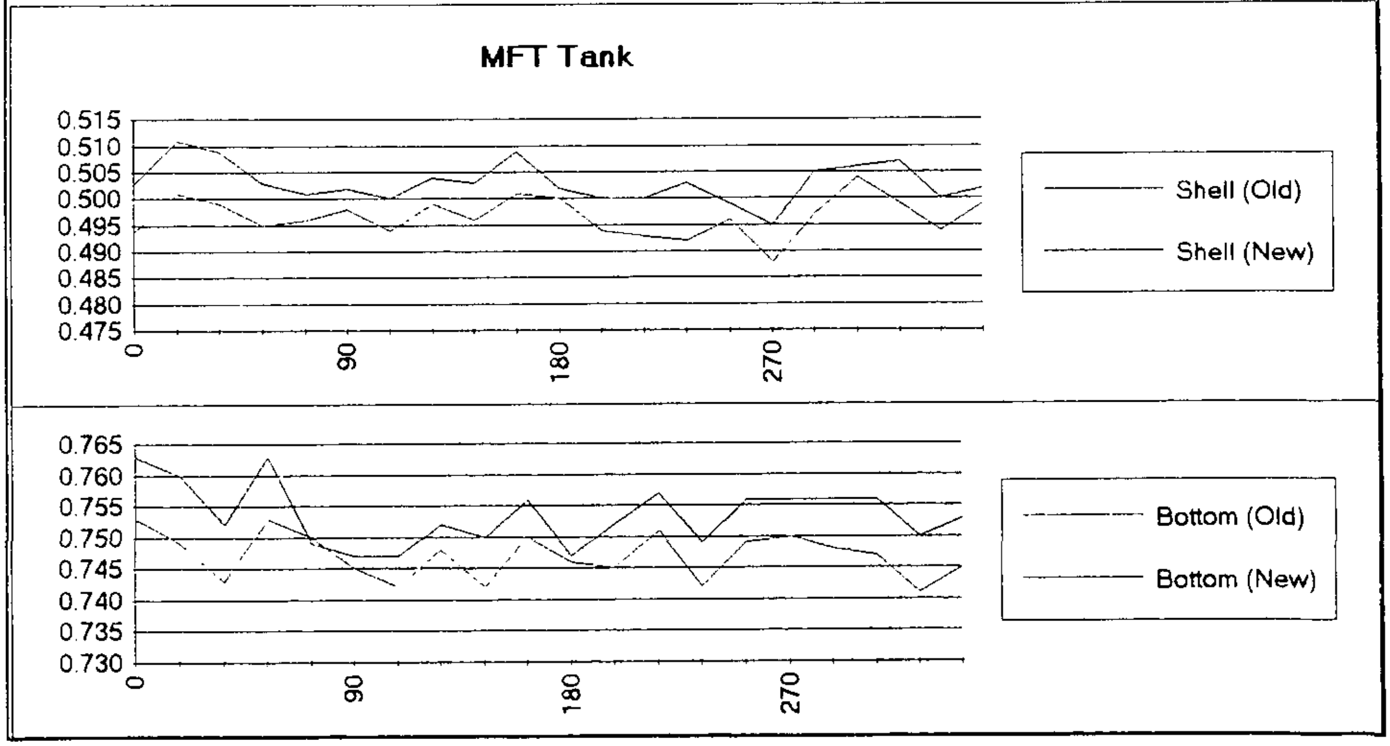


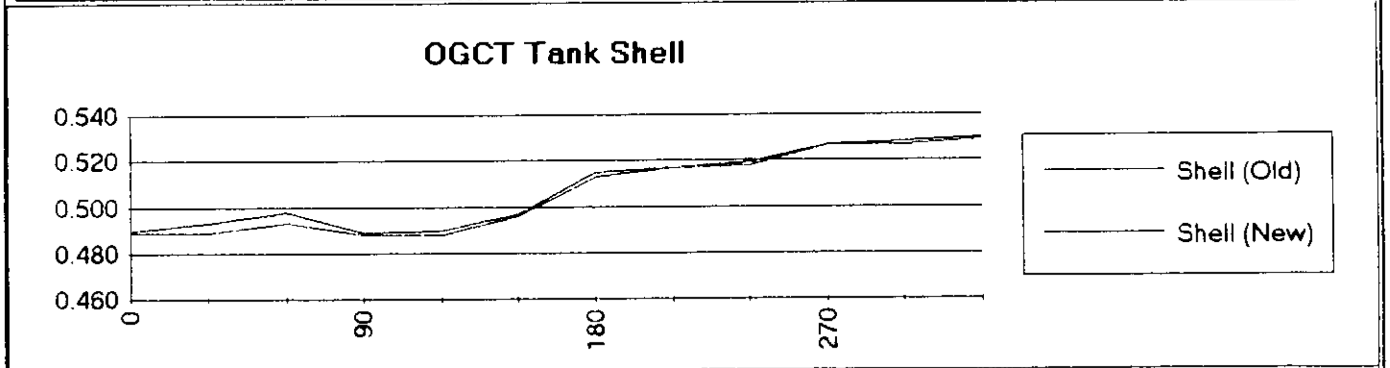
Figure 5. Comparison of UT wall thickness data for MFT tank shell and bottom before (i.e. "old") and after (i.e. "new") DWPF cold chemical runs.

OGCT TANK
Tank Bottom

	Bottom (Old)	Bottom (New)	Change
Ave	0.7526	0.7561	0.0035
min	0.7490	0.7510	0.0000
max	0.7550	0.7620	0.0120
Ave Dev.	0.0013	0.0013	0.0022
Stnd Dev.	0.0016	0.0024	0.0031
	Bottom (Old)	Bottom (New)	Change
0	0.752	0.762	0.010
	0.749	0.761	0.012
	0.753	0.753	0.000
	0.751	0.756	0.005
	0.750	0.751	0.001
90	0.755	0.756	0.001
	0.754	0.756	0.002
	0.754	0.756	0.002
	0.753	0.755	0.002
	0.753	0.757	0.004
180	0.755	0.756	0.001
	0.753	0.756	0.003
	0.754	0.756	0.002
	0.753	0.756	0.003
	0.753	0.756	0.003
270	0.751	0.756	0.005
	0.752	0.756	0.004
	0.753	0.757	0.004
	0.750	0.756	0.006
	0.753	0.753	0.000

OGCT TANK
Tank Shell

	Shell (Old)	Shell (New)	Change
Ave	0.5062	0.5078	0.0016
min	0.4880	0.4890	0.0000
max	0.5290	0.5300	0.0050
Ave Dev.	0.0157	0.0149	0.0011
Stnd Dev.	0.0171	0.0164	0.0015
	Shell (Old)	Shell (New)	Change
0	0.489	0.490	0.001
	0.489	0.493	0.004
	0.493	0.498	0.005
90	0.488	0.489	0.001
	0.488	0.490	0.002
	0.496	0.497	0.001
180	0.513	0.515	0.002
	0.517	0.517	0.000
	0.518	0.519	0.001
270	0.527	0.527	0.000
	0.527	0.528	0.001
	0.529	0.530	0.001



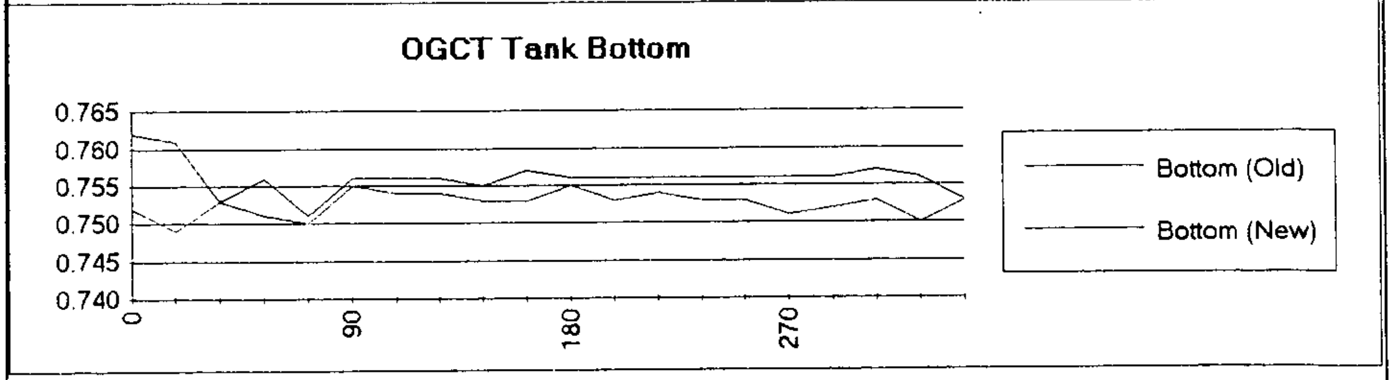


Figure 6. Comparison of UT wall thickness data for OGCT tank shell and bottom before (i.e. "old") and after (i.e. "new") DWPF cold chemical runs.

RCT TANK
Tank Bottom

	Bottom (Old)	Bottom (New)	Change
Ave	0.7812	0.7759	-0.0053
min	0.7720	0.7670	-0.0210
max	0.7900	0.7870	0.0080
Ave Dev.	0.0037	0.0039	0.0059
Stnd Dev.	0.0050	0.0053	0.0083
	Bottom (Old)	Bottom (New)	Change
0	0.779	0.775	-0.004
	0.777	0.778	0.001
	0.772	0.775	0.003
90	0.779	0.787	0.008
	0.781	0.782	0.001
	0.790	0.772	-0.018
180	0.788	0.767	-0.021
	0.777	0.772	-0.005
	0.782	0.776	-0.006
270	0.782	0.775	-0.007
	0.786	0.780	-0.006
	0.781	0.772	-0.009

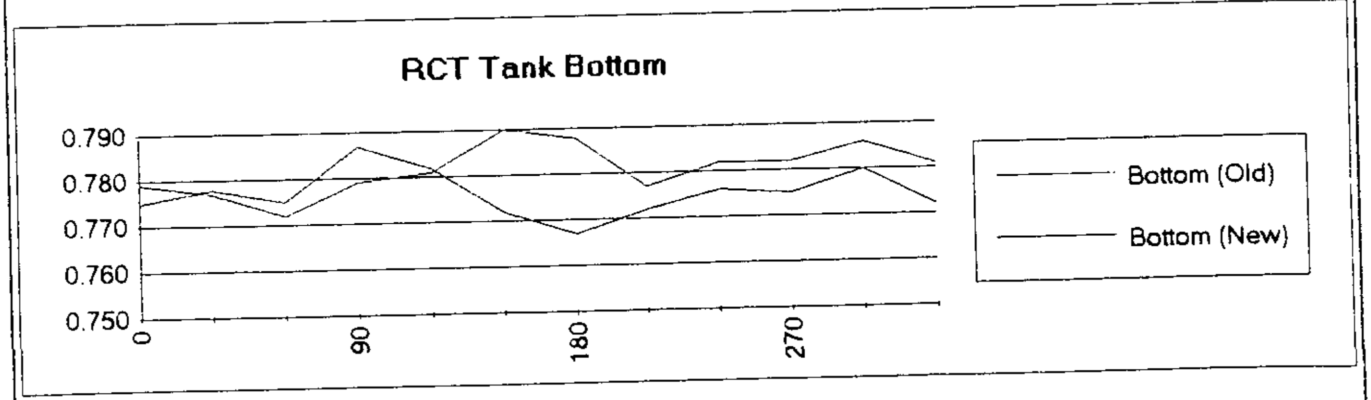


Figure 7. Comparison of UT wall thickness data for RCT bottom shell before (i.e. "old") and after (i.e. "new") DWPF cold chemical runs.

3.3 Process Cooling/Steam Coils

3.3.1 Removable Coils - Reported by W. D. Daugherty

The removable coil assemblies from four tanks (SRAT, SMECT, SME and MFT) were inspected. Each of these coil assemblies is of similar design. The SMECT cooling coils are constructed of Type 316L stainless steel, while the other coil assemblies are constructed of Hastelloy C-276. The SRAT and SME coil assemblies incorporate both steam and cooling coils while the SMECT and MFT coil assemblies provide only cooling.

Results and Conclusions:

Two of the coil assemblies (SME and MFT) showed local degradation due to erosion. In each of these, the patterns of wear were the same, although the SME coils experienced greater wear than the MFT coils. No indications of corrosion were observed on any of the coil assemblies.

The coil assemblies were examined through the use of visual observation and ultrasonic thickness measurements. The local erosion and general condition of the coil assemblies were documented by photography, videophotography and (for the SME) replication of eroded areas of support structures. The SME coils are shown in Figure 8. The areas of significant wear on the SME coil assembly include the following (the MFT coil was worn similarly, but to a lesser degree):

- The bottom portion of the downcomer for the inner coil (which extends below the coil itself) was worn smooth with a high degree of polish. The welds between elbows and straight pipe sections were virtually flush with the base metal (no relief remaining) on the sides towards the coil ID, and with reduced relief towards the coil OD. Wall thinning by up to 40% was measured ultrasonically on the downcomer pipe. (Similar measurements on the MFT downcomer pipe revealed 15% wall thinning.)

- The bottom portion of the downcomer for the middle coil (which extends below the coil to a lesser extent than for the inner coil) had a lesser degree of wear/polish, but followed the same trends described for the inner coil downcomer. UT thickness measurements show a minimum thickness in this area on the SME coil of about 9% less than the nominal wall thickness.

- The lower coil support structures (4 locations) had significant erosion patterns with loss of 50% or more of the support member cross section in some places. The same erosion pattern was seen at each of the 4 locations, with significant metal loss at three areas (see Figure 9). The supports for the inner and outer coils are connected by a straight bar (towards the inner coil) and a semicircular bar (towards the outer coil). The straight bar was deeply grooved adjacent to the vertical support coming down from the inner coil, and adjacent to the joint between the straight and semicircular bars.

> The third area with significant metal loss was on the supports for the middle coil. These supports consist of two small vertical bars (~1/4 x 1/2 inch cross section) which come down to meet a horizontal bar cantilevered from the outer coil support. The lower portion of the two vertical bars and the end of the horizontal bar they attach to was heavily eroded. The maximum metal loss of the vertical bars was just above the attachment weld, with at least 1/2 of the cross section gone. Replicas were made of these three areas on the supports at the 180° position (as identified for UT thickness measurements).

UT thickness measurements were also taken at other locations on the cooling coils and showed no significant wall thinning. The coils are fabricated from 2 inch Schedule 40 pipe, with a nominal wall thickness of 0.154 inch. The minimum wall thickness measured away from the locations noted above for all four coil assemblies is 0.142 inch, within 10% of the nominal thickness. The UT data are provided in inspection reports 95-IR-06-UT-0866, 95-IR-06-UT-0879, 95-IR-06-UT-0873 and 95-IR-06-UT-0851 for the SME, MFT, SMECT and SRAT coils respectively.

Wall thicknesses measured during the FA-04 program were consistently less than those measured in 1990 during baseline inspections. Although this suggested that general wall thinning might have occurred, further investigation revealed that the difference is due primarily to advancements in ultrasonic test equipment and calibration techniques [AID-QCM-950127, "Quality Control Condition Report, Nov. 16, 1995, J. G. Dickinson]. Direct comparison of previous and current techniques revealed a consistent bias in the previous equipment/procedures that led to overestimating the thickness of small bore pipe walls by about 0.01 inch. Taking this into account, there was no significant change in wall thickness of the coil assemblies except as already noted.

The observed wear patterns on the SME and MFT coil assemblies are consistent with the predominant flow patterns in these tanks. An agitator located inside the coils provides constant mixing of the tank contents. The lower blades are oriented vertically to drive the slurry outward, while the upper blades are canted to establish a downward flow. Together, the upper and lower blades set up a circulation pattern that includes rotation around the tank, upward motion outside the coils, and downward motion inside the coils. With the lower agitator blades at an elevation near the bottom of the cooling coils, the bottom portion of the downcomers and lower support structures are located in a region of relatively high flow velocity and turbulence. The presence of glass frit in the SME and MFT distinguishes these two coil assemblies from the SRAT and SMECT coil assemblies. With no abrasive material present in the other two tanks, those coil assemblies experienced no significant erosion.

The condition of the SME and MFT coil assemblies was documented by NCR (95-NCR-05-0215 and 95-NCR-05-0221, respectively). In both cases, additional C-276 material was added to increase the remaining service life. In addition, a Stellite coating was added to the SME coil support frame surfaces that are exposed to direct impact by the frit slurry. Both coil assemblies were then returned to service.

Based on the lack of degradation observed on the SRAT and SMECT coil assemblies, no significant limitations to their service life are identified. They are expected to continue operating for the life of the facility. Erosion due to the glass frit is expected to limit the service life of the SME and MFT coil assemblies. The MFT coil assembly, with the less severe erosion, is expected to serve an additional 5 years. The benefit of the Stellite overlay placed on the SME coil support structure cannot be quantified, but at least 2 years additional service is expected. The coils should be inspected at that point to determine the remaining service life.

3.3.2 Fixed Coils - Reported by J. T. Gee

The PR and OE vessels in the SPC contain fixed steam coils. As a result of the higher temperatures, corrosion of the steam coils is expected to be higher than that for the vessel wall. Thus, corrosion of the steam coils could be life limiting for the vessel. Note that both of these coils are fabricated from alloy C-276 which has a high degree of corrosion resistance.

Both of the fixed coils were visually inspected using remote video probe techniques. The inspection reports are documented in "FA-04 Materials Evaluations / Field Reports" (WSRC-TR-96-0197) under the following inspection report numbers:

Fixed Coils	Inspection Report (contained in WSRC-TR-96-0197)
PR	95-IR-06-VT-1177
OE	95-IR-06-VT-1178

Results and Conclusions:

While no evidence of significant localized corrosion was noted, this would not rule out the possibility of significant general corrosion which could occur when steam is flowing in the coils.

Corrosion of the PR and OE steam coils was considered under the DWPF Structural Integrity Program and results were documented. The document is provided in Appendix 7 in its entirety. This evaluation, based on laboratory coupon data at elevated temperatures, suggested corrosion rates of up to 5 mils/year. This would limit the useful life of the vessels (i.e. breach of corrosion allowance) to about twelve years. This evaluation was not realistic in that the steam coils will be at elevated temperatures for only a few hours per batch cycle when steam flow is present. It was therefore concluded that accelerated corrosion of the fixed coils would not significantly reduce the expected life of the PR and OE vessels.

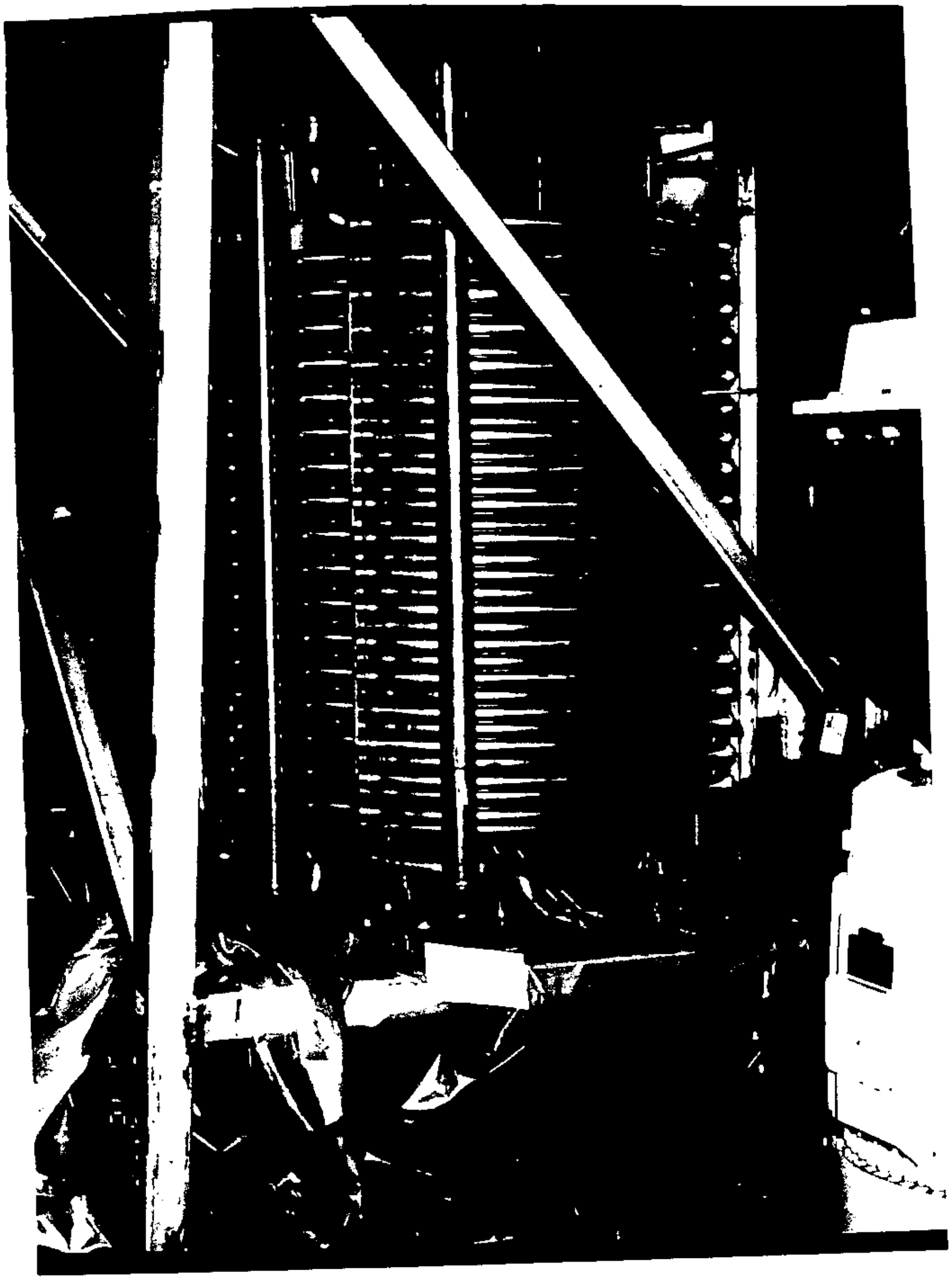


Figure 8. Lower portion of SME coil assembly (inspected in detail in FA-04 program) showing coils, downcomer pipes, and lower support structure. Negative WSRC-FM-95-004401.

Figure 9. Detail of erosion pattern at SME coil assembly lower supports. Negative WSRC-FM-95-0044-15.

3.4 Sample Pumps

3.4.1 PR, SRAT, SME, MFT, and OGCT Sample Pumps
- Reported by K. J. Imrich

As part of the FA-04 Inspection Program the 1.5 inch vertical cantilever shaft sample pumps from the PR, SRAT, SME, MFT, and OGCT were visually inspected for evidence of erosion and/or corrosion. The pumps are used to collect samples for analytical analysis from their respective process vessels. A typical Chemical Process Cell sample pump is shown in Figure 10. The impeller and impeller housings were fabricated from CW7M, a cast version of Hastelloy C-276, except for the housings and impellers from the SME and MFT, which were fabricated from cast Stellite 6 (AMS-5373B). All other sample lines were constructed from Hastelloy C-276. Visual inspection of all the pumps did not reveal any evidence of serious corrosion or erosion. . The following table includes a list of inspections that were performed and documented by Administration & Infrastructure Quality/Quality Control (A&IQ/QC).

Sample Pump	A&IQ/QC Inspection Report Numbers
PR	95-IR-06-VT-1173
PR	95-IR-06-UT-1175
PR	95-IR-06-PT-1174
SRAT	95-IR-06-VT-0847
SRAT	95-IR-06-UT-0846
SRAT	95-IR-06-PT-0845
SME	95-IR-06-VT-0860
SME	95-IR-06-UT-0859
SME	95-IR-06-PT-0861
MFT	95-IR-06-VT-0987
MFT	95-IR-06-UT-0877
MFT	95-IR-06-PT-0876
OGCT	95-IR-06-VT-1044
OGCT	95-IR-06-UT-1046
OGCT	95-IR-06-PT-1045

The individual reports were compiled in the report entitled, "FA-04 Materials Evaluation / Field Reports", document number WSRC-TR-96-0197. Measurements recorded during the FA-04 inspection were compared to baseline data. The following is a summary of the various inspections.

Results and Conclusions:

The pumps were fabricated by Lawrence Pumps Inc. and were generally similar in design. Design life of the pumps is five years. Although all the pumps were visually inspected, only the SME sample pump will be shown in this report. It was chosen because it was exposed to the harshest environmental conditions. The SME pump consists of a feed, return, and sample lines. No evidence of corrosion was observed on these lines or any external component. Figure 11 shows the strainer and suction line going the pump. The restriction nozzle assembly is shown in Figure 12. Both the strainer and restriction nozzle are located near the bottom of the of the vessel where the slurry would most likely abrade external portions of the pump. However, no evidence of external erosion was observed. The pump housing was disassembled and the internal parts were visually inspected (Figure 13a). Only a minor amount of erosion was found around the outlet region (Figure 13b). Otherwise the housing was in excellent condition. Figures 14a and 14b show side and bottom views of the impeller. Some erosion was observed on the spiral ribs on the bottom of the impeller but was insignificant. Overall the SME, PR, SRAT, MFT, and OGCT sample pumps were in excellent condition and should not be adversely affected by either erosion or corrosion over their five year design life.

3.4.2. Erosion of Sample Line Pick-up Points - Reported by J. T. Gee

In each sample pump, the sample required for analytical testing is pulled from a larger recirculating loop (one and one-half inch diameter) and is routed through small diameter pipe (i.e. half inch diameter) to the appropriate sample cell. SRTC personnel were concerned about erosion of the "sample line pick-up" where the liquid sample (i.e. containing glass frit) enters the smaller sample line going to the analytical sample cell. Figure 15 shows the block assembly on the SME sample pump containing the noted sample line pick-up point. This is typical for all CPC sample pumps. Any significant wear at this critical pick-up point as a result of erosion could conceivably impact the characteristics of the material entering the sample line. It was feared that if this occurred the sample may not be truly representative of the tank contents. Since the chemical analysis of the process streams is very critical for ensuring glass chemistry, anything that impacted the reliability of the sample quality could not be tolerated.

The sample line pick-up points for the SME and MFT sample pumps were radiographed before (baseline) and after cold chemical runs to monitor degradation. Special precautions were used to ensure that the radiographs performed after cold chemical runs were shot as close as possible to the baseline radiographs.

Results and Conclusions:

Radiographs for the sample line pick-up points (two comparisons for the SME and MFT sample pumps) were evaluated by Mr. Jim Dickinson of A&IQ NDE. He is a level III radiography inspector and is considered a site expert in radiograph interpretation. It was his conclusion that there was no discernible differences between the two sets of radiographs and therefore no wear had occurred (Reference: Appendix 2, NDE "Quality Control Condition Report for CPC," AID-QCM-950-127).

Based on the radiograph evaluations of Mr. Dickinson, it was concluded that there was no evidence of erosion of the sample line pick-up points for the SME and MFT and as a result, degradation of sample quality as a result of wear was not expected.

3.4.3 Mechanical Fatigue of Sample/Transfer Pumps - Reported by J. T. Gee

Failure of vendor reworked SMECT process pumps as a result of mechanical fatigues at pump dip tube cross bracing, led to decision to inspect selected process pumps under the FA-04 materials program.

3.4.3.1 CPC Pumps

The following process CPC pumps were inspected using PT and results documented in the referenced inspection reports. These reports are contained in the "FA-04 Materials Evaluation / Field Reports" (WSRC-TR-96-0197) document.

CPC Process Pumps	Inspection Report (contained in (WSRC-TR-96-0197)
MFT Feed Pump	95-IR-06-PT-0996
MFT Sample	95-IR-06-PT-0876
OGCT Sample	95-IR-06-PT-1045
SME Transfer	95-IR-06-PT-0858
SME Sample	95-IR-06-PT-0861
SRAT Sample	95-IR-06-PT-0845
SMECT Transfer	95-IR-06-PT-0871

Results and Conclusions:

No evidence of mechanical fatigue at welds was indicated by the PT examination. Note that the CPC pumps had been reworked at SRS to improve the support structure (i.e. bracing).

3.4.3.2 SPC Pumps

The following SPC pumps were inspected using PT and results were documented in the results documented in the referenced inspection reports. These reports are contained in the "FA-04 Materials Evaluation / Field Reports" (WSRC-TR-96-0197) document.

SPC Process Pumps	Inspection Report (contained in WSRC-TR-96-0197)
PR Sample	95-IR-06-PT-1174
PRFT Sample	95-IR-06-PT-1182
PRFT Transfer	95-IR-06-PT-1184

Results and Conclusions:

The PR sample pump contained four PT indications (i.e. mechanical fatigue cracks) at welds on the cross bracing as partially shown in Figure 16. As a result the PRFT sample and PRFT transfer pump were removed and inspected. The PRFT sample pump (identical to PR) contained two PT indications and the PRFT transfer pump none.

The SPC process pumps were "as-received" from the vendor and had not been reworked at SRS. The fact that the SPC pumps had not been reworked to improve structural support is thought to be the primary difference in the performance of the CPC and SPC process pumps. The damaged SPC sample pumps were repaired as referenced in the FA-04.03 Field Completion Report.

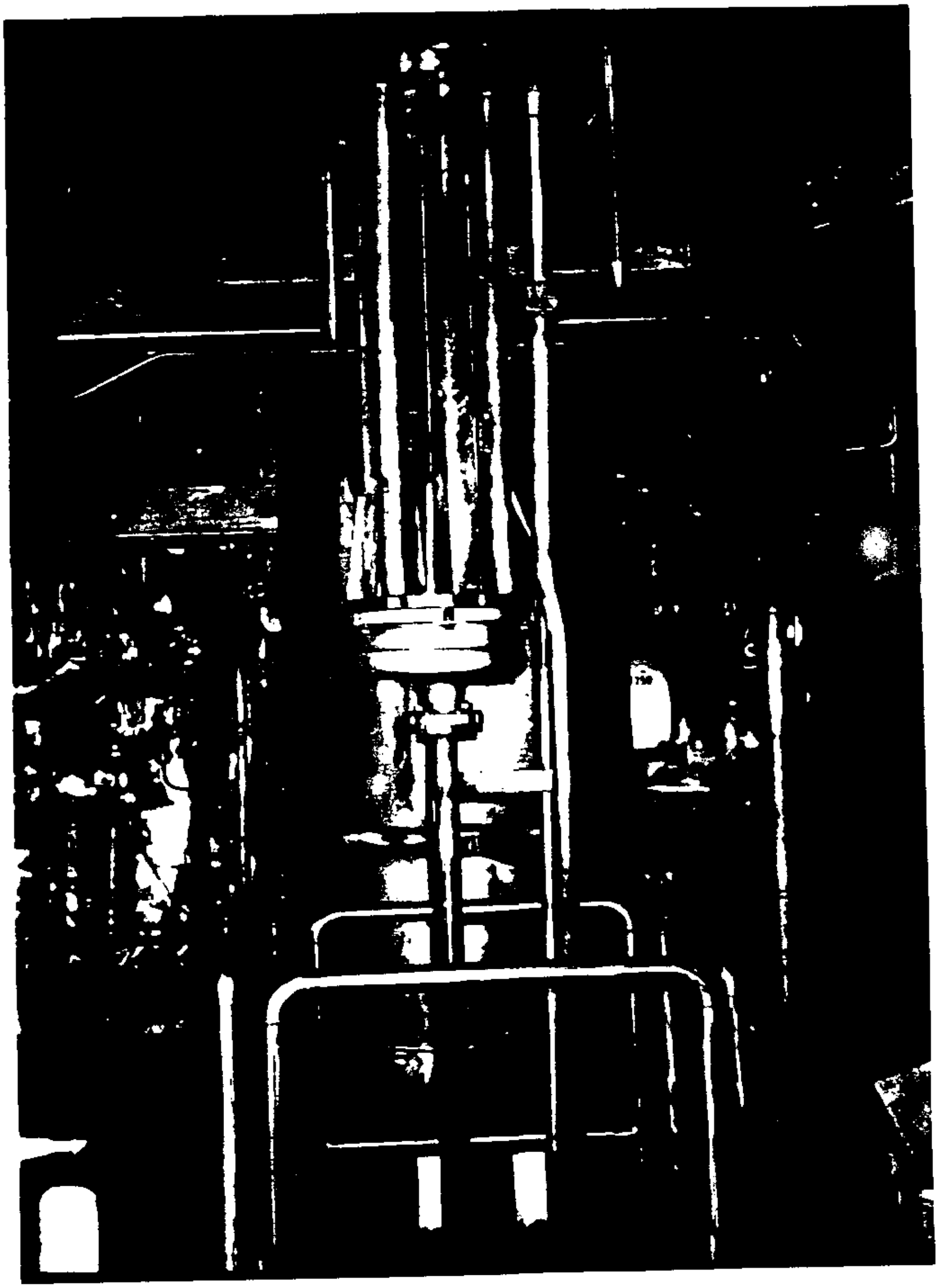


Figure 10. Photograph showing typical Chemical Process Cell sample pump (WSRC-FM-96-308-16).

Figure 11. Photograph of the strainer and suction line from the SME sample pump (WSRC-FM-95-0006-8). Note welds and strainer show visible signs of significant erosion.

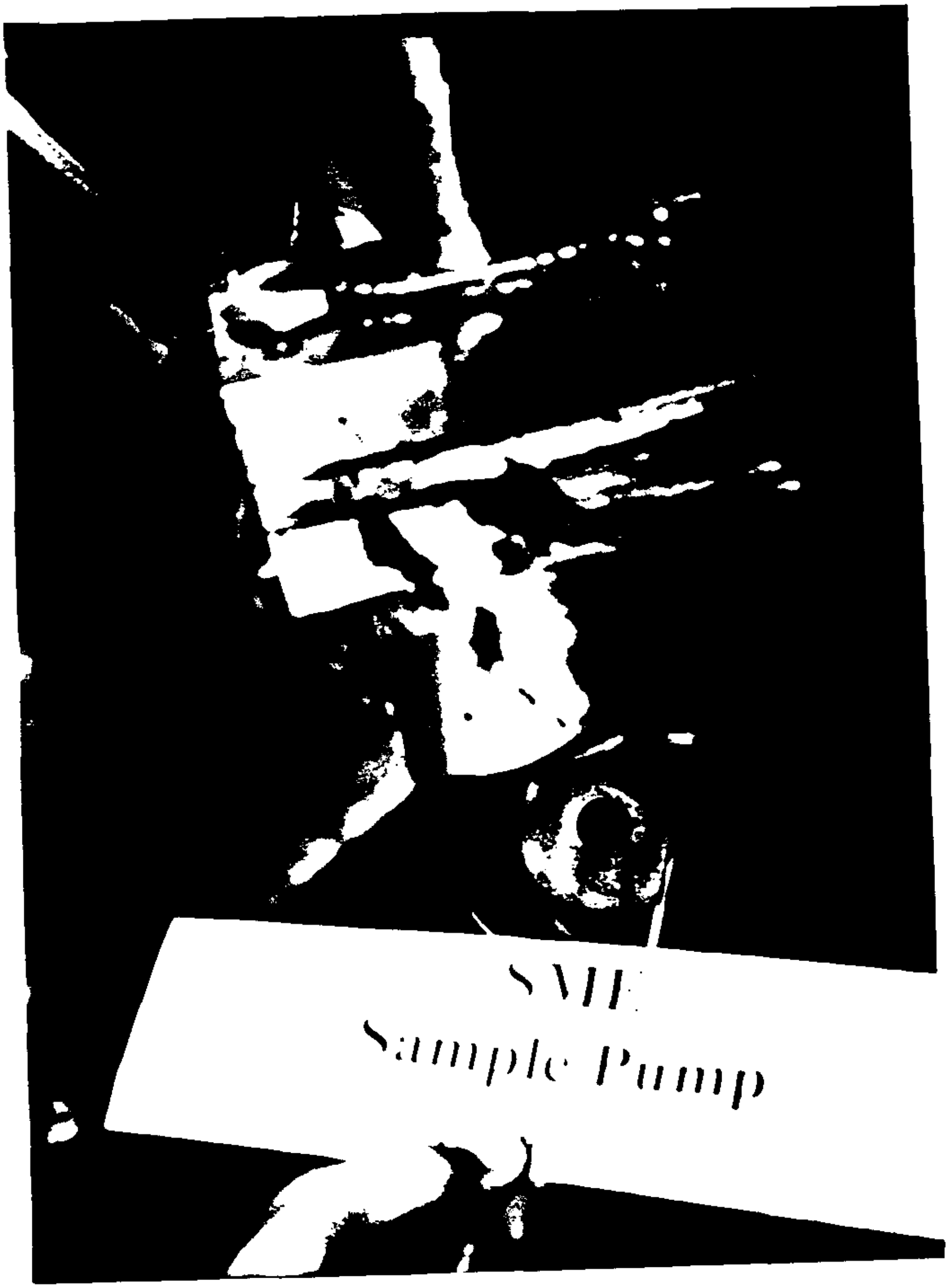


Figure 12. Photograph of the restriction nozzle assembly from the SME sample pump (WSRC-FM-95-0006-9). Degradation resulting from corrosion or erosion was not observed on the metallic components or the alumina nozzle.

Figure 13a. Photograph of the impeller housing from the SME sample pump showing inlet and outlet regions (WSRC-FM-95-0006-1).

Figure 13b. Photograph of the impeller housing from the SME sample pump showing outlet region. Arrow indicates region of minor erosion observed around the outlet of impeller housing (WSRC-FM-95-0006-2).

Figure 14a. Photograph showing a side view of the impeller from the SME sample pump (WSRC-FM-95-0006-32).

Figure 14b. Photograph showing a bottom view of the impeller from the SME sample pump (WSRC-FM-95-0006-34).

Figure 15. Photograph showing the block assembly on the SME sample pump that contains the "sample line pick-up point" (WSRC-FM-96-380-1), where the smaller sample line going to the sample cell is removed from the larger recirculating loop going back into the tank.

Figure 16. Photograph showing horizontal indications in PR sample pump (WSRC-FM-96-380-7) which were determined to be caused by fatigue.

3.5 PR, SRAT, SME, and MFT Agitator Blades - Reported by K. J. Imrich

The DWPF has operated with non-radioactive simulated waste solutions for approximately fourteen months. Because of the erosive/corrosive nature of processing frit/sludge/slurry mixtures and several process changes since the materials of construction were selected, the FA-04 erosion/corrosion evaluation program was performed on the DWPF feed preparation system prior to radioactive operations. As part of this program the agitators from the Precipitate Reactor (PR) Tank, Sludge Receipt and Adjustment Tank (SRAT), Slurry Mix Evaporator (SME), and Melter Feed Tank (MFT) were removed and evaluated for evidence of erosion, corrosion and cracking. Agitator blade assemblies, constructed of alloy Hastelloy C-276, are used in the feed processing vessels to adequately mix the viscous frit/sludge/slurry mixtures for proper sampling and processing. They consist of two sets of blades, an upper set of curved hydrofoil blades (three or four blades) and four lower flat rectangular blades. Design life of all the agitators is five years. Nondestructive evaluations (NDE), consisting of ultrasonic thickness testing (UT) and liquid penetrant testing (PT) were performed to identify and quantify the degree of general corrosion, erosion and cracking resulting from twelve months of operation. Thickness measurements using calipers were also taken at specific locations around the blades to document some of the irregular wear scars and to verify UT measurements in these areas. The following table includes a list of inspections that were performed and documented by Administration & Infrastructure Quality/Quality Control (A&IQ/QC).

Agitator	A&IQ/QC Inspection Report Numbers
PR	95-IR-06-VT-1176
SRAT	95-IR-06-VT-0848
SME	95-IR-06-UT-0862
MFT	95-IR-06-VT-1118
MFT	95-IR-06-VT-0878
MFT	95-IR-06-PT-1117

The individual reports were compiled in the report entitled, "FA-04 Materials Evaluation / Field Reports", document number WSRC-TR-96-0197. Measurements recorded during the FA-04 inspection were compared to baseline data. The following is a summary of the various inspections.

Results and Conclusions:

Precipitate slurry is processed by a hydrolysis reaction of cesium and potassium tetraphenylborate with formic acid in the PR. This chemical process removes mercury and organics. Since the slurry does not contain any abrasive particles, erosion is not a major concern with this system. The PR agitator is the only one having four upper hydrofoil blades (Figure 17a). A large dent was observed on the top edge of one of the lower blades (Figure 17b). The dent was mechanically induced and should not adversely affect its performance. Degradation due to corrosion or erosion was not observed. Therefore, this agitator is expected to perform satisfactorily for at least five years.

Washed sludge and bottoms product from the PR are reacted with nitric acid in the SRAT. Although the sludge processed in the SRAT contains some solids, it is not very abrasive. Corrosion is again the major concern. The agitator from SRAT consists of three upper hydrofoil blades and four rectangular lower blades (Figures 18a and 18b). Visual inspection of the SRAT agitator showed a minimal amount of erosion on the back side of the lower blades near the attachment tabs (Figure 18c). The tabs are approximately ¾ " thick and are used to secure the blades to the hub. No evidence of corrosion or cracking was observed. Upper hydrofoil blades were also in excellent condition. Overall the SRAT agitator was in excellent condition and should perform satisfactorily for its five year design life.

The sludge/slurry from the SRAT is next fed to the SME where it is mixed with glass frit and concentrated to the proper solid content for the melter. This mixture is more abrasive than those in the PR or in the SRAT, therefore, both erosion and corrosion are concerns in this vessel. The SME agitator is similar in design to that of the SRAT (Figure 19a). Minor erosion was observed on the leading edge and tip of the upper hydrofoil blades (Figure 19b). Deep wear scars, approximately 50% through wall, were observed on the back sides of the lower agitator blades. Severe erosion of the blades was observed at the corners of the attachment tabs (Figure 19c). Severe erosion of the blade was also observed above the tab and on the lower edge of the blade. The degree of blade thinning is shown in Figure 19d. Tips of these blades experienced some minor wear. Two of the four attachment tabs were beveled at the ends, however; beveling did not minimize the erosion (Figure 19c). Only a slight rounding of the edges was visible on the front sides of the lower blades (Figure 19e). No evidence of cracking or significant corrosion was observed on any of the blades. The SME agitator blade, as originally designed, experienced severe degradation and will not survive more than two years of continuous operation.

The adjusted slurry from the SME is finally sent to the MFT where it is held until it is ready to be fed into the melter. An agitator, similar in design to those in the SRAT and the SME, is used to keep solids in suspension (Figure 20a. Wear patterns, similar to those on the SME agitator blades were observed on the MFT agitator blades. Figures 20b and 20c show wear patterns on the upper hydrofoil and lower blades, respectively. Erosion of the MFT agitator blades was more severe than on the SRAT agitator blades, but, less severe than on the SME agitator blades. No evidence of corrosion or cracking was observed. The MFT agitator should perform satisfactorily for its five year design life.

To ensure that the SME and MFT agitators perform satisfactorily for their five year design life, replacement agitators with a modified lower blade design were installed prior to start of radioactive operations. This new design incorporates additional use of Stellite hard face coating (i.e. weld overlay) to mitigate erosion. Hard facing was applied around the entire attachment tab, approximately four inches in front of the tab, and around the outer edge of the blades. Hastelloy C-276 blocks were attached to the end of the two blades for balance (Figure 21). Hydrofoil blades were not hard faced.

Figure 17a. Photograph of the PR upper agitator blades (WSRC-FM-96-0357-7).

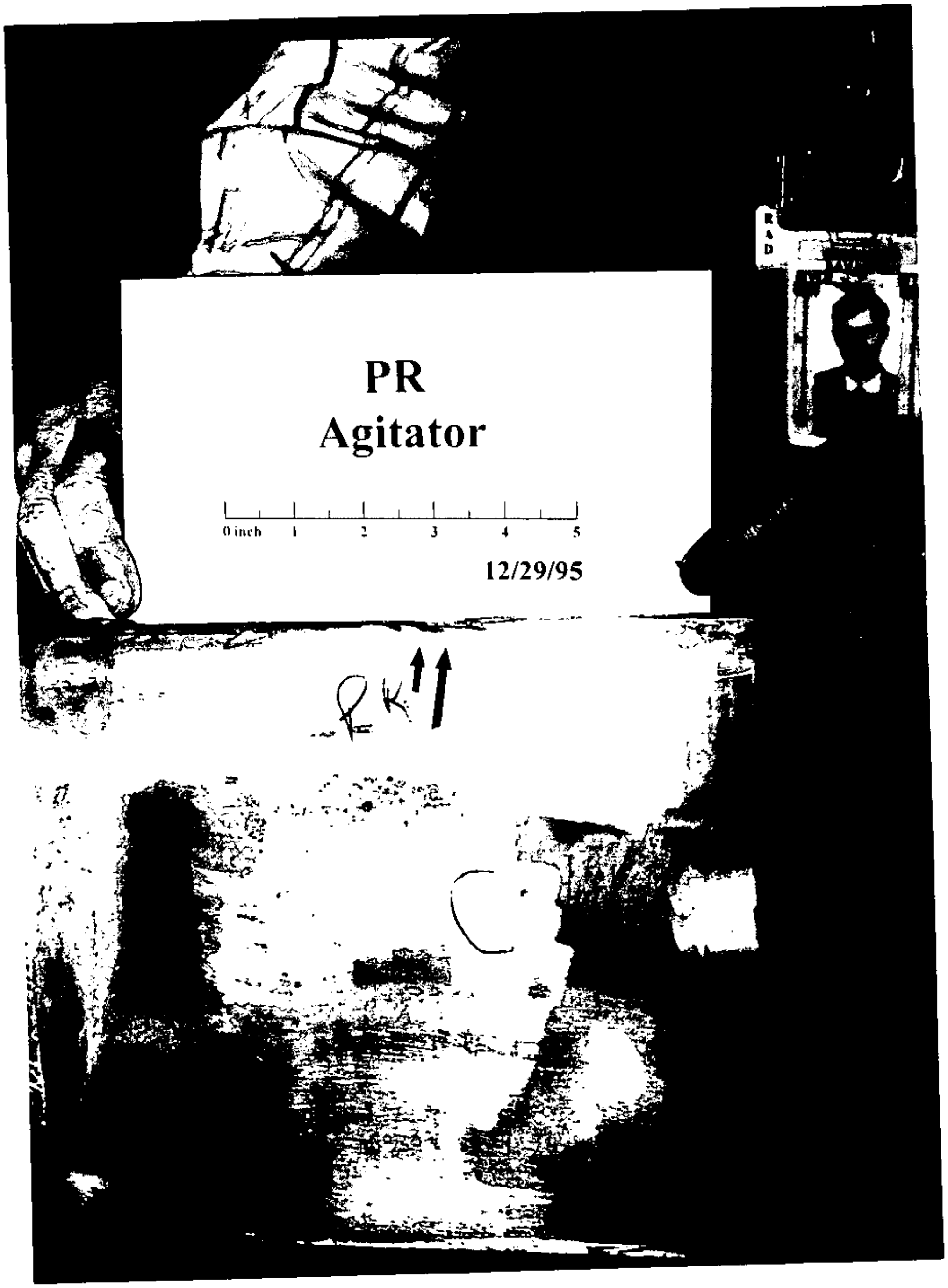


Figure 17b. Photograph of the front side of a PR lower agitator blade. Arrow indicates mechanically damaged area (WSRC-FM-96-0357-11).

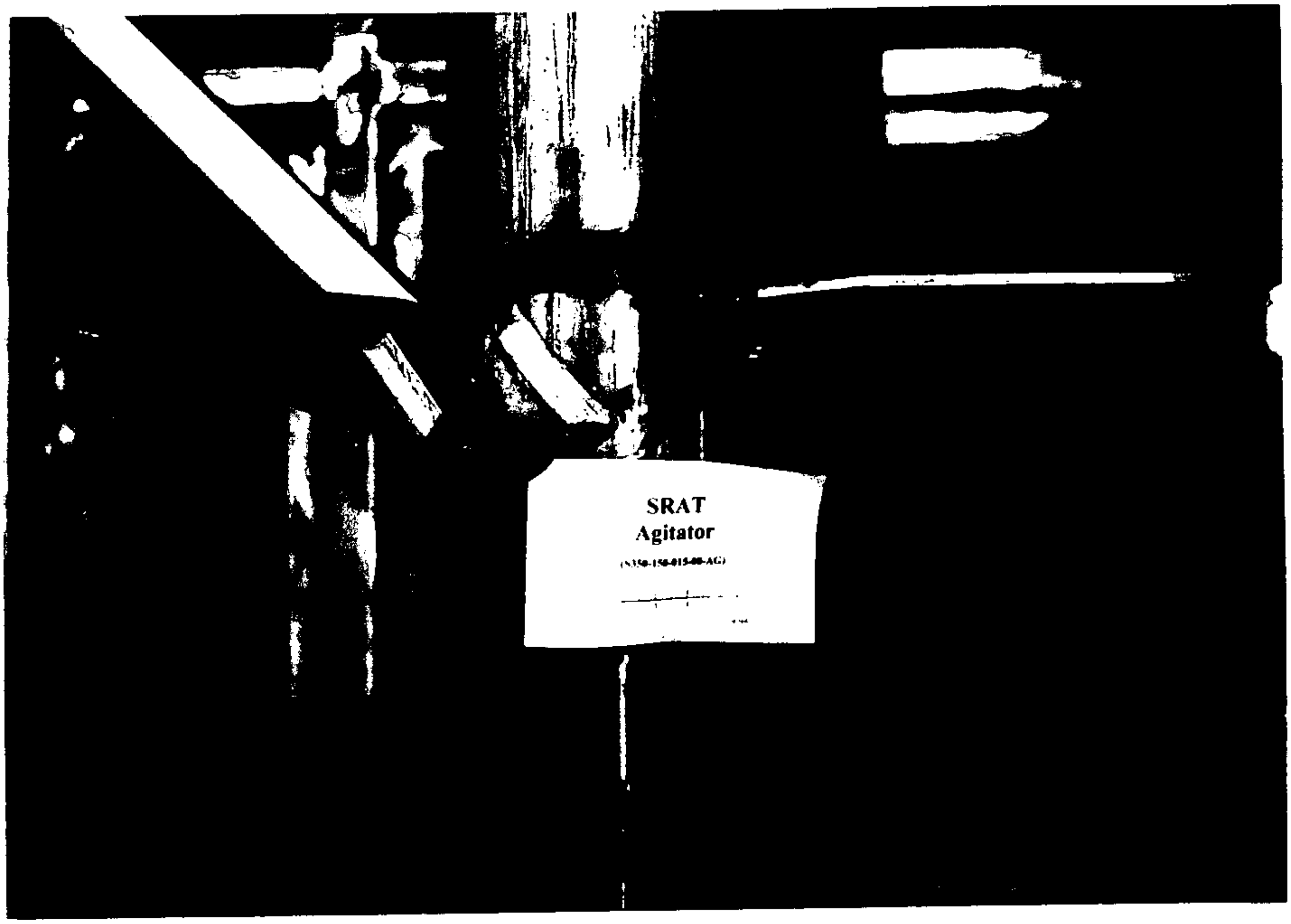


Figure 18a. Photograph of the SRAT upper agitator blades (WSRC-FM-95-0048-16).

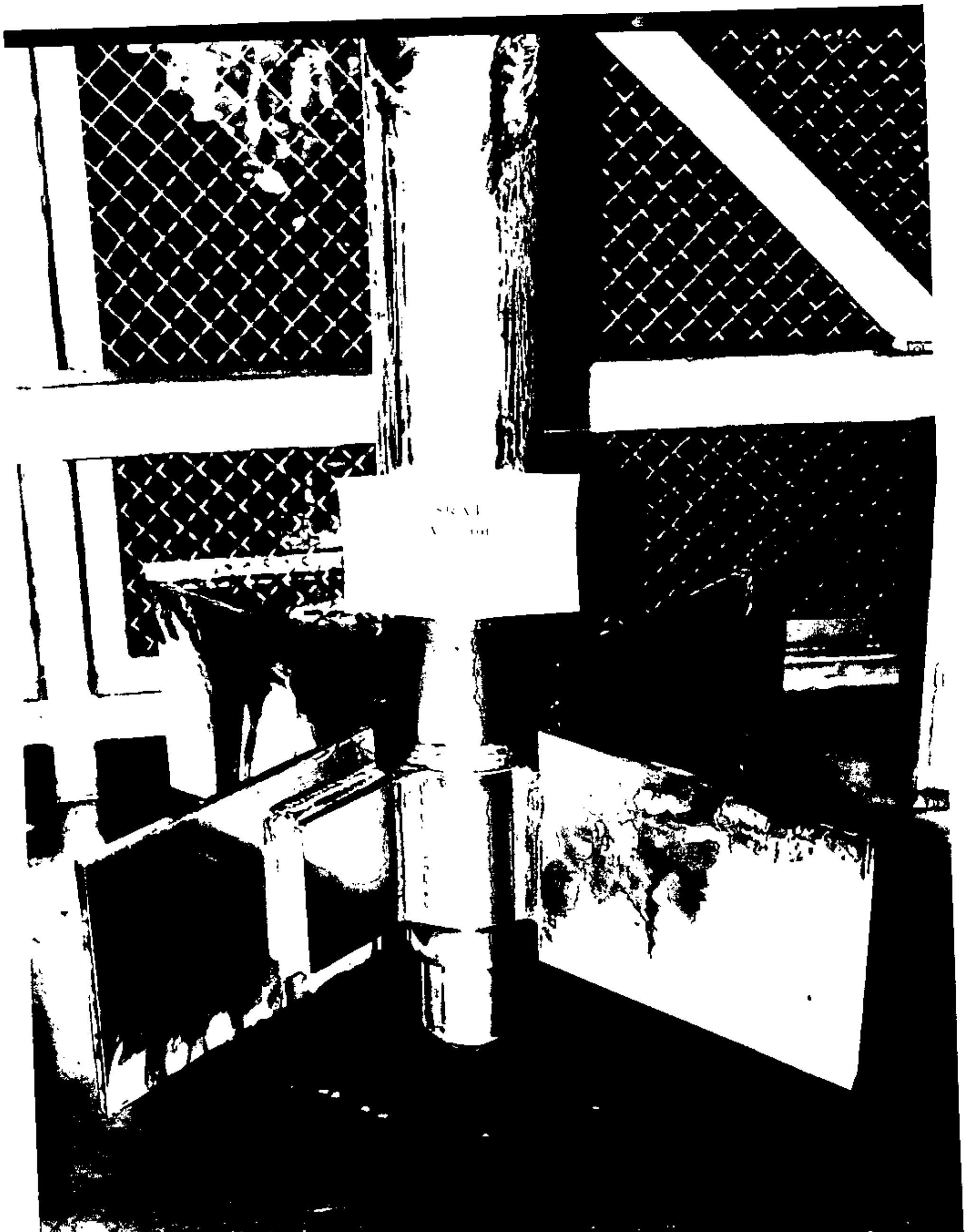


Figure 18b. Photograph of the SRAT lower agitator blades (WSRC-FM-95-0048-12).

Figure 18c. Photograph of the back side of a SRAT lower agitator blade (WSRC-FM-95-0048-19). Arrow shows location of minor erosion on the blade near the corner of attachment tab.

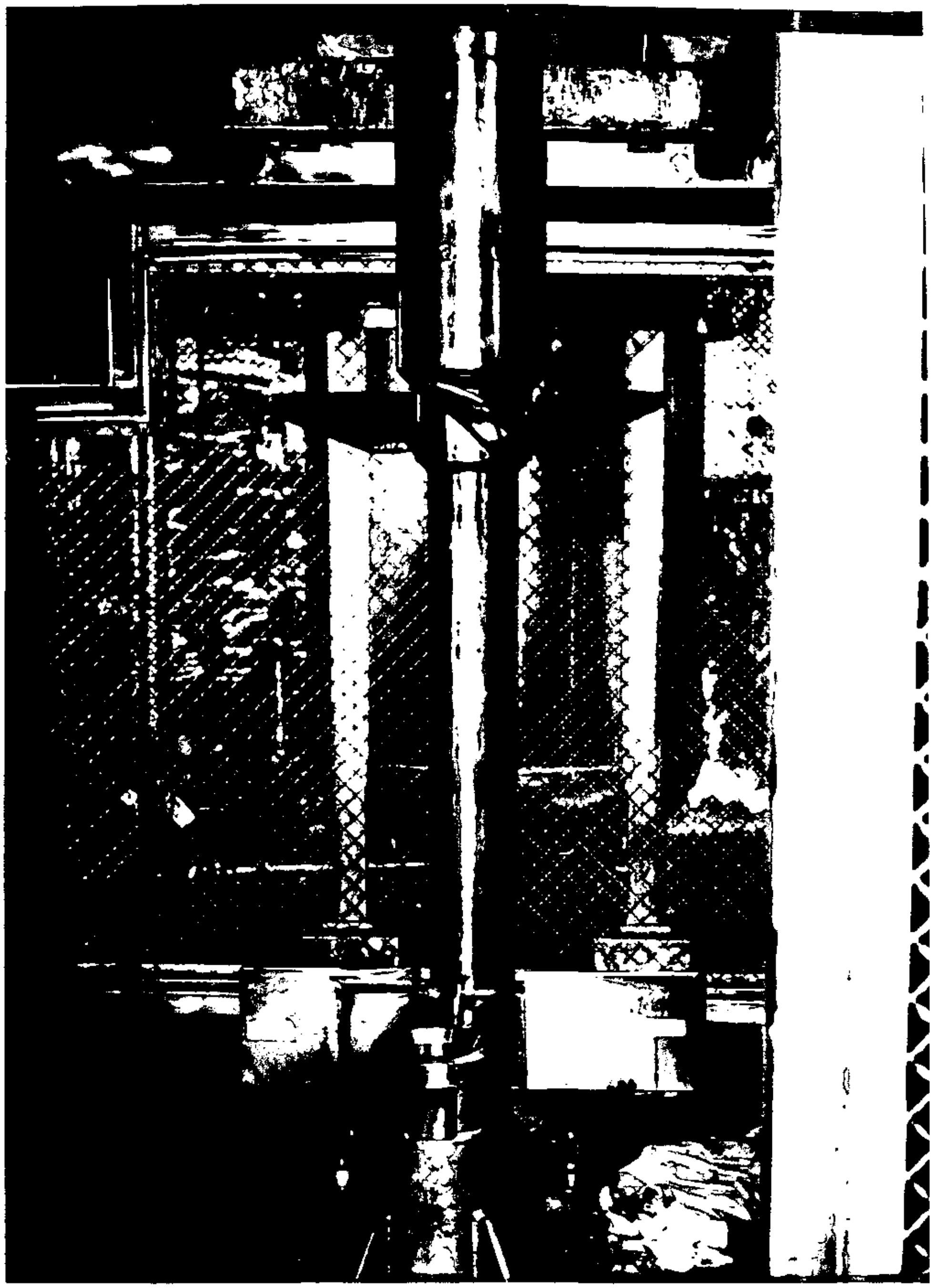


Figure 19a. Photograph of the SME agitator showing both the upper hydrofoil and the lower rectangular blades (WSRC-FM-95-0064-35).

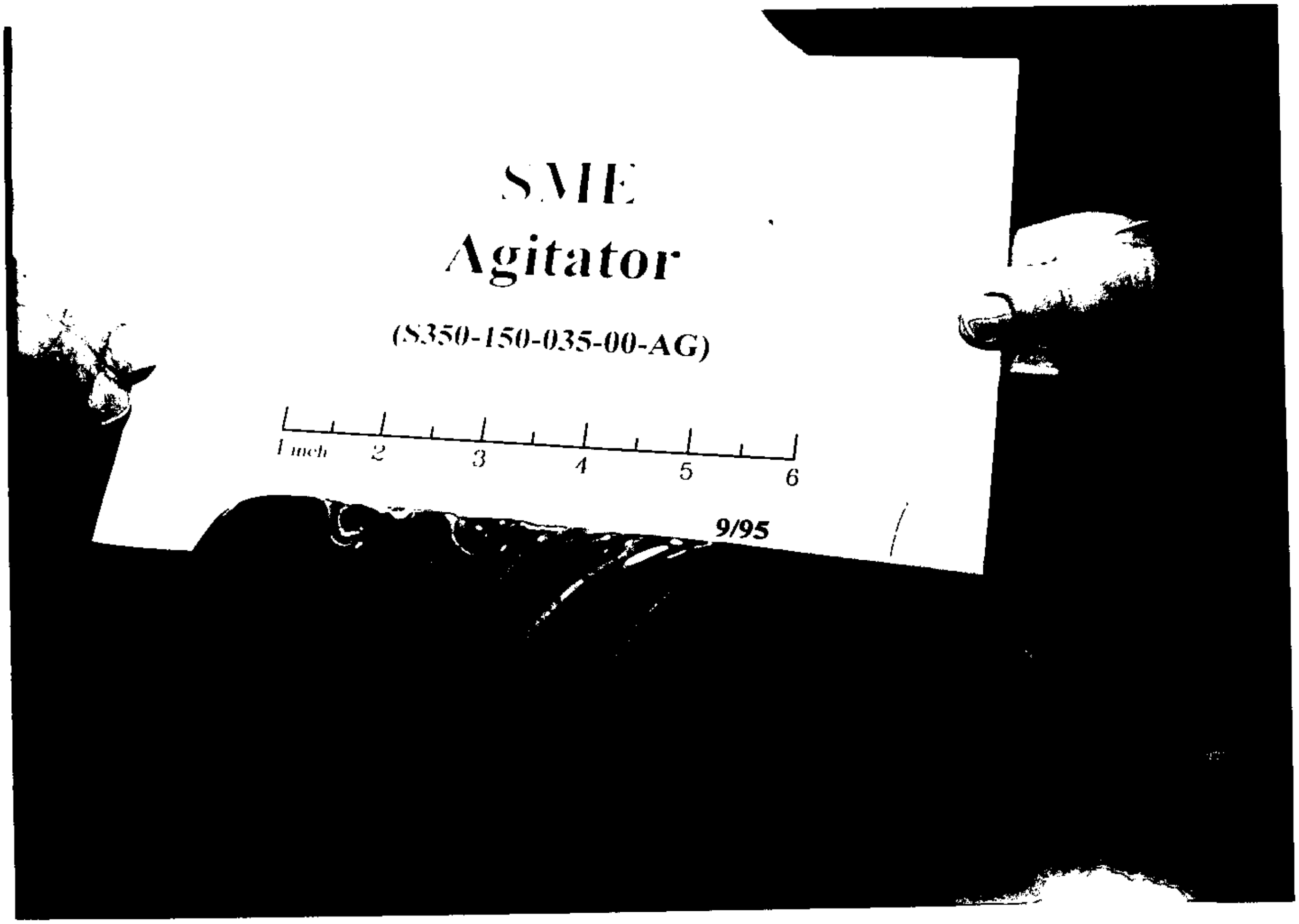


Figure 19b. Photograph of the top side of a SME agitator hydrofoil blade (WSRC-FM-95-0048-7). Wear was observed on the leading edge and tip of the blade.

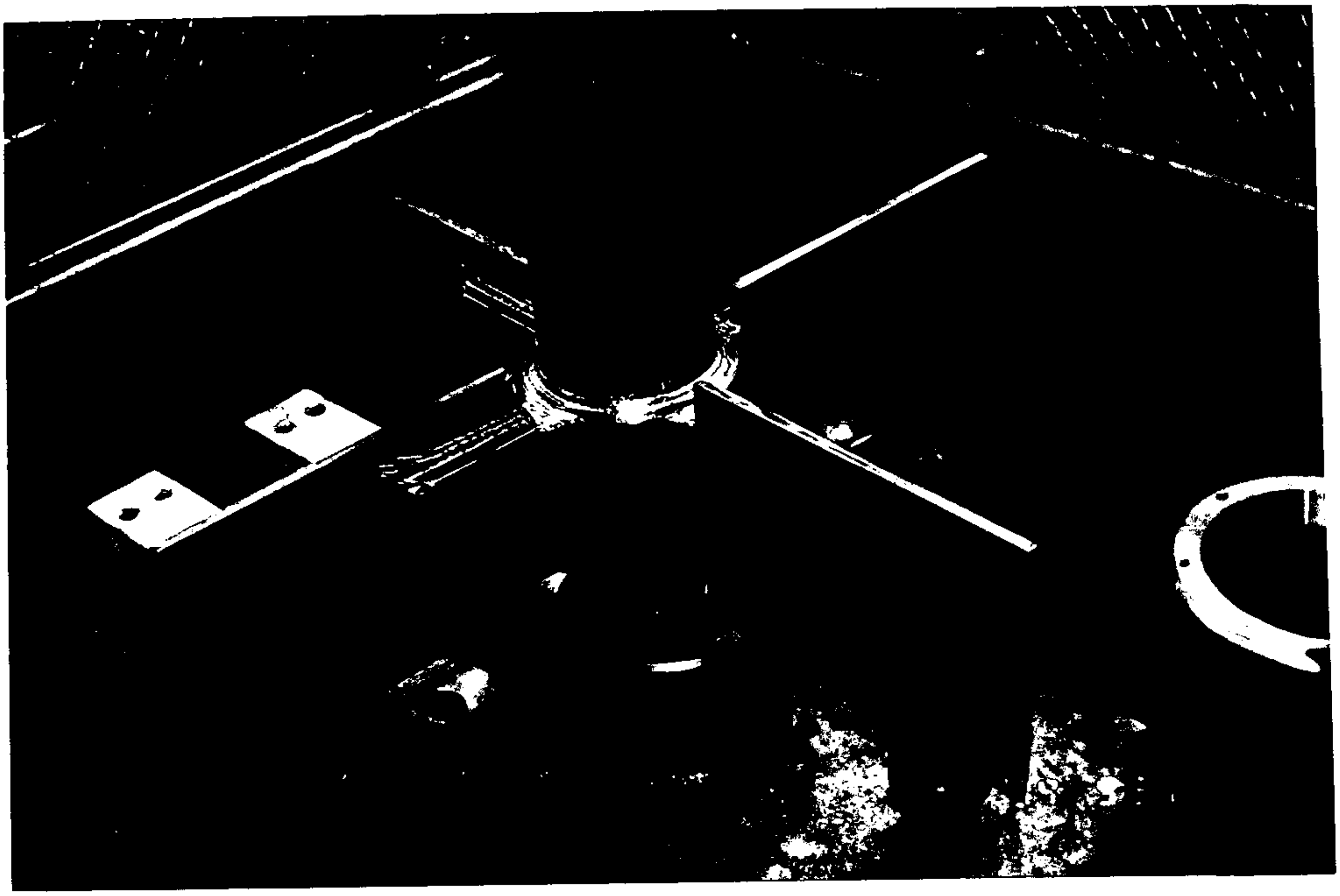


Figure 19c. Photograph of the back side of a lower SME agitator blade showing severe wear of the blade at corners of the tab and upper edge of the blade near the hub (WSRC-FM-95-0065-45). Wear was observed on the bottom edge and at the tip of the blades. Arrow indicates beveled region of tab.

Figure 19d. Photograph of the upper edge of a lower SME agitator blade (WSRC-FM-95-0006-11). The original nominal blade thickness was 0.375 inches.

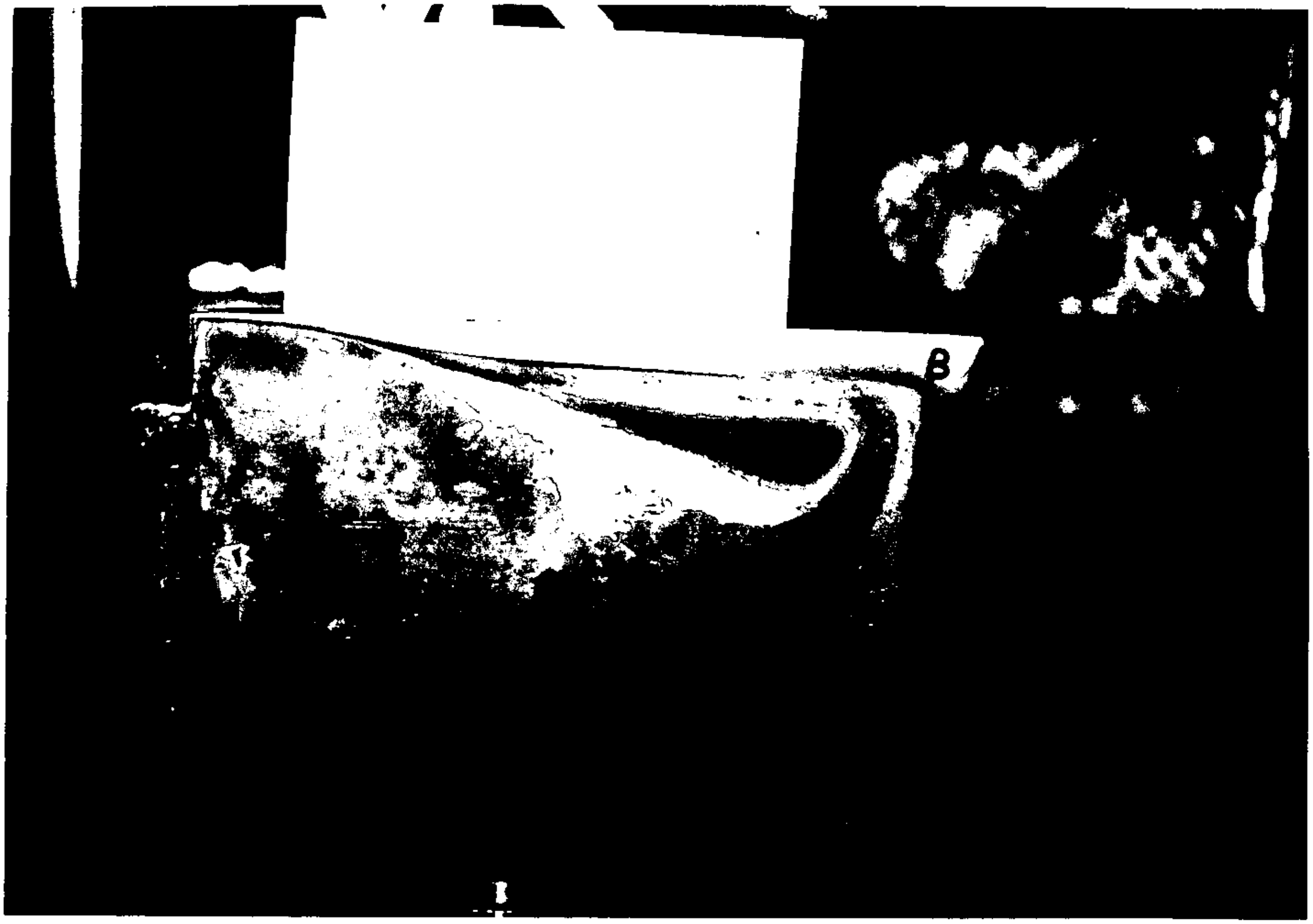


Figure 19e. Photograph of the front side of a lower SME agitator blade (WSRC-FM-95-0006-22). Only slight rounding of the blade edges was observed on the front sides.

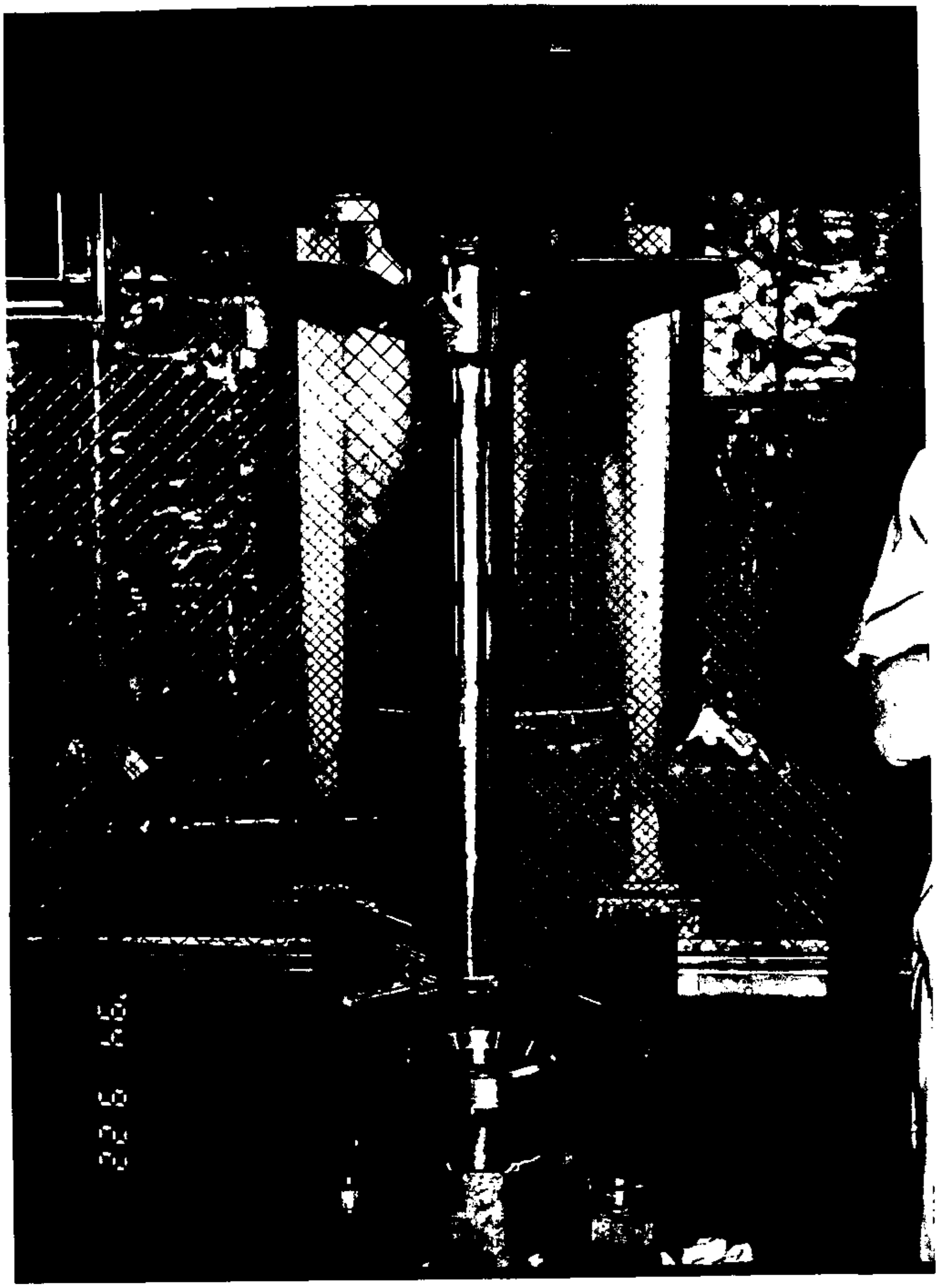


Figure 20a. Photograph of the MFT agitator showing both the upper hydrofoil and the lower rectangular blades (WSRC-FM-95-0066-12).

Figure 20b. Photograph of a MFT agitator hydrofoil blade (WSRC-FM-95-0066-16). Minimal erosion was observed on these blades.

Figure 20c. Photograph of a MFT agitator lower blade (WSRC-FM-95-0066-46). Erosion is visible on the blade at the corner of the attachment tab.

Figure 21. Photograph of the replacement MFT agitator showing the Stellite hard facing applied on the lower blades (WSRC-FM-96-0071-9).

3.6 Erosion of Melter Feed Loops - Reported by G. T. Chandler

Inspection Results

The inspections performed on the melter feed loop components are summarized in Table III. In general, no significant findings were reported. One location in the piping associated with the MFT feed pump #1 was significantly thinner than the remainder of the piping. The nominal thickness for this pipe is 0.154 inches. Four thickness measurements around the circumference were made at this thin spot. All 4 measurements were at or below 0.139 inches. While this is a straight run of pipe, the low values were obtained at or near a reducer. Based on available pre-service baseline data, this area had a reduced wall thickness (i.e. possibly due to reducer design) when received. For this reason, it is concluded that wall thinning did not occur as a result of erosion. Other pipe sections and fittings associated with the MFT feed pump #1 had acceptable wall thicknesses of 0.141 inches or greater, except for one measurement of 0.135 inches on the extrados of an elbow immediately downstream from the pipe section with the lowest measurements. Based on review of the other UT data at this location, the low value is a result of thinning due to pipe bending. This is acceptable as is further discussed in section 3.13.

The MFT Recirculating Feed Pump #1 was also inspected for evidence of erosion and/or corrosion. The pump housing was disassembled and the internal parts were visually inspected. The housing and impeller are constructed of cast Stellite 6. The MFT Feed Pump #1 housing and impeller are shown in Figures 22a & 22b. Significant thinning and wear scars were observed on the pump impeller. Significant wear was also observed around the outlet region of the pump. The mechanical lifetime of this pump is expected to be five years. Erosion/corrosion of this pump is not expected to reduce this lifetime.

Table III. Summary of Melter Feed Loop Inspections

Component Name	Equipment Number	Type of Inspection	Documentation
MF loop #1 DT assy	(7.6)DT	VT PT	95-IR-06-VT-0991 95-IR-06-PT-0992
#1 MF loop/return to tank	(7.1TP)3Y(7.6DT)1	VT	95-IR-06-VT-0990
MFT #1 feed loop line strainer	(7.1TP)3X North	VT	95-IR-06-VT-0884
Melter feed line jumper	257(7.2TP)3	VT UT	95-IR-06-VT-0882 95-IR-06-UT-0881
Melter feed system to return loop to tank jumper	(7.2TP)3V(7)7	VT	95-IR-06-VT-0989
MFT #2 feed loop line strainer	(7.2TP)3X South	VT	95-IR-06-VT-0885
#2 MF loop / return to tank	(7.2TP)3V(7.6DT)2	VT	95-IR-06-VT-0989
MFT feed pump #1	S350-170-011-00-P	VT UT PT	95-IR-06-VT-0994 95-IR-06-UT-0995 95-IR-06-PT-0996

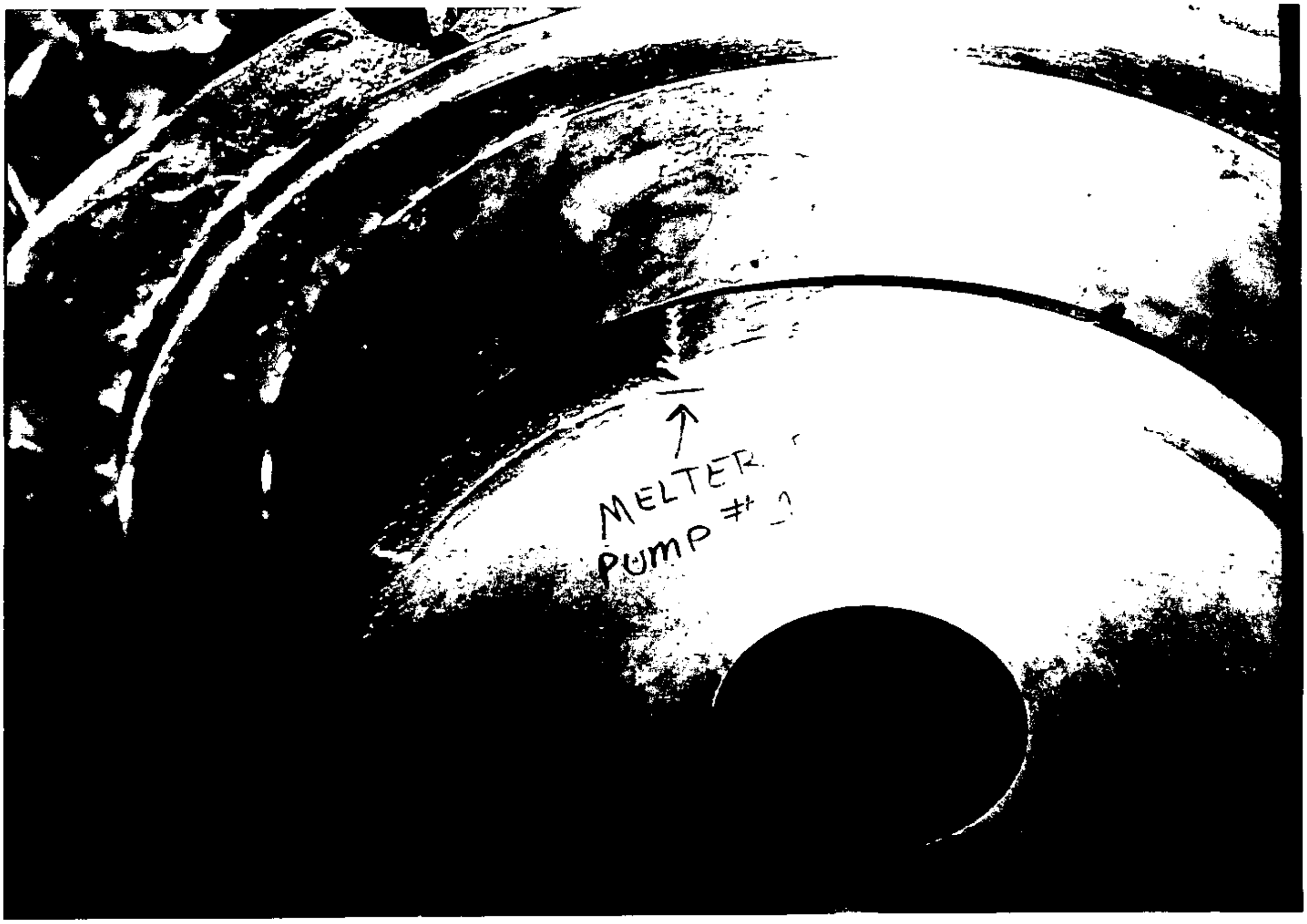


Figure 22a. Inner housing of Melter Feed Pump No. 1 (arrow indicates wear scar) (Negative WSRC-FM-96-0068-6).

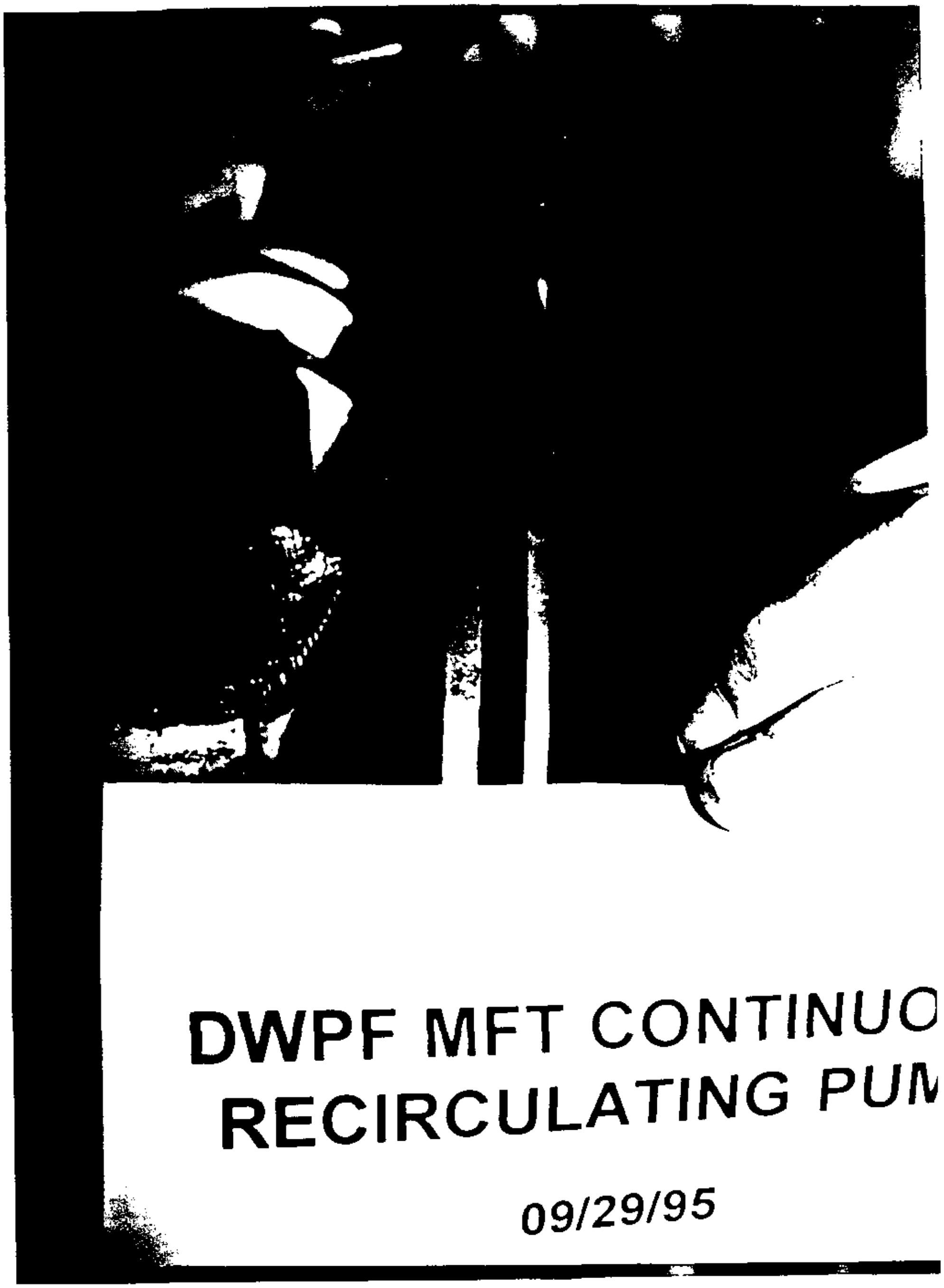


Figure 22b. Side view of impeller from Melter Feed Pump No. 1 indicating thinning (Negative WSRC-FM-96-0068-4).

3.7 Jumper Degradation Issues - Reported by W. L. Daugherty

Inspection Results:

Table IV summarizes the inspections performed on the various jumpers (not including jumpers specifically included in other sections of this report, such as melter feed loop jumpers). Inspection methods include visual and ultrasonic inspection. In most cases, the visual inspections were performed by A&IQ/QC either directly or by video probe. Tapes made from video probe inspections were also reviewed by Materials Technology personnel. No significant degradation was observed on any of the jumpers scheduled for inspection. However, fatigue failures of several jumper diptubes (not scheduled for inspection, but removed in preparation for other inspections) were found.

The three CDC jumpers received direct visual examination, with no reportable indications noted. The SRAT condenser to MWWT jumper was inspected remotely by video probe. Some scale-type debris and mercury was noted inside the pipe. The PRBT to SRAT feed jumper was inspected remotely by video probe. In addition, the orifice plate at one end received direct visual examination by Materials Technology. No indications were noted, and no significant wear was observed on the orifice plate.

Ultrasonic thickness measurements were made on several jumpers, as noted in Table IV. These measurements were generally consistent with the nominal pipe dimensions.

Diptubes extend to various of the DWPF process vessels to fulfill a number of functions. These tubes are a part of jumpers and can be removed. Typically, the diptubes extend some distance (up to about 14 feet) into the vessel and either hang freely or are restrained from excess motion by guides inside the tank. During inspections for the FA-04.02 test program, problems were discovered with four damaged dip tubes. Two diptubes in the SMECT failed as a result of fatigue, while a third diptube in the SMECT probably failed as a result of fatigue, but was not examined:

- The diptube on jumper (10)4Y-4 is of pipe-in-pipe construction, with the outer pipe (1.5 inch Schedule 80) almost completely broken off at a circumferential weld. This diptube carries condensate from the GC sample cooler. (refer to photographs WSRC-F-95-0044-42 through 48)
- The diptube on jumper (11.1C)3-(10)2 is a 2 inch Schedule 40 pipe, which separated at the fillet weld attaching it to the jumper block. This diptube carries condensate from the SME condenser. (refer to photographs WSRC-F-95-0044-25 through 27)
- A third diptube on jumper (10)16Y-16 was also reported failed, but was not examined by Materials Technology personnel. This diptube carries condensate from the GC sample cooler.

A failure analysis of the first two SMECT diptubes is documented in SRT-MTS-955223 ("SMECT Diptube Failure Analysis", Sept. 19, 1995, W. L. Daugherty). A fourth diptube in the SME had a hole worn through the side from repeated contact/impact against a nearby deflector plate. This diptube (jumper 501(12)-(11)17) is for frit addition.

Table IV. Summary of jumper inspections

Jumper Name	Jumper Number	Type of Inspection	Documentation
PRBT to SRAT feed	ASX(12.1TP)3	VT	95-IR-06-VT-1037, FA-04 Videotape #4, Photographs WSRC-F-95-0046-13 & -14
SRAT sample discharge	403(9.3SP)2	UT	95-IR-06-UT-0854
SRAT condenser to MWWT	(9.1C)3(10.2WT)3	VT UT	95-IR-06-VT-0853 95-IR-06-UT-0852 and 95-IR-06-UT-0849
SRAT condenser to FAVC	(9.1C)5-(10.7C)3	N/A	N/A - removed from process
SME sample discharge	403(11.3SP)2	UT	95-IR-06-UT-0867
PFSFT to SME	501(12)-(11)17	UT	95-IR-06-UT-0988
MFT sample discharge	404(7.3SP)2	UT	95-IR-06-UT-0883
OGCT sample discharge	403(6.4SP)2	UT	95-IR-06-UT-0993
CDC No. 1 jumper	357(23CD)11	VT UT	95-IR-06-VT-1065 95-IR-06-UT-1066
CDC No. 1 jumper	358(23CD)12	VT UT	95-IR-06-VT-1063 95-IR-06-UT-1067
CDC No. 1 jumper	359(23CD)13	VT UT	95-IR-06-VT-1064 95-IR-06-UT-1068

Discussion:

Jumper ASX(12.1TP)3 transfers solution from the PRBT to the SRAT. It contains a 7/16 inch diameter orifice to limit the rate of transfer. This orifice was examined due to the possibility of solids in the solution from the PRBT causing erosion. No evidence of erosion was noted - the diameter of the orifice was uniform, with no round-over of the visible edge. No corrosion was noted on the C-276 orifice plate, which has an estimated corrosion rate of less than 1 mil/yr (ref. WSRC-TR-95-0385). The condition of this jumper and orifice plate is documented by photographs (WSRC-F-95-0046-13 and -14) and videotape (to be stored with FA-04 test records).

In four of the jumpers, 2 or more thickness measurements were less than the minimum allowable thickness for new, straight pipe. Each of these measurements were taken at bends. The greatest decrease from nominal thickness was measured on the PFSFT to SME jumper, with a 0.120 inch minimum thickness. This jumper is constructed of 2 inch Schedule 40 pipe, which has a nominal thickness of 0.154 inch.

ASTM Standard B622 (invoked by piping code P213) identifies allowable variation in wall thickness for C-276 pipe, with a minimum allowable wall thickness of either 10 or 12.5% (depending on diameter) below the nominal thickness for the pipe sizes inspected. Code P213 provides zero allowance for erosion/corrosion in service. ASTM Standard A312 (invoked by piping codes P198 and P230) similarly applies to austenitic stainless steel pipe, and in turn invokes Standard A530 which has a minimum allowable wall thickness of 12.5% below the nominal thickness for the pipe sizes inspected. Codes P198 and P230 both provide zero allowance for erosion/corrosion in service. In addition, general requirements provided with the P Codes allow additional thinning of 10 to 18% at bends, depending on bend radius. Discussions between J. T. Gee (DWPF Engineering) and G. Rawls (E&CSD, and member of the Site Piping Committee) identified that current site practice increases this thinning allowance at bends up to 21% (for 3D bends).

All jumper thicknesses exceeded the allowable thickness after subtracting the additional 21% allowance for bends, and are considered technically acceptable. There is no indication that such wall thinning is related to service degradation (corrosion, erosion). It is noted that the true minimum wall thickness is that identified by analysis as necessary to account for design loads and in-service degradation (pressure, temperature, corrosion, etc.). This thickness can be much lower that the minimum specified by design practice as described above.

Since the dip tubes were not within the scope of the FA-04 test program, this information was provided to Operations. Repair of the damaged diptubes and evaluation of all the diptubes was covered under U-PMT-S-00665.

3.8 SRAT and SME Condensers - Reported by J. T. Gee

The interior of the SRAT and SME condensers (alloy C-276) were visually inspected using a video probe as documented in NDE inspection reports 95-IR-06-VT-0864 and 0850, respectively. Reports are located in the "FA-04 Materials Evaluation / Field Reports" document (WSRC-TR-96-0197).

Results and Conclusions:

Based on these inspections, there was little evidence of corrosion which would significantly impact the life expectancy of the equipment.

3.9 SRAT Ammonia Scrubber - Reported by J. T. Gee

The SRAT, SME and RCT/MFT ammonia scrubber vessels are essentially identical. All are fabricated from 316L stainless steel and recycle a dilute nitric acid solution from the SMECT. The SRAT ammonia scrubber was selected as typical of the three and inspected during the FA-04 test program. A remote visual inspection (i.e. video probe) was performed with entry into the vessel through an open nozzle. This inspection is documented in NDE inspection report 95-IR-06-VT-0997, and is contained in the "FA-04 Materials Evaluation / Field Reports" document (WSRC-TR-96-0197).

Results and Conclusions:

Inspection results indicated that all surfaces were clean and there was no evidence of erosion/corrosion, as would be expected for a stainless steel alloy for the given service conditions.

3.10 Melter Top Head and Off Gas Components - Reported by K. J. Imrich

The melter top head components were not considered under the FA-04 materials evaluation program. These components were inspected, however, and their predicted life expectancies are addressed in separate stand alone report authored by K. J. Imrich. This report, that also includes inspection results on melter off gas lines (part of FA-04 program) is contained in Appendix 5, and is entitled "Visual Examination of DWPF Melter Top Head and Off Gas Components."

3.11 Inspection of Off Gas System Downstream of Quencher

A decision was made to eliminate the planned inspections of the DWPF off gas system (i.e. SAS, HEME, HEPA, etc.) based on prior inspections at the IDMS facility at TNX. Field inspections and review of corrosion coupons removed from the IDMS off gas system demonstrated that corrosion in these components was not a concern. A report of these inspections authored by K. J. Imrich is contained in Appendix 6, and is entitled, "Remote Visual Inspection of IDMS Off Gas System."

3.12 CDC No. 1 and No. 2 Nozzle Racks - Reported by J. T. Gee

The Canister Decon Chamber (CDC) Nos. 1 and 2 spray nozzle racks were visually inspected after the cold chemical runs. Results are documented in NDE reports, 95-IR-06-VT-1058 & 1059 for racks 1 and 2 respectively. These reports are contained in the "FA-04 Materials Evaluation / Field Reports" document (WSRC-TR-96-0197).

Results and Conclusions:

The CDC No. 1 spray nozzle rack appeared to be in good condition. A photograph of the subject rack is provided in Figure 23a. Three of the seven boron carbide insert tubes that fit inside the frit feed nozzles (i.e. nozzles for blasting sides of canister) had small chips missing from the frit discharge end. This was thought to be from mechanical damage (e.g., installation, bumped by canisters, etc.) but did not appear severe enough to impact the life of the nozzle. All eleven of the rinse nozzles were in good condition. Portions of the 304L stainless steel (No. 1) ribbon nozzle showed significant erosion/corrosion. Figure 23b provides a photograph of the disassembled ribbon nozzle. Most of the attack appeared to be crevice or pitting corrosion. It is possible that it occurred as a result of frit being deposited on the stainless steel during cleaning operations, since portions of the stainless steel that should only see air had the noted localized corrosion.

Similar inspections of the No. 2 nozzle rack were performed. Both of the decon chambers had similar operating histories. The ribbon nozzle did not have significant crevice corrosion. Since the No. 2 ribbon nozzle is relatively clean, the noted corrosion on the No. 1 ribbon nozzle may have resulted from a one-time improper cleaning after use and may not be a major problem.

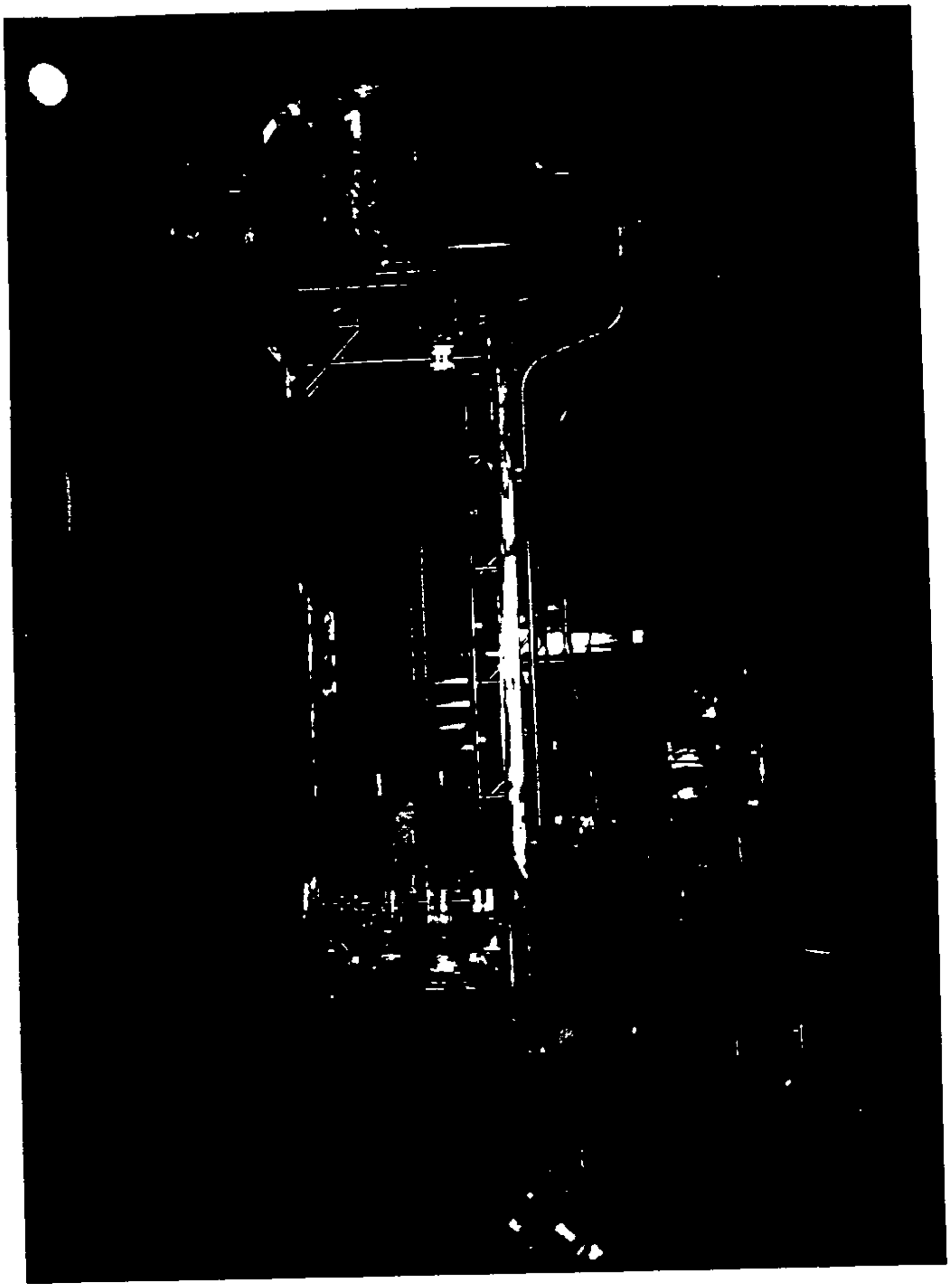


Figure 23a. Photograph providing an over view of CDC #1 Spray Nozzle Rack (WSRC-FM-96-307-9).

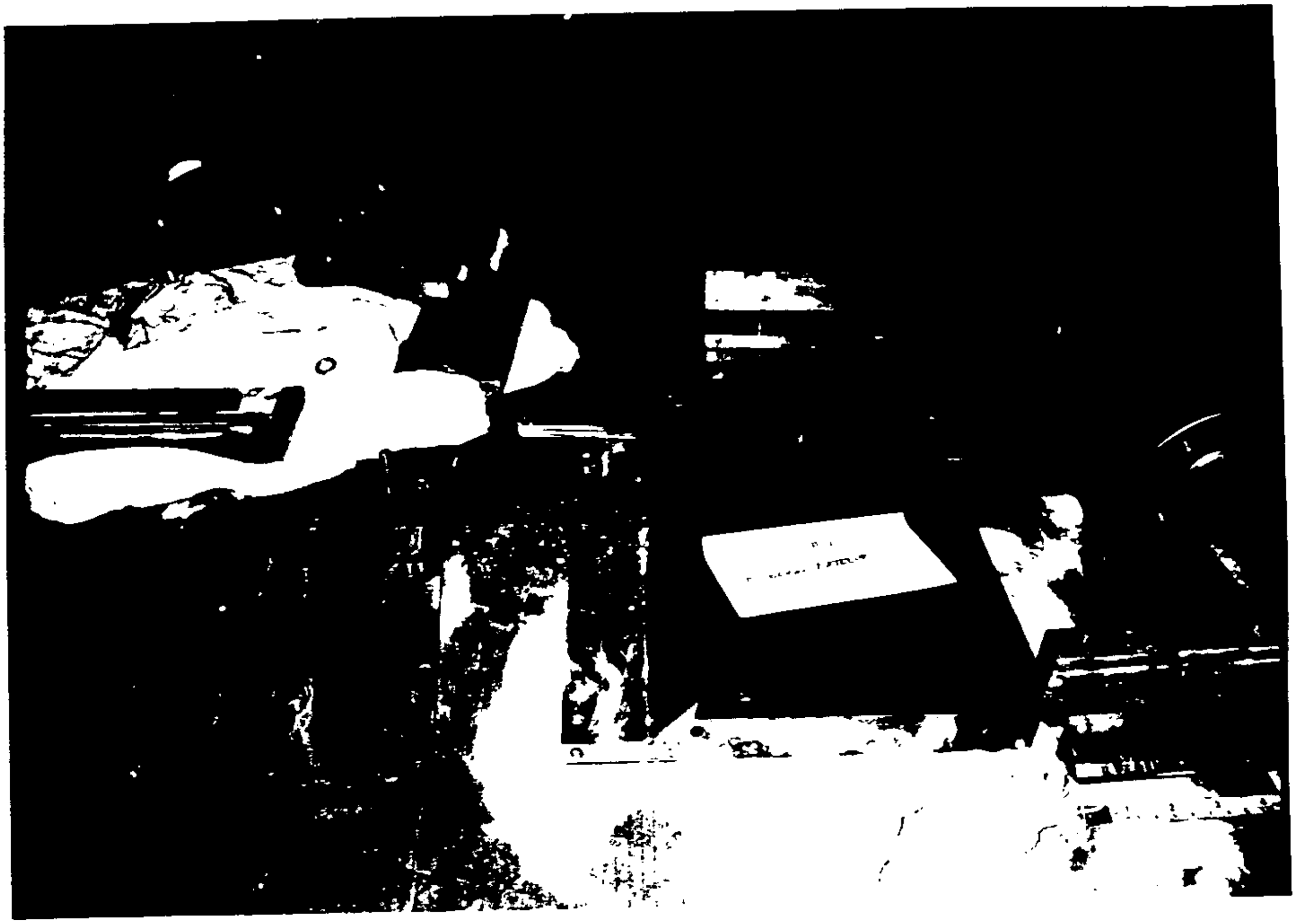


Figure 23b. Photograph of Disassembled CDC #1 Ribbon Nozzle. Note the evidence of localized corrosion on the stainless steel surfaces. (WSRC-FM-96-380-10)

3.13 Erosion/Corrosion of Permanent Sample Lines - Reported by J. T. Gee

Permanent sample lines running along the west side of the 221-S canyon to the analytical cell were designed to last the life of the DWPF facility. These lines are generally fabricated from alloy C-276, so general or localized corrosion would not be expected. However, the lines containing slurries with glass frit particles (i.e. SME and MFT) may be subject to erosion at weld protrusions, sharp bends or elbows where flow is obstructed. The lines, one-half inch diameter, schedule 40 pipe, were designed to reduce erosion by long radius bends and pipe sizing to reduce fluid velocity. The installed lines, however, contained many sharp bends where the piping runs were turned to enter nozzle boxes or the analytical cell.

A&IQ NDE performed inspections on the PR, SRAT, SME, MFT, and OGCT permanent sample lines using UT before and after cold chemical runs. All five sample lines were inspected under 95-IR-06-UT-0898, which is contained in the "FA-04 Materials Evaluation / Field Reports" document (WSRC-TR-96-0197).

A note of caution is provided concerning interpretation of UT data for small bore piping as was used for the sample lines. This was partially addressed in the summary Quality Control Condition Report for the CPC (AID-QCM-950127) which is provided in Appendix 2. Several factors could account for relative changes in UT data. The largest factor is that after the original baseline UT inspections were performed, the NDE group switched to a smaller and more accurate UT transducer. As noted in the referenced NDE summary report, a correction factor was calculated to account for the change in transducer. A second factor is the inability to exactly match the original UT reference mark. UT measurements are generally taken at four positions (i.e. 90, 180, 270, and 360 degrees) around the circumference of small bore piping. As the piping sections are bent to tight radii, a small change in location from the original UT reference mark can indicate a very significant change in wall thickness. This is due to the stretching and/or compression (i.e. wall thickness may increase or decrease) as the pipe is bent. Also, since different NDE inspectors were involved between the baseline and final UT inspections, it is possible that the noted angular reference marks were not perfectly matched. Thus, UT data on small bore piping should only be used for general trends.

The PR, SRAT, and OGCT sample lines are not expected to corrode, based on corrosion coupon testing results (discussed later). For this reason, UT trends on these lines can be used to compare against data collected on the SME and MFT sample lines where erosion may have occurred as a result of glass frit particles.

Another issue could account for apparent "thin" wall readings in the UT data. When pipe is bent, the wall will thin in some areas and get thicker in others as a result of stretching or compression of the material. Depending on the bend radius, current SRS practice allows up to 21% thinning of the pipe wall (i.e. 3D bends). In addition, ASME 31.3 allows up to 12.5% wall thickness reduction in as-procured schedule 40 pipe sections. Since the 12.5 and 21% wall thinning allowances are additive, based on SRS Piping

Committee clarification, apparently low UT measurements would be acceptable, particularly if they occurred at bends in piping sections.

Results and Conclusions:

Based on review of the UT data for the PR, SRAT, SME, MFT, and OGCT permanent sample lines, there was no discernible evidence of erosion/corrosion during the period of cold chemical runs. It was therefore concluded that the permanent sample lines should last the life of the DWPF facility.

3.14 Erosion/Corrosion in Analytical Cells

3.14.1 Remote Hydragard Sampler - Reported by G. T. Chandler

A Remote Hydragard Sampler system for the Slurry Mix Evaporator (SME) in the Analytical Cells was removed and examined for erosion/corrosion degradation in October 1995. The sampler had been in use for approximately 170 hours. The ball valve consists of a CF3M cast 316L stainless steel housing, a 316L stainless steel ball, and a Teflon seat. The piping components are constructed of 316L stainless steel. The sampler assembly is constructed of alloy C-276. Figure 24a shows an overall view of the sampler system.

Results and Conclusions:

The sampler ball valve and sampler needle valve were disassembled and visually inspected (Figures 24b and 24c). There were no signs of appreciable wear or corrosion in the ball valve or sample valve. Original machining marks were visible. No polished areas which might indicate abnormal wear were observed. Minimal scoring of the outside of the stainless steel ball was observed which is most likely due to a small amount of frit between the ball and the Teflon seat. These results are consistent with erosion testing performed by DWPT personnel on stainless steel valves in simulated feed slurry. The results of this testing indicated that the stainless steel valves withstand extended periods of simulated operation with an abrasive fluid without appreciable wear [3].

Slight mechanical damage was observed on the sample needle valve, however, the damage is located below the seat of the valve and is not expected to affect the valve performance. No localized corrosion was observed in the piping connections or mating surfaces. Staining was observed on the surfaces of the sample lifting mechanism below the sampler valve due to splatter from the sampling operation. No significant general or localized corrosion was observed on these surfaces. However, steps should be taken to minimize splatter and spills that occur during the sampling operation to minimize corrosion that may occur on the 304L stainless steel and alloy C-276 parts.

3.14.2 Analytical Shielded Cells - Reported by G. T. Chandler

The shielded cells of the DWPF Analytical Laboratory are constructed of type 304L stainless steel with a splash wall constructed of alloy C-276 (~ 2 feet in height) along the base of the cell walls. The exhaust ducts for the shielded cells are constructed of 12" diameter schedule 40 304L stainless steel surrounded by concrete. The exhaust duct openings are located at the bottom of the back wall of each cell. A picture of the bottom portion of one of the shielded cells is shown in Figure 25.

Corrosion of the cells and exhaust ducts are a concern due to the chemical operations that are performed in the cells. Pitting corrosion has been observed on the 304L stainless steel chemical hoods in the DWPF analytical laboratory due to contact with hydrochloric and nitric acid vapors [4]. Some of the major chemicals that are used in the analytical cells include: aqua regia (mixture of nitric and hydrochloric acid), hydrochloric acid, hydrofluoric acid, nitric acid, and sulfuric acid. 304L stainless steel does not have good corrosion resistance when in contact with these solutions or vapors from these solutions. Alloy C-276 has good corrosion resistance when exposed to these solutions.

Results and Conclusions:

A corrosion coupon study and video inspection was performed in the shielded cells during DWPF waste qualification runs to determine the effect of the analytical operations on the materials of construction. A video inspection was performed by SSQ personnel on approximately 10 feet of the exhaust ducts of DWPF Analytical cells #1 and #2 on January 7, 1994 and September 11, 1995. Both inspections revealed no indications of significant degradation of the 304L exhaust ducts. However, the second video inspection revealed that a small amount of dried sludge or process solution had entered the exhaust duct through the inlet located at the bottom of the back wall of cell #1. Steps should be taken to minimize the amount of chemicals or process solutions that are introduced into the exhaust ducts.

Corrosion coupons were used to determine a corrosion rate for the analytical cell materials of construction when exposed to exhaust fumes from normal chemical operations. Alloy C-276 and 304L coupons were placed in the analytical exhaust ducts directly behind the grating of each inlet on May 16, 1994. On September 11, 1995 the corrosion coupons were removed and examined in accordance with ASTM Standard G1 [5]. Typical chemical operations were performed during most of this time period that should be expected during normal operation of the DWPF.

Visual examinations and weight change determinations were performed on the coupons in accordance with ASTM Standard G1. The coupons were cleaned with soap and water after being removed from the cells. The examination of the corrosion coupons from the cells revealed no evidence of significant corrosion. Table V shows the weight losses of the corrosion coupons after 16 months of exposure in the exhaust ducts. As shown little or no weight loss was observed in all of the coupons studied.

There is concern that chemical fumes may condense further downstream in the duct work. However, the combined exhaust flows of the cells downstream should aid in diluting the concentration of fumes. In addition, DWPF Analytical personnel have developed procedures to minimize the exposure of fumes to the cell atmosphere during analytical tests.

3.14.3 Erosion of Hydragard Sample Inlet - Reported by J. T. Gee

In each sample loop, the sample required for analytical testing is pulled from a recirculating loop into the Hydragard Sampler. The sample entry point is similar to a needle valve restriction. SRTC personnel were concerned about erosion of the "sample inlet" where the liquid sample (i.e. containing glass frit) enters the Hydragard Sampler. Any significant wear at this critical inlet point as result of erosion could conceivably impact the characteristics of the material entering the sample line. It was feared that if this occurred the sample may not be truly representative of the tank contents. Since the chemical analysis of the process streams is very critical for ensuring glass chemistry, anything that impacted the reliability of the sample quality could not be tolerated.

The Hydragard sample inlet points for the SME and MFT sample loops were radiographed before (baseline) and after cold chemical runs to monitor degradation. Special precautions were used to ensure that the radiographs performed after cold chemical runs were shot as close as possible to the baseline radiographs.

Results and Conclusions:

Radiographs for the Hydragard sample inlet points (two comparisons for the SME and MFT sample inlet points) were evaluated by Mr. Jim Dickinson of A&IQ NDE. He is a level III radiography inspector and is considered a site expert in radiograph interpretation. It was his conclusion that there was no discernible differences between the two sets of radiographs and therefore no wear had occurred (Reference: Appendix 2, NDE "Quality Control Condition Report for CPC," AID-QCM-950-127).

Based on Mr. Dickinson's review of the noted radiographs, it was concluded that there was no evidence of erosion of the Hydragard sampler inlet points in the SME and MFT sample loops that would suggest degradation of sample quality as a result of wear.

REFERENCES

3. G. L. Gill and E. K. Hansen, "Results from the Erosion Test Stand - Erosion Characteristics of the Whitey Valve", WSRC-RP-94-305, March 21, 1994.
4. J. E. Marra, DWPF Materials Committee Meeting Minutes, SRT-MTS-92-3037, June 16, 1992.
5. American Society for Testing and Materials Designations G 1-90, 1994 Annual Book of ASTM Standards, Vol. 3.02.

Table V. Corrosion Coupon Data from DWPF Analytical Cell Exhaust Ducts after 16 Months of Exposure

ANALYTICAL CELL #1:

Coupon ID	Length (in.)	Width (in.)	Thickness (in.)	Center Hole Diameter (in.)	Upper Hole Diameter (in.)	Initial Weight (g)	Weight After Cleaning (g)	Weight Loss (g)
HC276W-01	1.9930	1.0060	0.1180	0.3740	0.1280	31.3259	31.3266	-0.0007
304L-11	2.0075	0.7670	0.1140	0.3725	X	20.5834	20.5835	-0.0001
304L-15	2.0135	0.7550	0.1135	0.3745	X	20.4193	20.4189	0.0004
HC276W-17	1.9950	1.0065	0.1185	0.3720	0.1210	31.7184	31.7183	0.0001

ANALYTICAL CELL #2:

Coupon ID	Length (in.)	Width (in.)	Thickness (in.)	Center Hole Diameter (in.)	Upper Hole Diameter (in.)	Initial Weight (g)	Weight After Cleaning (g)	Weight Loss (g)
HC276-05	1.9990	1.0085	0.1185	0.3735	0.1215	31.8354	31.8359	-0.0005
HC276-03	2.0000	1.0060	0.1170	0.3750	0.1210	31.4222	31.4220	0.0002
304L-18	2.0270	0.7625	0.1140	0.3745	X	20.6055	20.6059	-0.0004
304L-13	2.0125	0.7550	0.1125	0.3745	X	20.3531	20.3535	-0.0004

ANALYTICAL CELL #3 rack #1:

Coupon ID	Length (in.)	Width (in.)	Thickness (in.)	Center Hole Diameter (in.)	Upper Hole Diameter (in.)	Initial Weight (g)	Weight After Cleaning (g)	Weight Loss (g)
HC276W-02	1.9945	1.0090	0.1175	0.3725	0.1205	31.6521	31.6524	-0.0003
HC276W-19	2.0015	1.0025	0.1170	0.3740	0.1210	31.3301	31.3304	-0.0003
304L-12	2.0325	0.7660	0.1140	0.3745	X	20.9257	20.9262	-0.0005
304L-16	2.0210	0.7640	0.1140	0.3745	X	20.7530	20.7529	0.0001

ANALYTICAL CELL #3 rack #2:

Coupon ID	Length (in.)	Width (in.)	Thickness (in.)	Center Hole Diameter (in.)	Upper Hole Diameter (in.)	Initial Weight (g)	Weight After Cleaning (g)	Weight Loss (g)
HC276W-20	1.9975	1.0040	0.1200	0.3740	0.1200	32.0193	Not recoverd	-
HC276W-04	1.9980	1.0025	0.1165	0.3750	0.1215	31.5367	Not recoverd	-
304L-14	2.0145	0.7535	0.1150	0.3735	X	20.3561	Not recoverd	-
304L-17	2.0180	0.7635	0.1135	0.3785	X	20.6775	Not recoverd	-

ANALYTICAL CELL #4:

Coupon ID	Length (in.)	Width (in.)	Thickness (in.)	Center Hole Diameter (in.)	Upper Hole Diameter (in.)	Initial Weight (g)	Weight After Cleaning (g)	Weight Loss (g)
HC276W-16	2.0010	1.0050	0.1190	0.3780	0.1205	31.8877	31.8875	0.0002
HC276W-17	2.0010	1.0085	0.1180	0.3775	0.1295	31.8869	31.8869	0.0000
304L-8	2.0110	0.7750	0.1135	0.3725	X	20.5688	20.5687	0.0001
304L-10	2.0205	0.7590	0.1125	0.3785	X	20.5215	20.5216	-0.0001

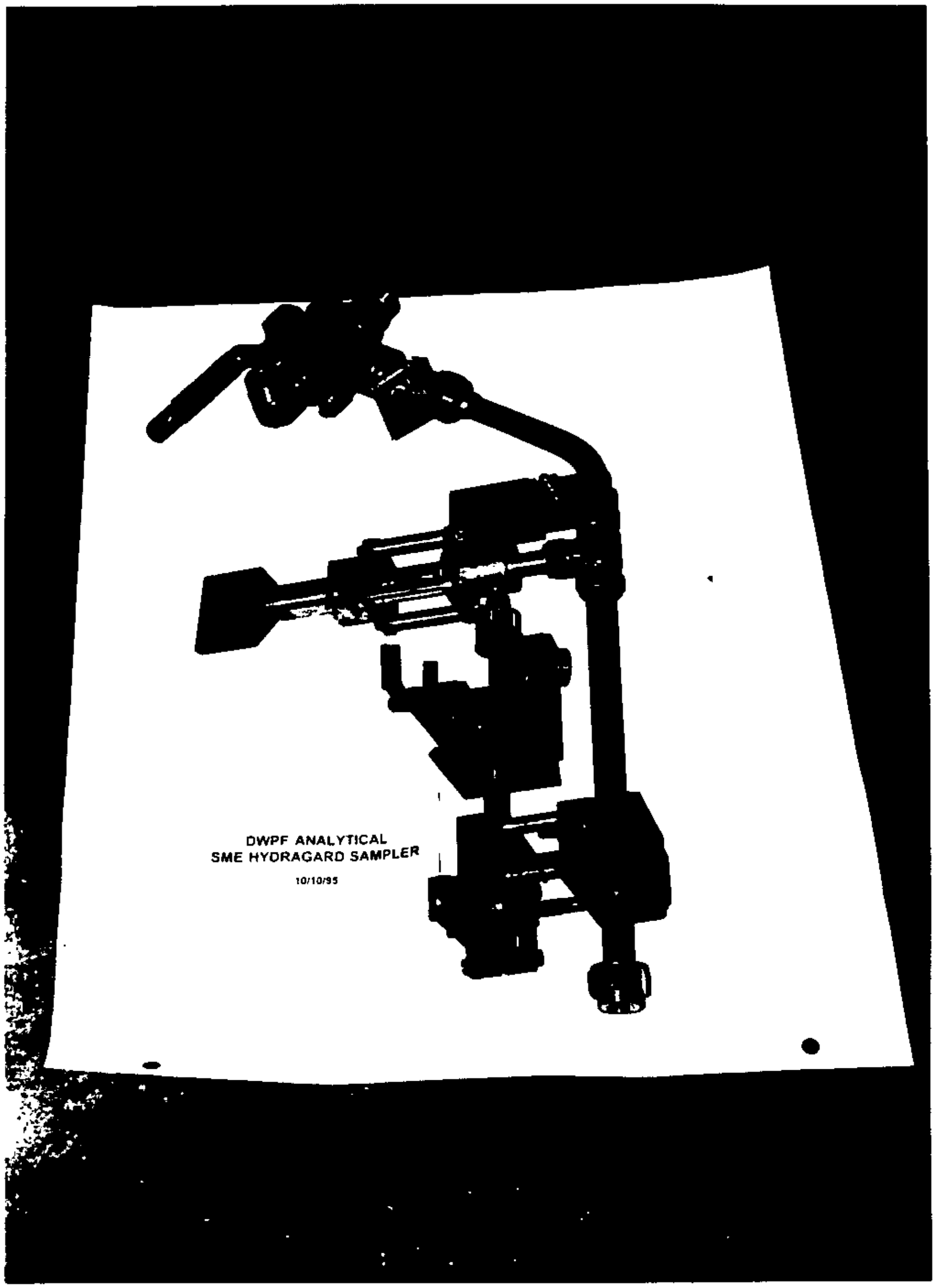


Figure 24a. Overall view of DWPF Analytical SME Hydragard Sampler (Negative # WSRC-FM-96-0067-47).

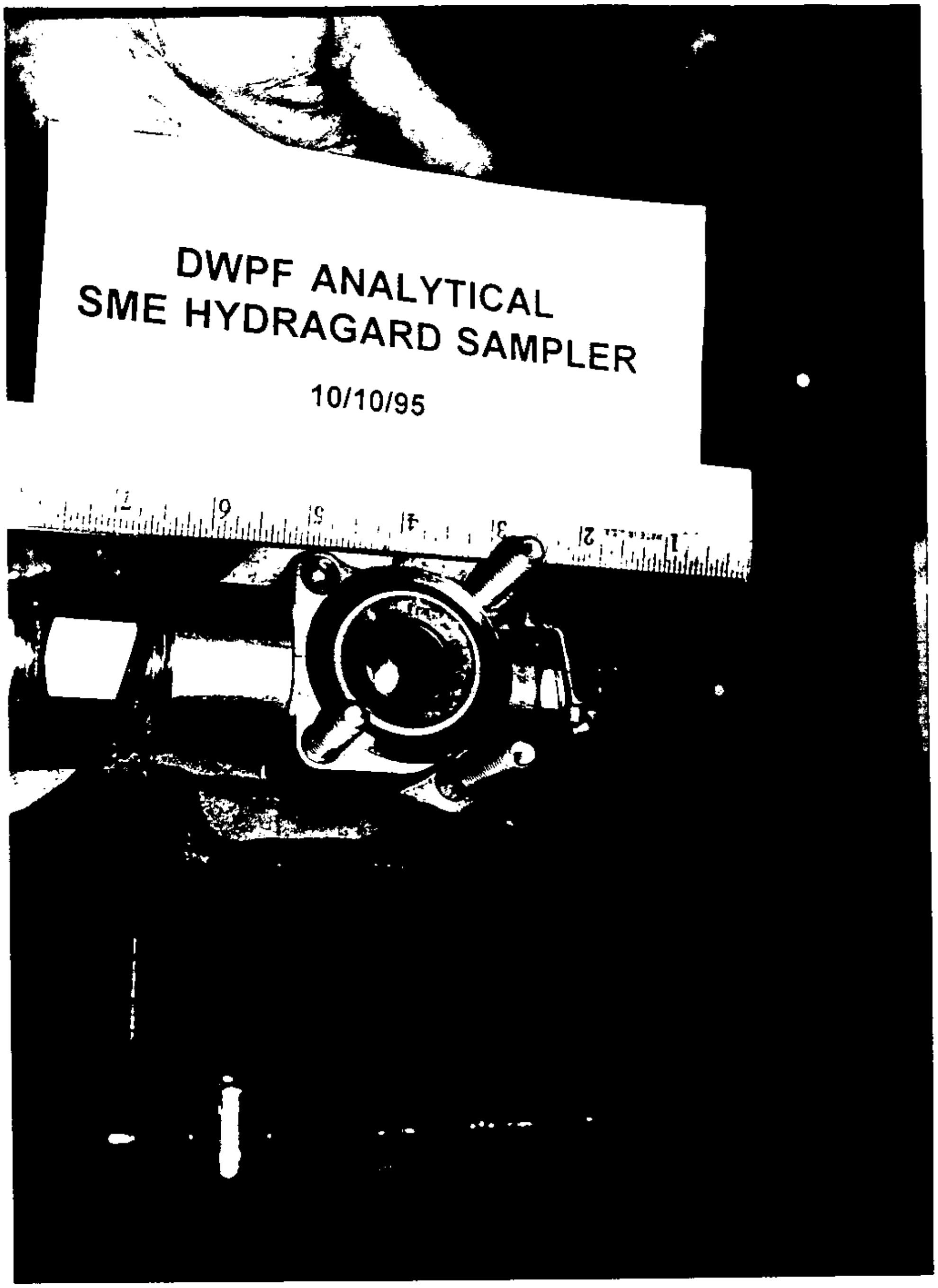


Figure 24b. Disassembled DWPF Analytical SME Hydragard Sampler Ball Valve (Negative # WSRC-FM-96-0067-24).

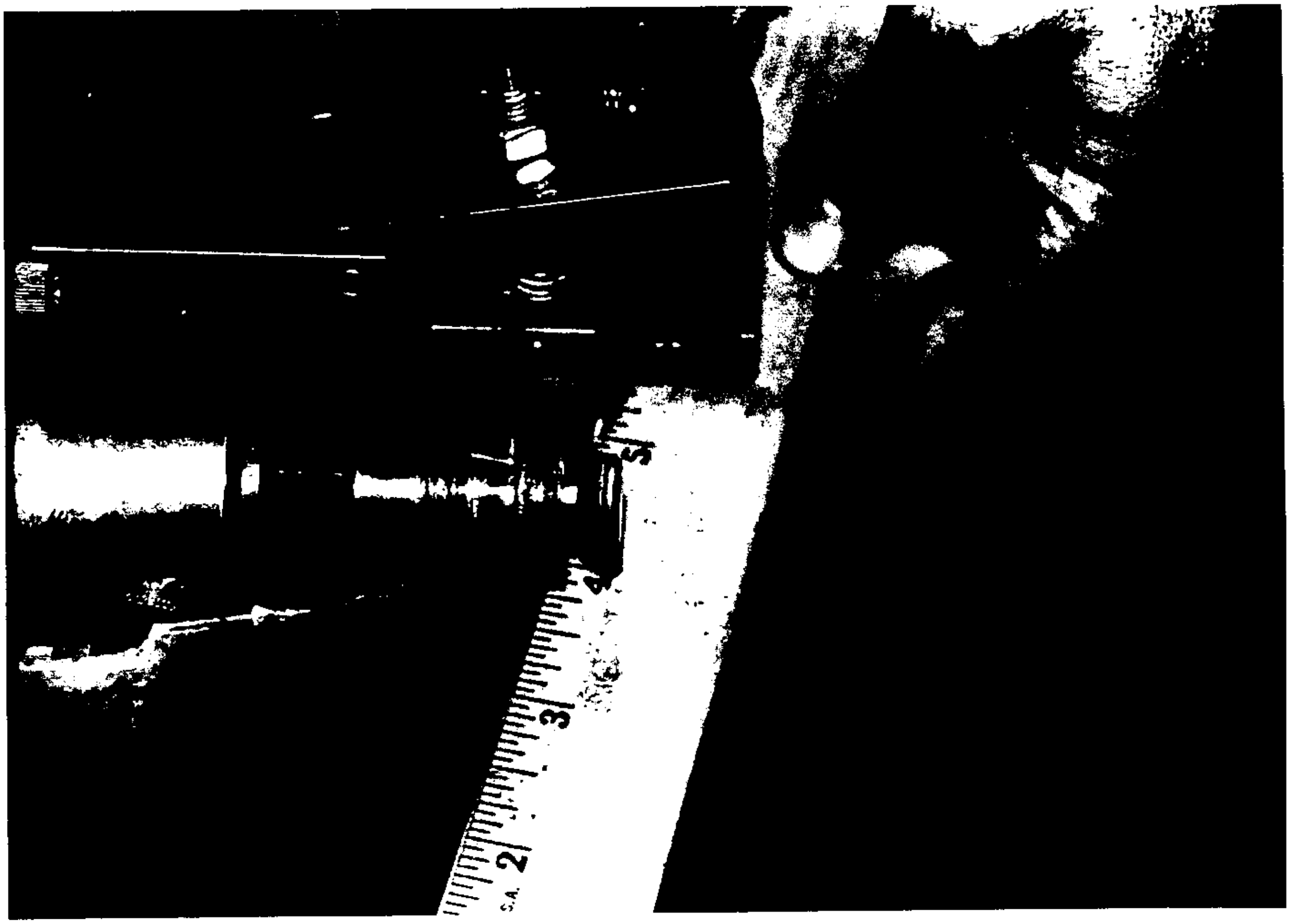


Figure 24c. Disassembled DWPF Analytical SME Hydragard Sampler Needle Valve (Negative # WSRC-FM-96-0067-27).

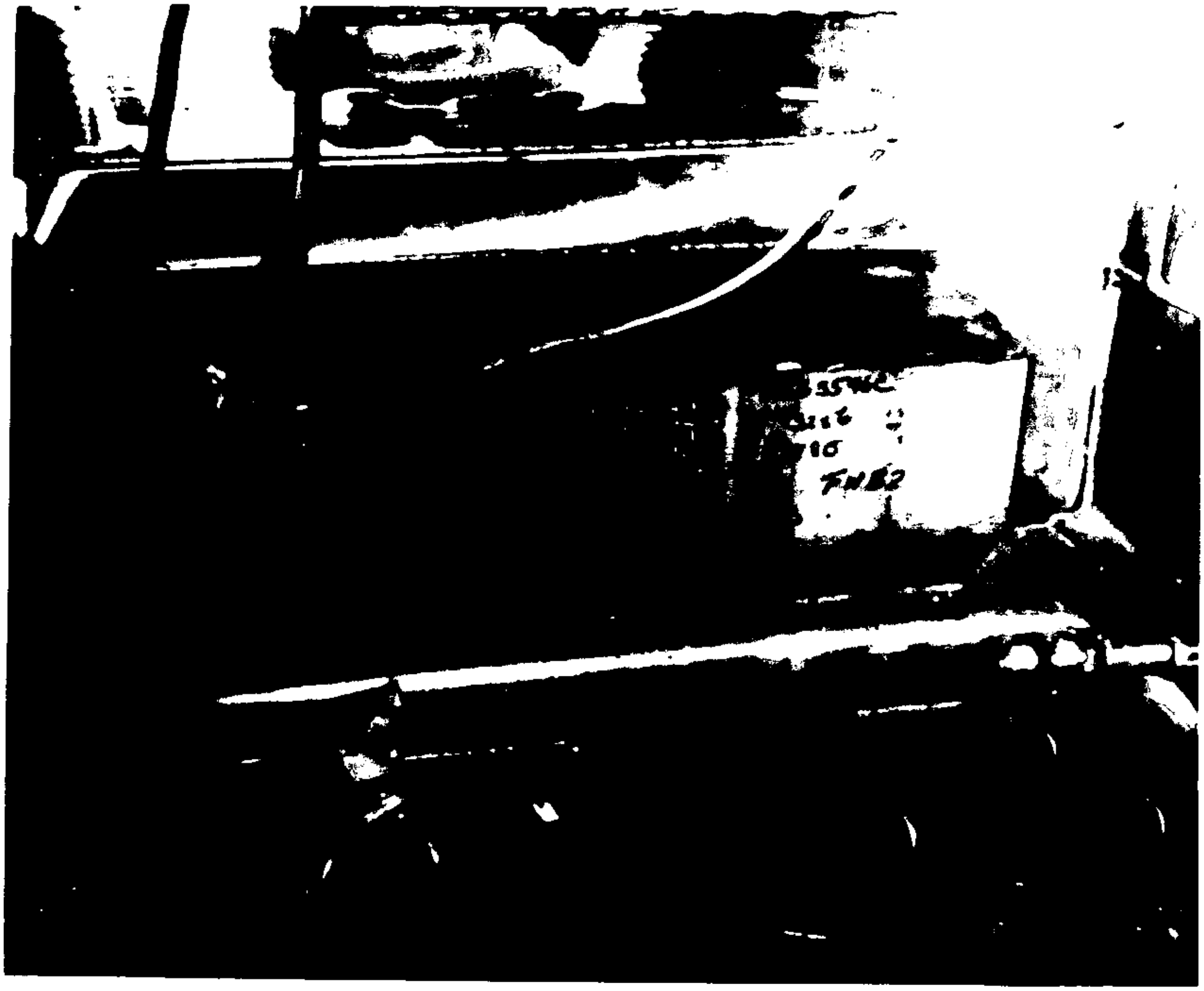


Figure 25. Picture of One of the Bottom Portions of the Shielded Cells.

3.15 Galvanic Couplings

3.15.1 General / Impact on Process Jumpers- Reported by W. L. Daugherty

Galvanic corrosion is the corrosive attack of one metal in electrical contact with a dissimilar metal in the presence of an electrolyte. The less noble of the two metals is preferentially attacked at a rate in proportion to the difference in electromotive force between the two metals. Since the electromotive force exhibited by a metal can vary depending on the solution it is in, galvanic corrosion is also dependent on the environmental conditions. In DWPF, a number of galvanic couples exist between Hastelloy C-276 and 304/316 stainless steel. The Metals Handbook (9th Ed., ASM, 1987, Vol 13, p. 235) gives the galvanic series for a number of alloys in seawater. In this series, Hastelloy C (similar to C-276) has a potential approximately 0.1 volts higher (more noble) than passivated 304/316 stainless steel. (If not passivated, the stainless steel potential drops to 0.4 - 0.5 volts below that of Hastelloy C.)

The following locations are typical of galvanic couples in the SPC and CPC.

- The jumper carrying slurry from the PRFT to the PR is 304L, while the PR and PRFT are both C-276.
- Vent lines from the PRCD, OECD, PRFT and OECT are 304L, while these tanks are C-276.
- Process water and steam lines are 304L, while the coils in the various tanks they attach to are C-276.
- Condensate from the MWWT is transferred to the C-276 SRAT in a 304L jumper.
- Various jumpers between the SMECT and other tanks involve 316L / C-276 couples.

In each of these areas, the chemistry is relatively mild (i.e. neither the stainless steel nor C-276 should experience significant corrosion rates.

A number of corrosion tests were performed on candidate materials for DWPF vessels by the DuPont Engineering Test Center (OPS-WMQ-89-0059, "DWPF Corrosion Report", M. K. Carlson, June 1989). Tests in one solution included galvanic couples between C-276 and 304L stainless steel, as well as tests on 304L coupons. These tests give a direct comparison to show whether being coupled to C-276 resulted in an increased corrosion rate of 304L (i.e. whether any galvanic corrosion occurred). These data are summarized in the following table.

Table VI. Summary of galvanic corrosion data

Test Solution 3B-2 (off-gas condensate)	Temp. (°C)	Test Coupon	Corrosion Test Results *
0.25 wt% Cl^-, 0.03 wt% F^-, 0.003 wt% I^-, 0.08 wt% $SO4^{-2}$, 0.1 wt% $NO3^-$, 0.1 wt% Hg (pH = 2.2)	90	304L with weld bead	11 mpy
	60	304L with weld bead	22 mpy
	40	304L with weld bead	11 mpy
	90	304L / C-276 couple	21 - 32 mpy

* mpy - mil/year general corrosion rate. All of these corrosion coupons experienced pitting, weld metal attack, end grain attack, and non-uniform general corrosion. In addition, the galvanic couple experienced crevice corrosion.

Results and Conclusions:

In the Table VI data, the corrosion rates are somewhat higher for the galvanic couple than for the 304L coupons. However, the fluctuation in corrosion rate with temperature for the 304L coupons suggests some variability in the data. The galvanic couples listed above in the SPC and CPC are exposed to process streams less aggressive than that listed in Table VI. The Cl^-, F^-, $SO4^{-2}$ and Hg concentrations of test solution 3B-2 are all conservative compared to those contacting the galvanic couples. The magnitude of 304L corrosion rates reported for test solution 3B-2 indicates the protective oxide layer has been removed. In contrast, corrosion data for 304L in less aggressive solutions (such as ETC solution 3C-1 representing the OECT chemistry) shows much lower corrosion rates (~0.1 mil/yr) [WSRC-TR-95-0385, "Evaluation of Potential for Materials Degradation of DWPF Safety Class and Safety Significant Components", W. L. Daugherty, Sept. 1995, Appendix 7] and indicates the protective oxide layer remains intact. Therefore, in more realistic solution chemistries, the oxide layer remains intact, and the electromotive force is about 0.1 volt (in favor of C-276) rather than about 0.4 - 0.5 volt. Therefore, a galvanic effect of the magnitude observed in test solution 3B-2 is not expected in the galvanic couples in the SPC and CPC.

Based on the above data, galvanic corrosion is not considered significant for the C-276 / 304L and C-276 / 316L couples in the SPC and CPC. It is also noted that some of the galvanic couples are further protected by isolation from the process chemistry (for example, the steam coils transition from 304L to C-276 outside the process tanks). Bounding corrosion rates developed for the SPC and CPC tanks in WSRC-TR-95-0385 were generally < 1 mil per year. The presence of galvanic couples should not significantly affect this bounding corrosion rate.

3.15.2 Analytical Sample Cells Galvanic Couplings - Reported by J. T. Gee

As noted in discussions on permanent sample lines, most of the sample lines going to the analytical sample cell are fabricated from a nickel based C-276 alloy. As these lines enter the analytical sample cell, the piping is changed to 304L stainless steel. Since this combination of alloys creates a galvanic couple as was discussed in section 3.15.1, there was some concern about this interface for each of the liquid sample stations. If corrosion did occur, it would be in the form of localized corrosion in areas where the protective oxide layer was removed from the stainless steel. To determine if this had occurred, A&IQ NDE performed UT testing on the respective interfaces for the PR, SRAT, SME and OGCT lines (i.e. two lines at each station for sample and return). The UT test results are documented in NDE inspection report 95-IR-06-UT-1049, which is contained in "FA-04 Materials Evaluation / Field Reports" (WSRC-TR-96-0197).

Results and Conclusions:

None of the galvanic couple interfaces examined showed evidence of significant localized corrosion over the period of cold run testing. This data suggests that given the process chemistry (Table VII) experienced in cold run testing, the stainless steel alloy will remain passive (i.e. protective oxide layer) and not corrode.

CHEMICAL PARAMETER	DWPF PROCESS STREAMS - RANGE OF TESTED CHEMICAL COMPOSITIONS							
	PR FEED	PR PRODUCT	SLUDGE RECEIPT	SRAT PRODUCT	SMECT OUTPUT	SME PRODUCT	MFT PRODUCT	OGCT OUTPUT
pH	8.3-9.4	3.0-7.0	6.7-10.4	4.5-9.4	1.8-1.9	4.4-8.6	3.8-7.4	1.6-6.5
NO3- (ppm)	N/A	100-1000	100-940	160-530	100-320	180-480	250-400	<200
NO2- (ppm)	350-400	10-100	100-1000	100-900	<100	<245	N/A	<100
SO4-- (ppm)	120-180	10-120	700-1000	100-1000	<100	100-900	100-1000	<100
COOH- (ppm)	N/A	N/A	300-800	130-370	N/A	200-500	210-440	N/A
Cl- (ppm)	120-150	10-110	100-700	100-730	<100	100-1000	100-1000	<120

Table VII - Range of DWPF Process Chemistry Experienced During Cold Chemical Runs

3.16 Evaluation of Corrosion Coupon Racks - Reported by G. T. Chandler

SUMMARY

Corrosion coupons were examined after approximately 12 months of exposure during waste qualification and mercury runs in the Defense Waste Processing Facility (DWPF) Precipitate Reactor (PR) Tank, Sludge Receipt and Adjustment Tank (SRAT), and Off Gas Condensate Tank. The corrosion coupon racks contained coupons of alloy C-276, the material of construction for the major feed processing vessels, and various candidate replacement materials, such as, Hastelloy C-22, Hastelloy G-30, Inconnel 625, and Stellite 6. Flat (autogenously welded and unwelded) with crevice washers, galvanically coupled, and U-bend coupons were examined from the liquid and vapor space regions of each tank. No significant general corrosion, localized corrosion, or stress corrosion cracking was observed in any of the coupons. These results are consistent with results obtained from the examination of corrosion coupons from the Integrated DWPF Melter System (IDMS).

BACKGROUND

The major process vessels for the DWPF are constructed of a nickel base alloy, Hastelloy C-276. This alloy was selected based on corrosion studies performed by Bickford, et al. in 1984 [6]. AISI Type 304L and 316L stainless steel and Alloy 20 were determined to be unacceptable for processing solutions derived from sludge due to the combined effects of elevated temperatures and concentration of corrosive species such as halides and mercury.

A corrosion coupon evaluation program was performed in the DWPF to provide additional information on the suitability of the materials of construction and various candidate alternative materials for the process vessels. Corrosion coupon racks were fabricated by Metal Samples, Inc. and installed in the vapor and liquid regions of three selected DWPF feed process tanks: the Precipitate Reactor (PR) Tank, the Sludge Receipt and Adjustment Tank (SRAT), and the Off Gas Condensate Tank (OGCT). Flat (autogenously welded and unwelded) with Teflon crevice washers, galvanically coupled, and U-bend coupons were used. A picture of the coupon rack taken from the SRAT vapor space is shown in Figure 26. The coupon racks were attached to the dip tubes of the sample pumps in the various tanks. Table VIII shows the heat analyses of the materials tested in this program.

The corrosion coupons were examined in accordance with ASTM Standard G1 [7]. Weight and dimensional measurements were performed on the corrosion coupons prior to placement in the various tanks. The corrosion coupons were exposed to simulated process solutions for a cumulative operating time of approximately 12-18 months during the DWPF waste qualification, and mercury runs from 1994 to Fall of 1995. Compositions of process solutions for the various tanks during these runs are presented in Table VII. As part of this investigation all coupons were photographed before and after cleaning. In most cases the use of a soft brush with light pressure and mild soap mixed with domestic water was sufficient to remove any deposits. Coupon evaluation included visual and microscopic examinations and weight and dimensional change measurements. Visual and microscopic examinations of the coupons included inspection of the faces and edges of the coupons, areas beneath crevice washers, fusion and heat affected zones of welded samples, and high stress areas of U-bend samples.

Corrosion rates were determined from weight change measurements according to ASTM Standard G1 and are based on a minimum exposure of 12 months. The following equation was used to determine the corrosion rate:

$$\text{Corrosion rate} = (K \times W) / (A \times T \times D)$$

where: K = constant (8.76×10^7 for micrometers per year (µm/y) or 3.45×10^6 for mils per year (mpy))
T = time of exposure in hours
A = area in cm^2
W = mass loss in g
D = density in g/cm^3 (from ASTM G1)

VISUAL OBSERVATIONS AND TEST RESULTS

Precipitate Reactor (PR) Tank

Both vapor and liquid space coupons were covered with a thin brown layer after being removed from the PR vessel after approximately 12-18 months cumulative exposure. The layer was easily removed from most of the coupons during cleaning, however, a heavy stain remained on some of the coupons from the liquid region. A picture of the PR tank coupons after cleaning is shown in Figures 27a and 27b. The examination of the corrosion coupons from the PR tank revealed no evidence of significant general corrosion, localized corrosion, galvanic corrosion, or stress corrosion cracking. The weight losses and corrosion rates based on 12 months of exposure for the PR tank coupons in the vapor and liquid space are shown in Tables IX and X. The maximum corrosion rate measured for the material of construction for the PR tank, alloy C-276, is 0.6 micrometers per year (µm/y) or 0.02 mils per year (mpy) in the liquid region of the tank. The corrosion rates for alloy C-276 in the vapor region were < 0.2 µm/y (< 0.01 mpy). The alternate materials had similar corrosion rates in the vapor region and had slight weight gains in the liquid region due to staining.

Sludge Receipt and Adjustment Tank (SRAT)

Both vapor and liquid region coupons were covered with a thin brown layer of dried sludge after being removed from the SRAT on 9/8/95 after approximately 12-18 months process exposure. The layer was easily removed from the liquid space coupons during cleaning, however, a stain remained on the vapor space coupons after cleaning. A picture of the SRAT coupons before cleaning is shown in Figures 28a and 28b. The examination of the corrosion coupons from the SRAT revealed no evidence of significant general corrosion, localized corrosion, galvanic corrosion, or stress corrosion cracking. The weight losses and corrosion rates based on 12 months of exposure for the SRAT coupons in the vapor and liquid space are shown in Tables XI and XII. The maximum measured corrosion rate for the SRAT material of construction, alloy C-276, exposed to liquid was 0.4 μm/y (0.02 mpy). The alternate materials had similar corrosion rates in the liquid region. Slight weight gains were measured for all coupons exposed to the vapor region of the SRAT.

Off Gas Condensate Tank (OGCT)

The corrosion coupons were removed from the OGCT on 10/23/95 after approximately 12-18 months of process exposure. The liquid space coupons were covered with a thin brown layer which was easily removed during cleaning. Most of the vapor space coupons did not have a coating after being removed and required very little cleaning. A picture of the OGCT coupons after cleaning is shown in Figures.29a and 29b. The examination of the corrosion coupons from the OGCT revealed no evidence of significant general corrosion, localized corrosion, galvanic corrosion, or stress corrosion cracking. The weight losses and corrosion rates based on 12 months of exposure for the OGCT coupons in the vapor and liquid space are shown in Tables XIII and XIV. The maximum measured corrosion rate for the OGCT material of construction, alloy C-276, exposed to vapor was 0.04 μm/y (0.002 mpy). Slight weight gains were observed in coupons from the liquid region. The alternate materials had similar corrosion rates in both liquid and vapor regions.

DISCUSSION AND CONCLUSIONS

Based on the results of the DWPF corrosion coupon study, the material of construction for the major process vessels, alloy C-276, is expected to perform satisfactorily. Similar results were obtained during the examination of corrosion coupons removed from the Integrated DWPF Melter System (IDMS) [8]. Very little degradation was observed in alloy C-276 and alternate materials in the vapor and liquid regions of the IDMS Sludge Receipt and Adjustment Tank / Slurry Mix Evaporator (SRAT/SME), the Mercury Water Wash Tank (MWWT), the Melter Feed Tank (MFT), the Off Gas Condensate Tank (OGCT) after exposure to simulated waste solutions from 1989-1993 (represents approximately 4 months of process exposure).

No significant increase in corrosion was observed in alloy C-276 or Stellite-6 due to galvanic coupling in the coupon study of the DWPF PR or SRAT. Therefore, galvanic corrosion should not be a concern with Stellite coated alloy C-276 agitator blades in the major process vessels. This result is consistent with galvanic corrosion studies performed on alloy C-276 and Stellite-6B in simulated high level waste sludge at 95 °C [9].

REFERENCES

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7. American Society for Testing and Materials Designations G 1-90, 1994 Annual Book of ASTM Standards, Vol. 3.02.
8. K. J. Imrich and C. F. Jenkins, "Final Examination of IDMS Corrosion Coupons", WSRC-TR-93-461, September 16, 1993.
9. B. K. Sides, "Galvanic Corrosion Susceptibility of Hastelloy C-276 and Stellite 6B in a Simulated Sludge Environment", SRT-MTS-95-2015, February 23, 1995.

Figure 26. Corrosion coupon rack from the SRAT vapor space.
(Negative # WSRC-FM-96-0067-15)

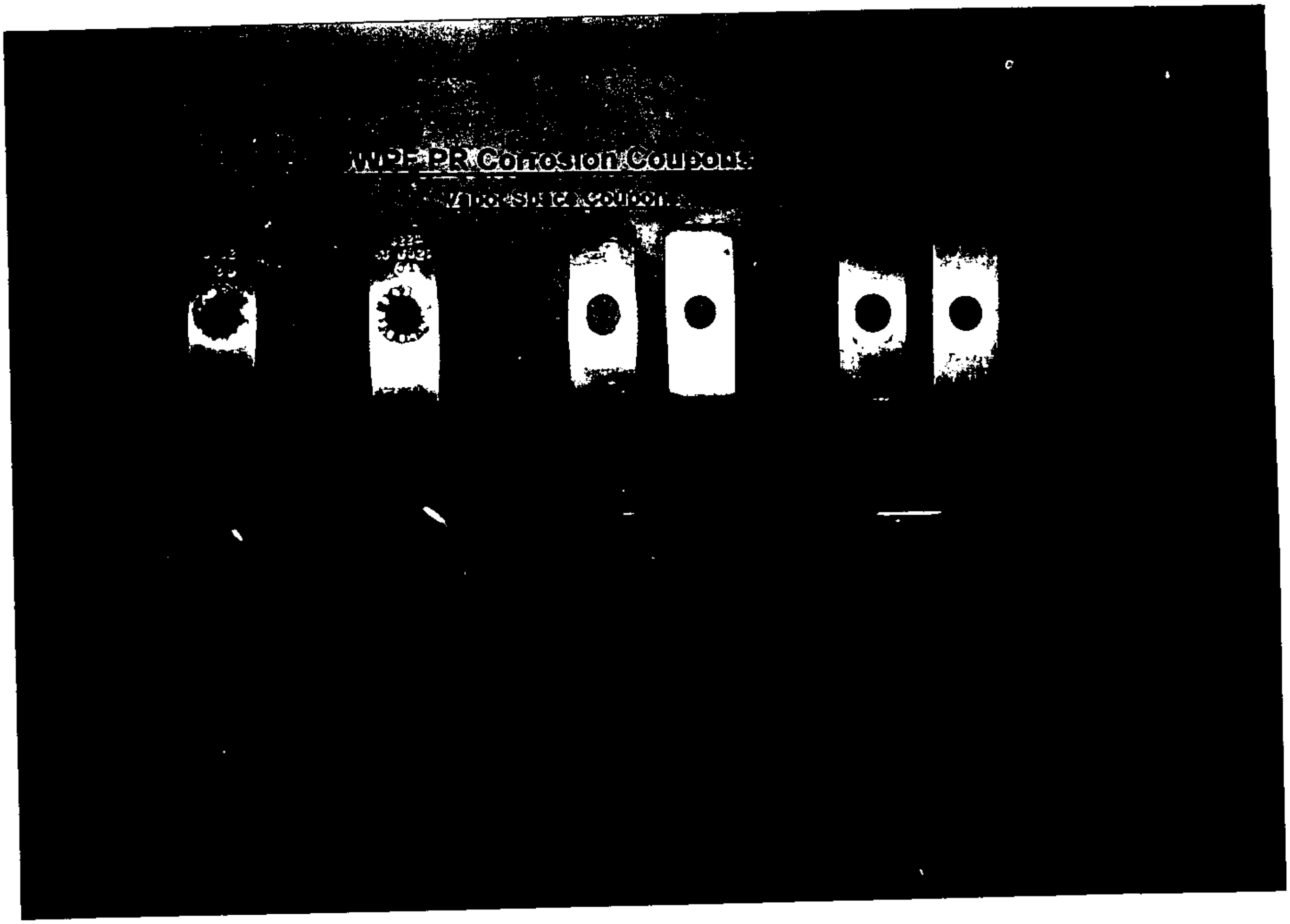


Figure 27a. PR tank vapor space corrosion coupons after cleaning.
(Negative # WSRC-FM-96-303-7)

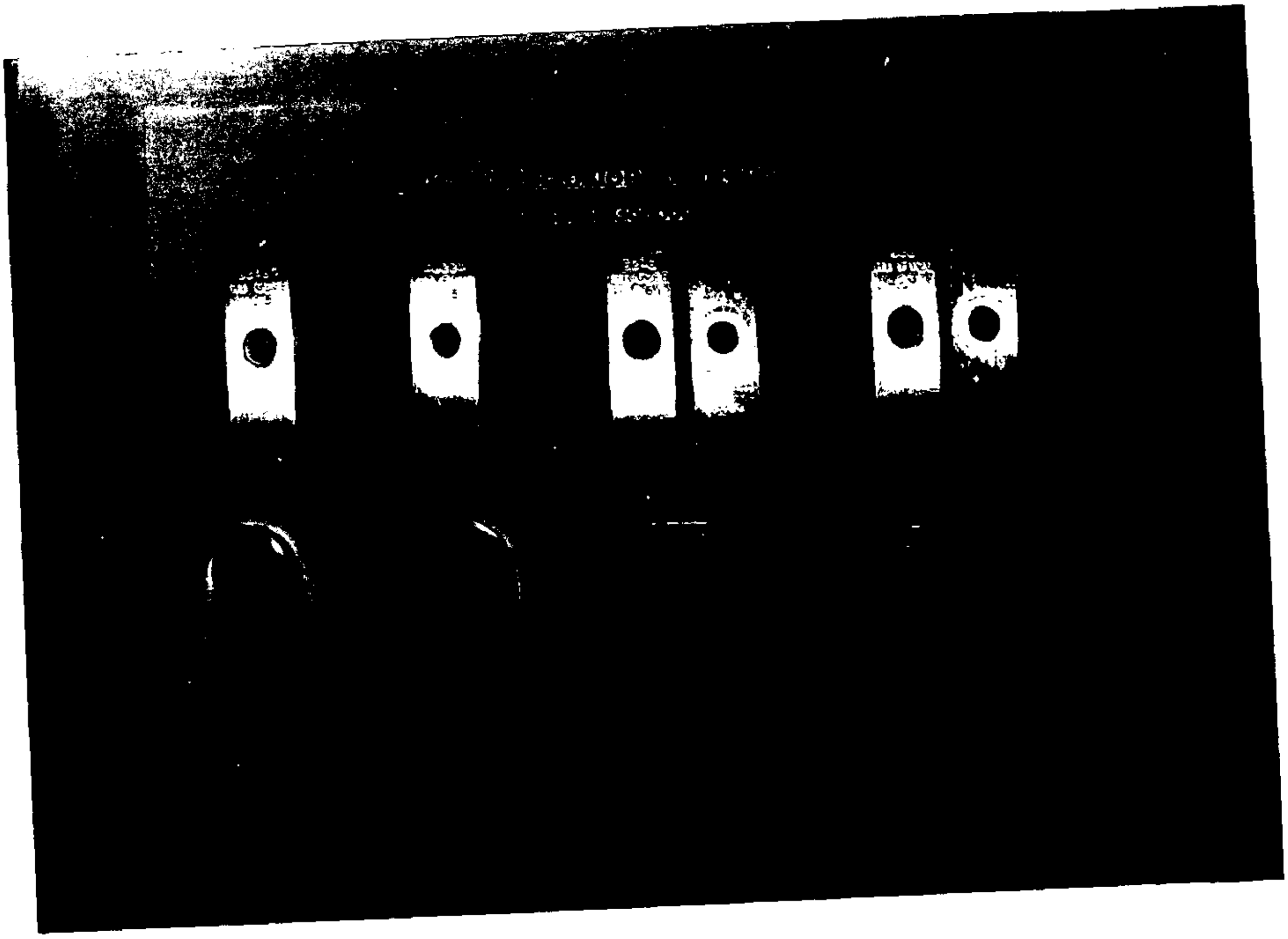


Figure 27b. PR tank liquid space corrosion coupons after cleaning.
(Negative # WSRC-FM-96-0303-26)

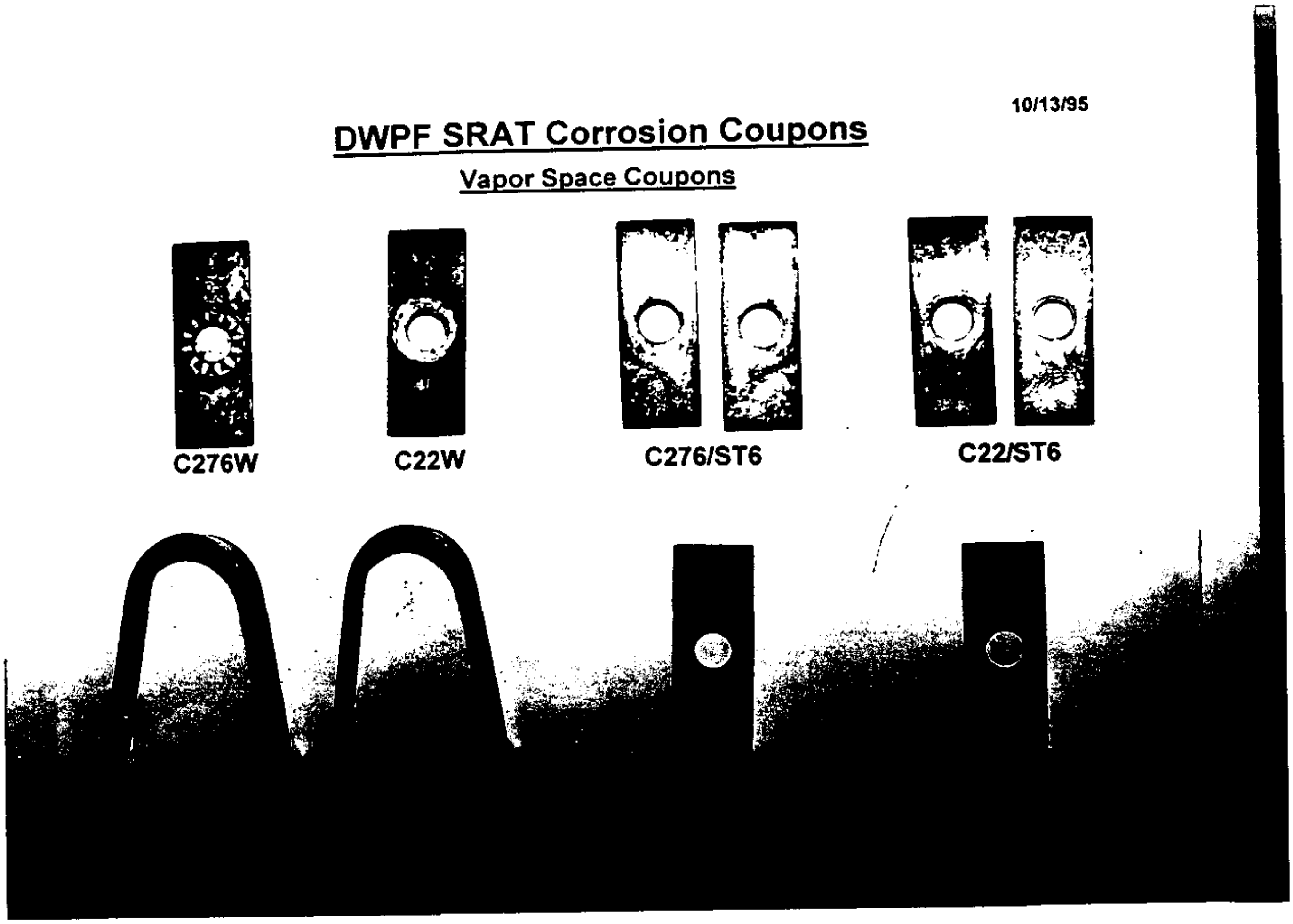


Figure 28a. SRAT vapor space corrosion coupons before cleaning.
(Negative # WSRC-FM-96-0067-04)

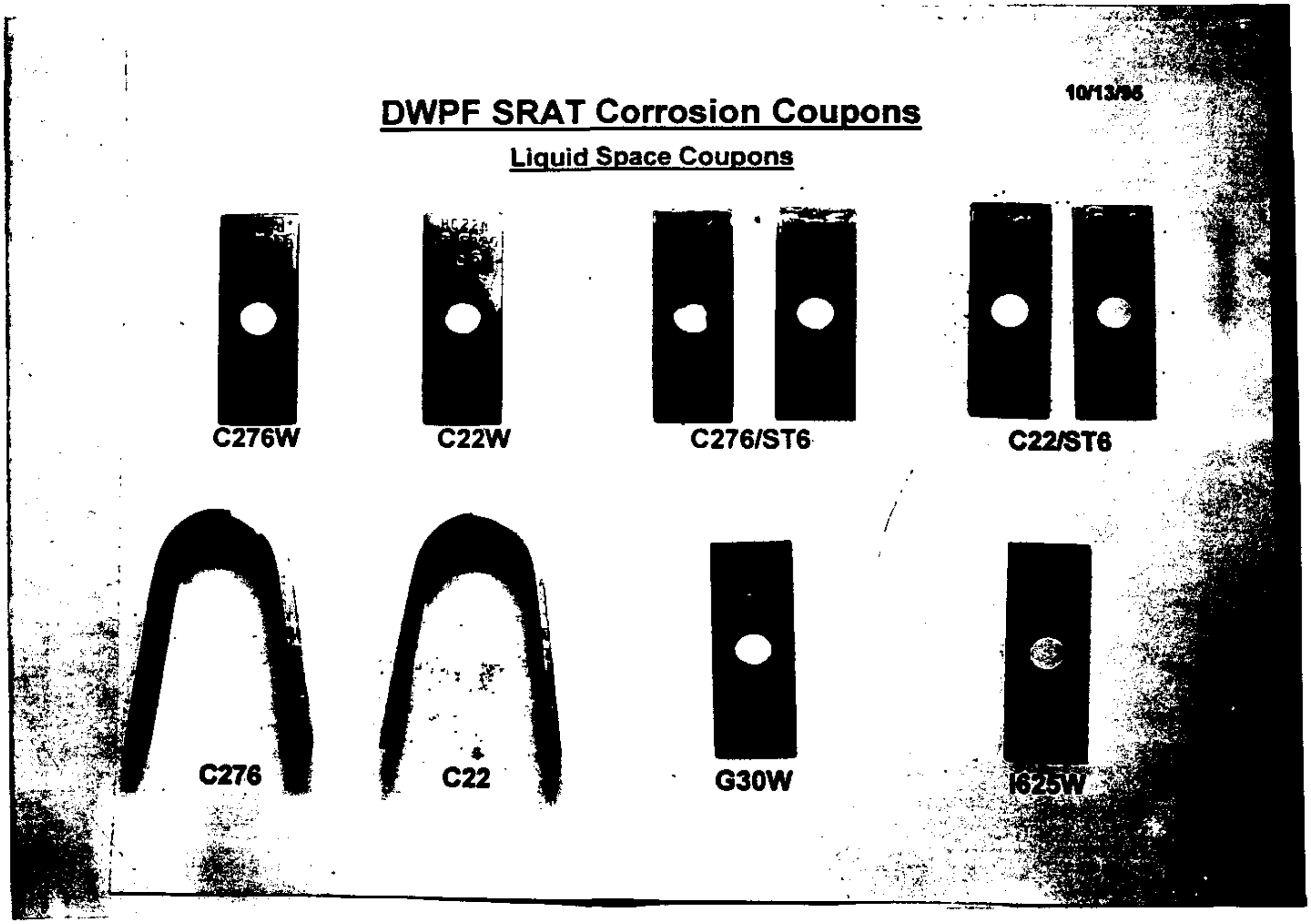


Figure 28b. SRAT liquid space corrosion coupons after cleaning.
(Negative # WSRC-FM-96-0067-07)

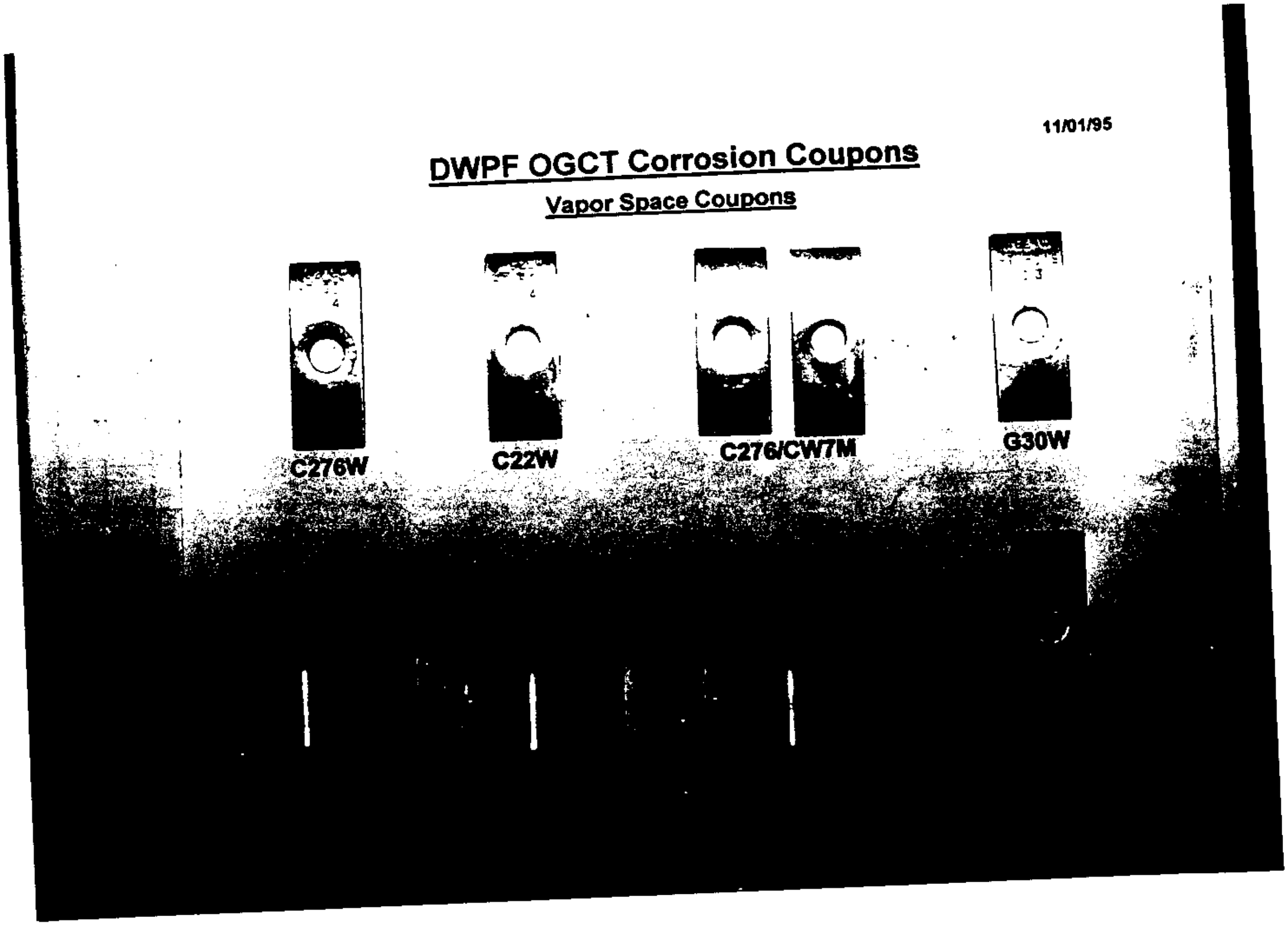


Figure 29a. OGCT vapor space corrosion coupons after cleaning.
(Negative # WSRC-FM-96-372-11)

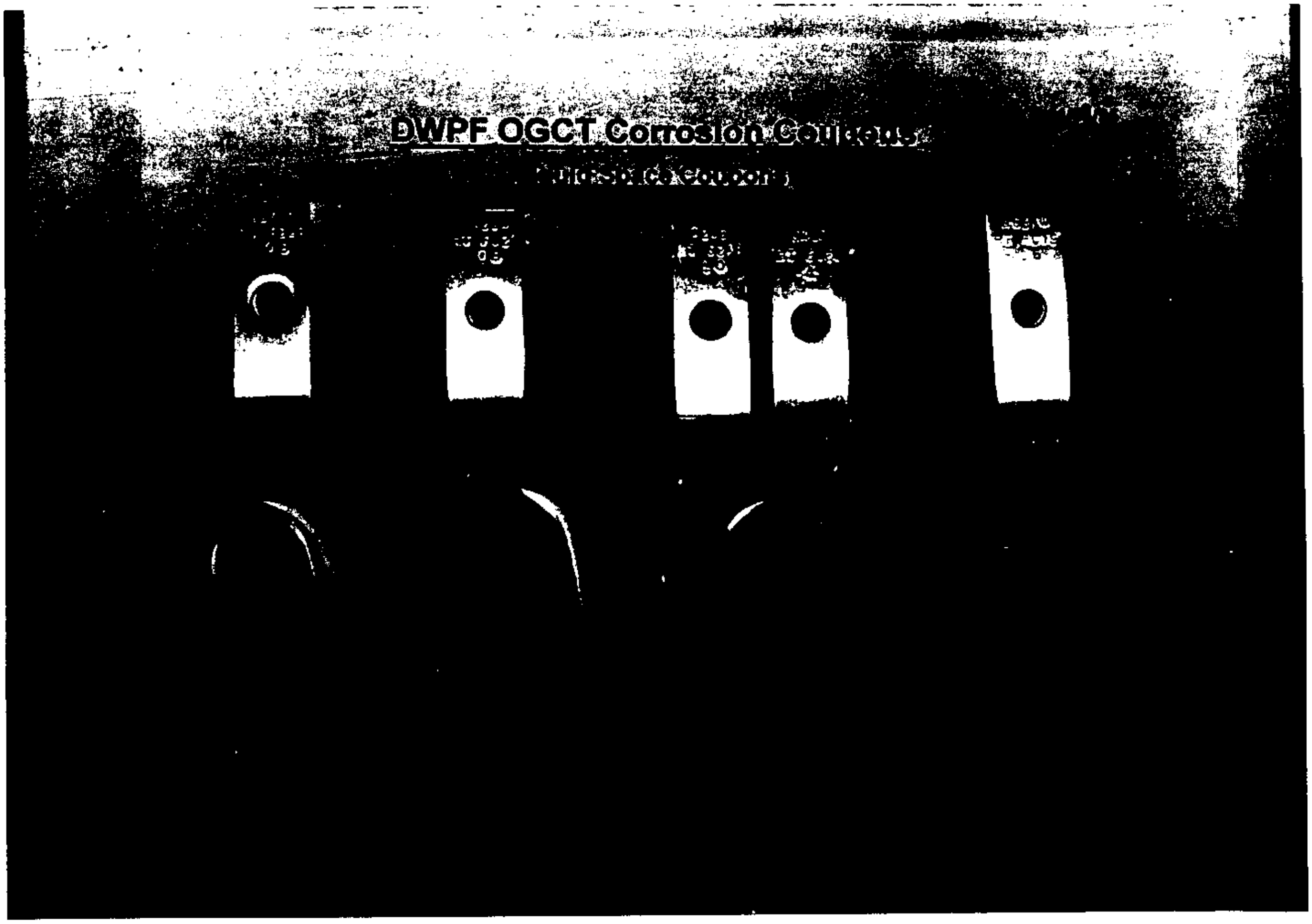


Figure 29b. OGCT liquid space corrosion coupons after cleaning.
(Negative # WSRC-FM-96-372-16)

KEY TO TABLES

HT	Heat number
C276 or HC276	Hastelloy alloy C-276
C22 or HC22	Hastelloy alloy C-22
CW7M	Cast alloy C-276
HG30 or G30	Hastelloy alloy G-30
I-625	Inconel 625
316L	AISI Type 316L stainless steel
ST-6	Stellite 6
UB	U-Bend sample
FC	Flat coupon
W	Autogenous weld

Table VIII. Heat Analyses (wt%) of Alloys Used in DWPF Corrosion Coupon Study

Component	C276 U-bend Samples HT E642	C276 Flat Coupons HT G238	CW7M Flat Coupons HT E164	C22 U-bend Samples HT F289	C22 Flat Coupons HT F120	G30 Flat Coupons HT H019	I-625 Flat Coupons HT F340*	316L U-bend Samples HT G393	ST-6 Flat Coupons HT F906
Nickel	55.81	57.60	61.52	55.70	56.71*	42.42	58.0 min	10.19	0.88
Chromium	16.02	15.57	18.79	22.0	21.10	29.10	20.0-23.0	16.19	28.17
Iron	6.27	5.67	1.09	4.30	4.10	14.70	5.0 max	69.21	1.25
Molybdenum	15.89	15.47	17.51	13.60	13.80	5.10	8.0-10.0	2.10	0.08
Silicon	0.04	0.02	0.48	0.02	0.03	0.28	0.5 max	0.39	1.22
Carbon	0.003	0.004	0.009	0.004	0.002	0.01	0.1 max	0.17	1.34
Cobalt	1.83	1.73		0.80	0.93	3.80	1.0 max		61.42
Others	Mn-0.45 V-0.16 P-0.011 S-0.002 W-3.51	Mn-0.47 V-0.15 P-0.005 S-0.003 W-3.31	Mn-0.59 P-0.007 S-0.005	V-0.15 Mn-0.30 W-3.10 S-0.02 P-0.009	V-0.14 Mn-0.28 W-2.90 S-0.002 P-0.008	Cb+Ta-0.78 Cu- 1.90 P-0.009 S-0.002 Cu-1.90	Cb+Ta-3.2-4.2 P-0.015 max S-0.015 max Al-0.4 max	P-0.034 S-0.001 Mn-1.72	W-5.46 Mn-0.18

* - indicates only typical composition information available

Table IX. Corrosion Coupon Data From the Vapor Space of the DWPF Precipitate Reactor (PR) Tank after Twelve Months of Exposure

Coupon ID	Type Coupon	Length (cm)	Width (cm)	Hole Diameter (cm)	Thickness (cm)	Surface Area (cm^2)	Volume (cm^3)	Density (g/cc)	Initial Weight (g)	Weight After Exposure (g)	Weight Loss (g)	Corrosion Rate (μm/y)	Corrosion Rate (mpy)
C276W-01	FC	5.1016	1.9230	0.9990	0.2974	23.2	2.7	8.80	22.2977	22.2942	0.0035	0.17	0.007
HC276-01	UB	12.7267	1.9340	0.9535	0.1562	51.9	3.6	8.80	31.5245	31.5184	0.0061	0.14	0.005
C276-01[a]	FC	5.0940	1.9342	0.9959	0.2934	23.2	2.7	8.80	22.3110	22.3075	0.0035	0.17	0.007
ST-6-1[a]	FC	5.0884	1.9045	0.9063	0.3152	23.4	2.9	8.00	22.6321	22.6313	0.0008	0.04	0.002
HC22W-01	FC	5.0843	1.9248	0.9540	0.3038	23.3	2.8	8.89	22.8142	22.8123	0.0019	0.09	0.004
HC22-01	UB	12.7292	1.9395	0.9418	0.1537	52.0	3.6	8.89	30.1259	30.1244	0.0015	0.03	0.001
C22-01[b]	FC	5.1041	1.9266	0.9926	0.3228	23.7	2.9	8.89	24.3034	24.3021	0.0013	0.06	0.002
ST-6-2[b]	FC	5.0874	1.9020	0.9606	0.3101	23.2	2.8	8.00	22.5272	22.5266	0.0006	0.03	0.001
I-625W-01	FC	5.1250	1.9289	1.0018	0.3172	23.7	2.9	8.14	23.3901	23.3892	0.0009	0.05	0.002
HG30W-01	FC	5.0963	1.9220	0.9515	0.2898	23.1	2.6	8.22	20.7986	20.7974	0.0012	0.06	0.003

a C276-1 and ST6-1 galvanically coupled

b C22-1 and ST6-2 galvanically coupled

Table X. Corrosion Coupon Data From the Liquid Space of the DWPF Precipitate Reactor (PR) Tank after Twelve Months of Exposure

Coupon ID	Type Coupon	Length (cm)	Width (cm)	Hole Diameter (cm)	Thickness (cm)	Surface Area (cm^2)	Volume (cm^3)	Density (g/cc)	Initial Weight (g)	Weight After Exposure (g)	Weight Loss (g)	Corrosion Rate (μm/y)	Corrosion Rate (mpy)
C276W-05	FC	5.0998	1.9164	0.9921	0.2957	23.1	2.7	8.80	22.6615	22.6492	0.0123	0.61	0.024
HC276-05	UB	12.7310	1.9347	0.9456	0.1554	51.9	3.6	8.80	31.2237	31.2032	0.0205	0.45	0.018
C276-06[a]	FC	5.0963	1.9319	0.9942	0.3058	23.4	2.8	8.80	23.3774	23.3657	0.0117	0.58	0.023
ST-6-5[a]	FC	5.0884	1.9136	0.9228	0.3114	23.4	2.8	8.00	22.6218	22.6232	-0.0014	-0.08	-0.003
C22W-5	FC	5.0843	1.9213	0.9548	0.3142	23.4	2.8	8.89	23.1479	23.1481	-0.0002	-0.01	0.000
HC22-05	UB	12.7503	1.9355	0.9495	0.1527	51.9	3.6	8.89	30.1661	30.1680	-0.0019	-0.04	-0.002
C22-03[b]	FC	5.1087	1.9243	0.9733	0.3211	23.7	2.9	8.89	24.0912	24.0920	-0.0008	-0.04	-0.002
ST-6-6[b]	FC	5.0884	1.9022	0.9241	0.3119	23.3	2.8	8.00	22.5873	22.5910	-0.0037	-0.20	-0.008
I-625W-04	FC	5.1173	1.9309	0.9964	0.2972	23.3	2.7	8.14	21.3639	21.3702	-0.0063	-0.34	-0.013
HG30W-04	FC	5.0869	1.9253	0.9525	0.2957	23.2	2.7	8.22	20.8133	20.8218	-0.0085	-0.45	-0.018

a C276-6 and ST6-5 galvanically coupled

b C22-3 and ST6-6 galvanically coupled

Table XI. Corrosion Coupon Data From the Vapor Space of the DWPF Sludge Receipt and Adjustment Tank (SRAT) / Twelve Months of Exposure

Coupon ID	Type Coupon	Length (cm)	Width (cm)	Hole Diameter (cm)	Thickness (cm)	Surface Area (cm^2)	Volume (cm^3)	Density (g/cc)	Initial Weight (g)	Weight After Exposure (g)	Weight Loss (g)	Corrosion Rate (µm/y)	Corrosion Rate (mpy)
C276W-02	FC	5.0991	1.9225	0.9820	0.3028	23.3	2.7	8.80	22.9535	22.9558	-0.0023	-0.11	-0.004
HC276-02	UB	12.7300	1.9342	0.9416	0.1557	51.9	3.6	8.80	31.3817	31.3871	-0.0054	-0.12	-0.005
C276-02[a]	FC	5.0980	1.9210	0.9987	0.3104	23.4	2.8	8.80	23.6021	23.6046	-0.0025	-0.12	-0.005
ST-6-3[a]	FC	5.0894	1.9012	0.9525	0.3071	23.1	2.8	8.00	22.3674	22.3691	-0.0017	-0.09	-0.004
HC22-02	UB	12.7287	1.9370	0.9459	0.1529	51.9	3.6	8.89	30.1931	30.1985	-0.0054	-0.12	-0.005
HC22W-02	FC	5.0932	1.9223	0.9543	0.3058	23.4	2.8	8.89	23.0535	23.0571	-0.0036	-0.18	-0.007
C22-02[b]	FC	5.1031	1.9312	0.9980	0.3205	23.7	2.9	8.89	24.2387	24.2407	-0.0020	-0.10	-0.004
ST-6-4[b]	FC	5.0841	1.8966	0.9149	0.3134	23.2	2.8	8.00	22.3461	22.3484	-0.0023	-0.13	-0.005
I-625W-2	FC	5.1232	1.9246	0.9883	0.3165	23.6	2.9	8.14	23.3229	23.3263	-0.0034	-0.18	-0.007
HG30W-02	FC	5.0942	1.9286	0.9451	0.3035	23.4	2.8	8.22	21.6288	21.6320	-0.0032	-0.17	-0.007

a C276-2 and ST6-3 galvanically coupled // b C22-2 and ST6-4 galvanically coupled

Table XII. Corrosion Coupon Data From the Liquid Space of the DWPF Sludge Receipt and Adjustment Tank (SRAT) / Twelve Months of Exposure

Coupon ID	Type Coupon	Length (cm)	Width (cm)	Hole Diameter (cm)	Thickness (cm)	Surface Area (cm^2)	Volume (cm^3)	Density (g/cc)	Initial Weight (g)	Weight After Exposure (g)	Weight Loss (g)	Corrosion Rate (µm/y)	Corrosion Rate (mpy)
C276W-06	FC	5.0963	1.9319	0.9942	0.3058	23.4	2.8	8.80	22.7784	22.7760	0.0024	0.12	0.005
HC276-06	UB	12.7150	1.9296	0.9507	0.1544	51.7	3.6	8.80	31.0999	31.0827	0.0172	0.38	0.015
C276-07[a]	FC	5.0950	1.9294	0.9982	0.3086	23.4	2.8	8.80	23.5567	23.5541	0.0026	0.13	0.005
ST-6-7[a]	FC	5.0866	1.9233	0.9530	0.3119	23.4	2.8	8.00	22.7962	22.7952	0.0010	0.05	0.002
HC22W-06	FC	5.0907	1.9276	0.9522	0.3193	23.6	2.9	8.89	23.7950	23.7909	0.0041	0.20	0.008
HC22-06	UB	12.7330	1.9370	0.9492	0.1542	51.9	3.6	8.89	30.1960	30.1939	0.0021	0.05	0.002
C22-04[b]	FC	5.1018	1.9309	0.9975	0.3183	23.6	2.9	8.89	24.0124	24.0097	0.0027	0.13	0.005
ST-6-8[b]	FC	5.0874	1.8989	0.9243	0.3104	23.2	2.8	8.00	22.2712	22.2709	0.0003	0.02	0.001
I-625W-5	FC	5.1201	1.9261	0.9914	0.3056	23.4	2.8	8.14	22.2167	22.2173	-0.0006	-0.03	-0.001
HG30W-05	FC	5.0970	1.9284	0.9543	0.2985	23.3	2.7	8.22	21.0839	21.0784	0.0055	0.29	0.011

a C276-7 and ST6-7 galvanically coupled

b C22-4 and ST6-8 galvanically coupled

Table XIII. Corrosion Coupon Data From the Vapor Space of the DWPF Off Gas Condensate Tank (OGCT) after Twelve Months of Exposure

Coupon ID	Type Coupon	Length (cm)	Width (cm)	Hole Diameter (cm)	Thickness (cm)	Surface Area (cm^2)	Volume (cm^3)	Density (g/cc)	Initial Weight (g)	Weight After Exposure (g)	Weight Loss (g)	Corrosion Rate (µm/y)	Corrosion Rate (mpy)
C276W-04	FC	5.1044	1.9246	0.9972	0.2946	23.2	2.7	8.80	22.7053	22.7045	0.0008	0.04	0.002
HC276-04	UB	12.7630	1.9299	0.9545	0.1580	52.0	3.7	8.80	31.4102	31.4094	0.0008	0.02	0.001
C276-05[a]	FC	5.1016	1.9309	0.9639	0.2837	23.1	2.6	8.80	21.3586	21.3580	0.0006	0.03	0.001
CW7M-2[a]	FC	5.0874	1.8903	0.9510	0.3147	23.1	2.8	8.80	23.1690	23.1674	0.0016	0.08	0.003
I-625W-03	FC	5.1209	1.9177	0.9934	0.3175	23.6	2.9	8.14	23.0363	23.0372	-0.0009	-0.05	-0.002
HC22-04	UB	12.7305	1.9337	0.9456	0.1527	51.8	3.5	8.89	30.2691	30.2695	-0.0004	-0.01	0.000
HC22W-4	FC	5.0970	1.9154	0.9467	0.3147	23.5	2.9	8.89	23.5356	23.5364	-0.0008	-0.04	-0.002
HG30W-03	FC	5.0975	1.9301	0.9464	0.3040	23.4	2.8	8.22	21.7288	21.7291	-0.0003	-0.02	-0.001
316L-02	UB	12.7488	1.9314	0.9441	0.1427	51.5	3.3	7.98	26.1581	26.1582	-0.0001	0.00	0.000

a C276-5 and CW7M-2 galvanically coupled

Table XIV. Corrosion Coupon Data From the Liquid Space of the DWPF Off Gas Condensate Tank (OGCT) after Twelve Months of Exposure

Coupon ID	Type Coupon	Length (cm)	Width (cm)	Hole Diameter (cm)	Thickness (cm)	Surface Area (cm^2)	Volume (cm^3)	Density (g/cc)	Initial Weight (g)	Weight After Exposure (g)	Weight Loss (g)	Corrosion Rate (µm/y)	Corrosion Rate (mpy)
C276W-08	FC	5.1044	1.9136	0.9886	0.2969	23.1	2.7	8.80	22.8846	22.8854	-0.0008	-0.04	-0.002
HC276-08	UB	12.7198	1.9304	0.9520	0.1529	51.7	3.5	8.80	31.1234	31.1249	-0.0015	-0.03	-0.001
C276-10[a]	FC	5.0942	1.9479	0.9782	0.2959	23.4	2.7	8.80	22.7635	22.7640	-0.0005	-0.02	-0.001
CW7M-4[a]	FC	5.0818	1.8875	0.9553	0.3002	22.8	2.7	8.80	22.5869	22.5852	0.0017	0.09	0.003
I-625W-06	FC	5.1214	1.9223	0.9954	0.3134	23.5	2.8	8.14	22.7611	22.7624	-0.0013	-0.07	-0.003
HC22-08	UB	12.7348	1.9383	0.9510	0.1527	51.9	3.6	8.89	30.1810	30.1814	-0.0004	-0.01	0.000
HC22W-08	FC	5.0899	1.9195	0.9393	0.3155	23.5	2.9	8.89	23.4984	23.4992	-0.0008	-0.04	-0.002
HG30W-06	FC	5.0998	1.9324	0.9487	0.3000	23.4	2.7	8.22	21.4614	21.4629	-0.0015	-0.08	-0.003
316L-04	UB	12.6642	1.9215	0.9512	0.1453	50.9	3.3	7.98	26.1931	26.1932	-0.0001	0.00	0.000

a C276-10 and CW7M-4 galvanically coupled

3.17 Comparison of Process Chemistry to that Used in Coupon Testing to Define Materials of Construction / Corrosion Estimates for Fabricated Equipment

- Reported by W. L. Daugherty

The potential for degradation of the DWPF process tanks in the SPC and CPC was evaluated in Appendix 7 to WSRC-TR-95-0385 ("Evaluation of Potential for Materials Degradation of DWPF Safety Class and Safety Significant Components", W. L. Daugherty, Sept. 1995). In this report, the chemical composition of each tank was estimated from a material balance for the DWPF startup with Batch 1 sludge. This chemistry was in turn compared to various test solutions for which corrosion data was available in order to estimate corrosion rates and the susceptibility to various forms of localized attack. Subsequently, chemical analyses of various tank contents have been compiled, profiling the actual chemistry in the tanks for a number of batch compositions. These chemical analysis results have been reviewed to check that the previous results and conclusions of WSRC-TR-95-0385 remain valid.

The test solutions from which corrosion rate estimates were obtained do not represent a perfect match with the actual tank chemistry. In fact, due to changes over time in the process chemistry, the closest match to the actual chemistry of some tanks is provided from test solutions that were originally intended to simulate other tank conditions. These existing data were utilized to the extent practical.

The actual process chemistry was measured for a number of tanks for batches 1 through 27. Note that there were 27 PR batches of SPC product (i.e. PR batches) and 16 CPC batches (i.e. SRAT, SME, MFT). Of these data, those for batches 2-6 and 15-16 are considered the best match for typical DWPF production runs. Table XV summarizes the comparison between the actual process chemistry and that of the test solutions from which the corrosion rates were estimated for these typical batches. The remaining batches incorporated variations in chemistry to simulate extremes in feed composition. Table XVI compares the range of actual process chemistry for all batches to that of the test solutions. In several tanks, the process chemistry changes significantly as a batch of material is processed. In these cases, both the input and output solution chemistries are considered. If the test solution chemistry bounds the actual chemistry for both input and output solutions, then it conservatively estimates the actual corrosion rates. For tanks in which no significant change in solution chemistry occurs, both input and output streams are assumed to have the same chemistry. (More complete chemistry data on feed, product, and waste streams collected in the test program is contained in the "FA-04 Materials Evaluation / Field Reports" document, WSRC-TR-96-0197.)

In many cases, the quantity of ionic species in the test solutions exceeds that measured in the various samples; and in several cases it does not. It is primarily these cases in which the actual chemistry is not bounded by the test solutions that are evaluated to validate the conservatism of the corrosion rate estimates. An additional source of conservatism in some of the corrosion rate estimates is the fact that the measured corrosion rates were generally rounded up to a greater value to obtain a bounding corrosion rate. The test data indicate corrosion rates of less than 1 mil/yr for most test solutions; in these cases the corrosion rate was rounded up to a bounding rate of 1 mil/yr. Table XVII summarizes the actual corrosion rates measured in the test solutions and the bounding corrosion rates that were assigned for analysis purposes.

The process chemistry in a given tank changes with time. For example, the SRAT receives the PR product and sludge from the LPPP. Formic acid is also added to the SRAT. The final SRAT product has a different chemistry from that of the inputs. Therefore, the SRAT must be evaluated for compatibility with each of these process streams. In previous estimates of corrosion rates for each tank, only that chemistry stage that was judged most severe was considered for each tank. Tables XV and XVI provide a more complete listing of the process streams. In situations where the measured ionic concentration exceeds that of the test solution used to estimate a corrosion rate, the measured concentrations are printed with boldface type. It is these situations that are evaluated to determine whether the estimated corrosion rates are valid. Any measured concentration that was reported as "< x" (where x is the sensitivity of the measurement and varies from one measurement to another) is treated as a concentration of essentially zero.

Results and Conclusions:

For the PRFT, no test solution provided a close match to the estimated chemistry, primarily due to the high pH. Corrosion concerns for stainless steel and C276 (the materials of construction for the tanks and jumpers) at high pH levels are minimal. Accordingly, a bounding corrosion rate of 1 mil/yr was used. The measured chemistry for the PRFT is not considered severe, and a corrosion rate of 1 mil/yr is still considered valid.

For the PR, OGCT, and SMECT the measured chemistry is generally bounded by that of the test solution. The nitrate level in the PR feed exceeds that of the test solution, but this difference is not significant considering that the test solution had higher sulfate and chloride levels. Also note that the PR feed has a much higher pH than the test solution. The OGCT measured chemistry is completely bounded by the test solution. The bounding corrosion rates of 1 mil/yr for the PR and OGCT are considered valid. The SMECT chemistry is bounded by the test solution except for the nitrate level of 1 batch. Since the test solution had a lower pH, and most batches are bounded by the test solution, the bounding corrosion rate of 1 - 5 mil/yr is considered valid. The upper end of this range (5 mil/yr) was established based on greatly increased corrosion rates (plus pitting and crevice corrosion) that were observed in a more severe test solution. With the measured SMECT chemistry now confirming the accuracy of the calculated chemistry, this more severe test solution is considered overly conservative, and a bounding corrosion rate of 1 mil/yr should be used.

The SRAT, SME and MFT were found to contain greater quantities of nitrite, sulfate and formate than were in the test solution. The sludge input to the SRAT also contained a greater amount of fluoride. On the other hand, the test solution for each of these three tanks contained a much higher level of nitrate and a lower pH. Higher levels of sulfate and formate were shown to not produce excessive corrosion rates in the test solution for the OGCT and PR, respectively. And the higher fluoride levels in the sludge are offset by lower chlorides - the total halide content is bounded by the test solution. Since the actual corrosion rate in the test solution was only 0.01 mil/yr, a bounding corrosion rate of 1 mil/yr is still considered reasonable for the SRAT, SME and MFT.

Another source of data validating the estimated corrosion rates is the tank wall thickness measurements taken under the FA-04 program. These measurements showed no significant wall thinning, within measurement uncertainty levels. Therefore, even in cases where the test solutions used to estimate corrosion rates did not quite match the actual chemistry, or where the concentration of some of the chemical species (such as mercury) was not measured, this evidence indicates that these differences are not a source of significant impact to the estimated corrosion rates.

Table XV. DWPF process chemistry comparison for "typical" batches (Concentrations are ppm.)

	PRFT	(output)	(input)	PR	(output)	OGCT	(input/output)
	Calculated / Test Sol'n Chemistry	PR Feed Measured Chemistry	PR Feed Measured Chemistry	Calculated / Test Sol'n Chemistry	PR Product Measured Chemistry	Calculated / Test Sol'n Chemistry	OGCT Measured Chemistry
Temp. (C)	40 / NA			100 / 90		50 / 101	
pH	12 / NA	8.8 - 9.1	8.8 - 9.1	2 / 1.8	Not available. See Table 2 for chemistry of other (non-typ.) batches.	2 / 3.2	2 - 6.5
NO3-	10 / NA	NA	NA	5 / 5000		230 / 1000	<99 - 172
NO2-	4000 / NA	406 - 407	**406 - 407**	0 / 0		5 / 0	<10 - <99
SO4(-2)	500 / NA	131 - 157	131 - 157	170 / 700		60 / 800	<10 - <99
COOH-	0 / NA	NA	NA	21950 / 10**5		0 / 0	NA
PO4(-3)	1 / NA	NA	NA	1 / 0		0 / 0	NA
F-	0 / NA	<96	<96	1 / 100		5 / 3000	<10 - <99
Cl-	10 / NA	139 - 140	139 - 140	5 / 450		5 / 26200	<10 - <99
Cu(+2)	0 / NA	NA	NA	960 / 2000		0 / 0	NA
Hg(+2)	560 / NA (Hg)			350 / 1250 (Hg)		160 / 73800 (most Hg)	

	(input)	(input)	SRAT	(output)	SMECT	(input/output)
	PR Product Measured Chemistry	Sludge Measured Chemistry	Calculated / Test Sol'n Chemistry	SRAT Product Measured Chemistry	Calculated / Test Sol'n Chemistry	SMECT Measured Chemistry
Temp. (C)			100 / 100		50 / 70	
pH	Not available. See Table 2 for chemistry of other (non-typ.) batches.	6.7 - 8.8	3 / 4	5.9 - 9.4	1 / 1	NA
NO3-		126 - 804	27460 / 46500	104 - 403	3600 / 1400	**1230 - 3190**
NO2-		**<97 - 494**	0 / 10	**<11 - 122**	0 / 0	<96
SO4(-2)		**781 - 977**	1420 / 167	**108 - 994**	0 / 40	<96
COOH-		**279 - 591**	22920 / 1	**129 - 311**	0 / 2400	NA
PO4(-3)		NA	10 / 1	<11 - <99	0 / 0	NA
F-		**<97 - 165**	40 / 133	<11 - <99	0 / 0	<96
Cl-		104 - 160	50 / 1014	105 - 673	0 / 80	<96
Cu(+2)		NA	1440 / 0	NA	0 / 0	NA
Hg(+2)			690 / 0 (Hg)		280 / trace (Hg)	NA

	(input)	SME	(output)	(input)	MFT	(output)
	SRAT Product Measured Chemistry	Calculated / Test Sol'n Chemistry	SME Product Measured Chemistry	SME Product Measured Chemistry	Calculated / Test Sol'n Chemistry	MFT Product Measured Chemistry
Temp. (C)		100 / 100			50 / 100	
pH	5.9 - 9.4	7 / 4	5.1 - 8.6	5.1 - 8.6	7 / 4	5.6 - 7.4
NO3-	104 - 403	21290 / 46500	177 - 409	177 - 409	20990 / 46500	285 - 348
NO2-	**<11 - 122**	0 / 10	<75 - <98	<75 - <98	0 / 10	NA
SO4(-2)	**108 - 994**	1100 / 167	**111 - 951**	**111 - 951**	480 / 167	**122 - 987**
COOH-	**129 - 311**	17330 / 1	**187 - 455**	**187 - 455**	19720 / 1	**218 - 323**
PO4(-3)	<11 - <99	10 / 1	<75 - <98	<75 - <98	10 / 1	NA
F-	<11 - <99	30 / 133	<75 - <98	<75 - <98	30 / 133	<43 - <97
Cl-	105 - 673	40 / 1014	104 - 295	104 - 295	30 / 1014	122 - 975
Cu(+2)	NA	1120 / 0	NA	NA	1070 / 0	NA
Hg(+2)		430 / 0 (Hg)			400 / 0 (Hg)	

Table XVI. DWPF process chemistry comparison for all batches (Concentrations are ppm.)

	PRFT	(output)	(input)	PR	(output)	OGCT	(input/output)
	Calculated / Test Sol'n Chemistry	PR Feed Measured Chemistry	PR Feed Measured Chemistry	Calculated / Test Sol'n Chemistry	PR Product Measured Chemistry	Calculated / Test Sol'n Chemistry	OGCT Measured Chemistry
Temp. (C)	40 / NA			100 / 90		50 / 101	
pH	12 / NA	8.3 - 9.8	8.3 - 9.8	2 / 1.8	NA	2 / 3.2	1.6 - 6.5
NO3-	10 / NA	NA	NA	5 / 5000	101 - 993	230 / 1000	<99 - 201
NO2-	4000 / NA	<91 - 422	**<91 - 422**	0 / 0	<10 - <98	5 / 0	<10 - <99
SO4(-2)	500 / NA	<11 - 181	<11 - 181	170 / 700	<10 - 190	60 / 800	<10 - <99
COOH-	0 / NA	NA	NA	21950 / 10**5	NA	0 / 0	NA
PO4(-3)	1 / NA	NA	NA	1 / 0	NA	0 / 0	NA
F-	0 / NA	<10 - <98	<10 - <98	1 / 100	<10 - <98	5 / 3000	<10 - <99
Cl-	10 / NA	<91 - 153	<91 - 153	5 / 450	<10 - 107	5 / 26200	<10 - 117
Cu(+2)	0 / NA	NA	NA	960 / 2000	NA	0 / 0	NA
Hg(+2)	560 / NA (Hg)			350 / 1250 (Hg)		160 / 73800 (most Hg)	

	(input)	(input)	SRAT	(output)	SMECT	(input/output)
	PR Product Measured Chemistry	*Sludge* Measured Chemistry	*Calculated /* Test Sol'n Chemistry	*SRAT. Product* Measured Chemistry	*Calculated /* Test Sol'n Chemistry	*SMECT* Measured Chemistry
Temp. (C)			100 / 100		50 / 70	
pH	NA	6.7 - 10.4	3 / 4	4.5 - 9.4	1 / 1	1.8 - 1.9
NO3-	101 - 993	103 - 935	27460 / 46500	104 - 527	3600 / 1400	**111 - 3190**
NO2-	<10 - <98	**<97 - 992**	0 / 10	**<11 - 907**	0 / 0	<10 - <99
SO4(-2)	**<10 - 190**	**<6 - 977**	1420 / 167	**108 - 994**	0 / 40	<10 - <99
COOH-	NA	**279 - 790**	22920 / 1	**129 - 427**	0 / 2400	NA
PO4(-3)	NA	NA	10 / 1	<11 - <99	0 / 0	NA
F-	<10 - <98	**<12 - 165**	40 / 133	<10 - <99	0 / 0	<10 - <99
Cl-	<10 - 107	104 - 708	50 / 1014	105 - 848	0 / 80	<10 - <99
Cu(+2)	NA	NA	1440 / 0	NA	0 / 0	NA
Hg(+2)			690 / 0 (Hg)		280 / trace (Hg)	NA

	(input)	SME	(output)	(input)	MFT	(output)
	SRAT Product Measured Chemistry	Calculated / Test Sol'n Chemistry	SME Product Measured Chemistry	SME Product Measured Chemistry	Calculated / Test Sol'n Chemistry	MFT Product Measured Chemistry
Temp. (C)		100 / 100			50 / 100	
pH	4.5 - 9.4	7 / 4	4.4 - 8.6	4.4 - 8.6	7 / 4	3.8 - 7.4
NO3-	104 - 527	21290 / 46500	177 - 480	177 - 480	20990 / 46500	249 - 422
NO2-	**<11 - 907**	0 / 10	**<75 - 245**	**<75 - 245**	0 / 10	NA
SO4(-2)	**108 - 994**	1100 / 167	**<92 - 951**	**<92 - 951**	480 / 167	**103 - 987**
COOH-	**129 - 427**	17330 / 1	**187 - 500**	**187 - 500**	19720 / 1	**218 - 441**
PO4(-3)	<11 - <99	10 / 1	<75 - <98	<75 - <98	10 / 1	NA
F-	<10 - <99	30 / 133	<75 - <98	<75 - <98	30 / 133	<10 - <97
Cl-	105 - 848	40 / 1014	104 - 999	104 - 999	30 / 1014	110 - 975
Cu(+2)	NA	1120 / 0	NA	NA	1070 / 0	NA
Hg(+2)		430 / 0 (Hg)			400 / 0 (Hg)	

Table XVII. DWPF process tank corrosion rates

		Bounding Corrosion Rate for Analysis	
Tank	Corrosion Rate from Test Data	Previously Reported	Recommended by this Report
PRFT	No applicable test data available	1 mil/yr	1 mil/yr
PR	0.8 - 0.9 mil/yr	1 mil/yr	1 mil/yr
SRAT	0.01 mil/yr	1 mil/yr	1 mil/yr
SME	0.01 mil/yr	1 mil/yr	1 mil/yr
MFT	0.01 mil/yr	1 mil/yr	1 mil/yr
SMECT	0.05 mil/yr, 10 mil/yr for more severe test (2500 ppm Cl-, etc.)	1 - 5 mil/yr	1 mil/yr
OGCT	0.02 mil/yr	1 mil/yr	1 mil/yr

3.18 Predicted Equipment Life - Reported by J. T. Gee

Life expectancies of critical process equipment were estimated during the FA-04 materials evaluation program. While summaries of the projected equipment lives are included in the Field Completion Reports for FA-04.02 and FA-04.03, it was thought worthwhile to provide copies in the main portion of the report. Complete details are provided in Appendix 1. Predicted equipment life estimates are provided in Tables XVIII and XIX for the CPC and SPC equipment respectively.

Discussion:

Several factors were considered in estimating equipment life. These included condition of the equipment at inspection, review of corrosion coupon data, and engineering judgments. Failures such as mechanical fatigue that are not related to erosion/corrosion were not considered.

The expected service life of the PR and its respective fixed coils was predicted to be twelve years as reported in Table XIX. This was tentatively predicted on the basis of corrosion of the steam coil. Since the noted table was drafted (further discussed in section on fixed coils), it was concluded that the time of steam flow in the coils is minimal (i.e. a few hours per batch cycle) and for this reason, it is now expected the PR and their supporting fixed coils will last the life of the DWPF facility (i.e. 20 years).

Results and Conclusions:

It was concluded that with the exception of the SME coil and agitator, all of the equipment should achieve its design life (i.e. twenty years for process tanks and vessels, five years for pumps, coils, and agitators, and one year for replaceable jumpers).

The MOG line melter end is expected to require replacement in three years as a result of pitting corrosion. While this is a replaceable jumper, it is relatively large and contains an isolation valve. For these reasons, it would be expensive to replace (and subsequently dispose of) this jumper. It is therefore recommended that design changes be implemented in replacement MOG line melter end jumpers to extend the expected service life.

TABLE XVIII

PREDICTED EQUIPMENT LIFE

Equipment Description	Materials of Construction	Total Operating Time at Inspection	No. of Process Batch Cycles Com.	Primary Materials Concern to Component	Predicted Additional Service Life
LPPP Sludge Tank	304L	12-18 months	N/A	No materials concern	Life of Facility
LPPP Precipitate Tank	304L	12-18 months	N/A	No materials concern	Life of Facility
PRBT Vessel	C-276	12-18 months	17	No materials concern	Life of Facility
SRAT Vessel	C-276	12-18 months	17	No materials concern	Life of Facility
SRAT Sample Pump	C-276	180 hours	N/A	No materials concern	5 year (Note 3)
SRAT Coil Assembly	C-276	10.1 months (Note 1)	17	No materials concern	Life of Facility
SRAT Agitator	C-276	10.1 months	N/A	Slight erosion on lower blades	5 year (Note 3)
SRAT Condenser	C-276	N/A	17	No materials concern	Life of Facility
SRAT Ammonia Scrubber	316L	N/A	N/A	No materials concern	Life of Facility
SMECT Vessel	316L	12-18 months	N/A	No materials concern	Life of Facility
SMECT Coil	316L	N/A	N/A	No materials concern	Life of Facility
SME Vessel	C-276	15-18 months	17	Erosion of tank floor, guides	Life of Facility
SME Transfer Pump	C-276	30 hours	17	Erosion of impeller, piping	5 year (Note 3)
SME Sample Pump	C-276	170 hours	17	Erosion of impeller, piping	5 year (Note 3)
SME Coil Assembly	C-276	14.1 months (Note 1)	17	Erosion of bottom structure	Inspect after 2 years
SME Condenser	C-276	N/A	17	No materials concern	Life of Facility
SME Agitator	C-276	14.1 months	N/A	Erosion of agitator blades	Inspect after 3 years
MFT Vessel	C-276	15-18 months	17	No materials concern	Life of Facility
MFT Sample Pump	C-276	310 hours	17	Erosion of impeller, lines	5 year (Note 3)
Melter Feed Pump No. 1	C-276	3.3 months	17	Erosion of impeller, lines	5 year (Note 3)
MFT Coil Assembly	C-276	14.2 months (Note1)	17	Erosion of bottom structure	5 year (Note 3)
MFT Agitator	C-276	14.2 months	N/A	Erosion of agitator blades	5 year (Note 3)
Process Jumpers - no frit	C-276, 316L	N/A	17	Minimal materials concern	Inspect after 5 years (Note 4)
Process Jumpers - with frit	C-276	N/A	17	Minimal materials concern	Inspect after 5 years (Note 4)
RCT Vessel	C-276	N/A	N/A	No materials concern	Life of Facility
MOG Line Melter End	I690	11.5 months (Note 2)	N/A	Corrosion/pitting on I690 line	Replace after 3 years
MOG Line Quencher End	ALLCORR	11.5 months (Note 2)	N/A	No materials concern	Life of Facility
OGCT Vessel	C-276	15-18 months	N/A	No materials concern	Life of Facility
OGCT Sample Pump	C-276	< 200 hours	N/A	No materials concern	5 year (Note 3)
SAS Vessel	C-276	11.5 months	N/A	No materials concern	Life of Facility
HEME Vessel	C-276	11.5 months	N/A	No materials concern	Life of Facility

TABLE XVIII (Cont.)

PREDICTED EQUIPMENT LIFE

Equipment Description	Materials of Construction	Total Operating Time at Inspection	No. of Process Batch Cycles Com.	Primary Materials Concern to Component	Predicted Additional Service Life
CDC No. 1 Recirculation Pump	304L	N/A	about 60 canisters	No materials concern	5 year (Note 3)
CDC No. 1 Spray Nozzle Rack	304L	N/A	about 60 canisters	Crevice corrosion on ribbon nozzle	Inspect ribbon nozzle / 5 years
CDC No. 2 Spray Nozzle Rack	304L	N/A	about 60 canisters	Crevice corrosion on ribbon nozzle	Inspect ribbon nozzle / 5 years
MFT Hydragard Liquid Sampler	C-276	310 hours	N/A	No materials concern	Life of Facility
SME Hydragard Liquid Sampler	C-276	170 hours	N/A	No materials concern	Life of Facility
SME Sample Station	304L	170 hours	N/A	Possible erosion/corrosion of tubing	2 year minimum / run to failure
PR Perm. Sample. Lines	C-276	450 hours	N/A	No materials concern	Life of Facility
SRAT Perm. Sample Lines	C-276	180 hours	N/A	No materials concern	Life of Facility
SME Perm. Sample. Lines	C-276	170 hours	N/A	No materials concern	Life of Facility
MFT Perm. Sample. Lines	C-276	310 hours	N/A	No materials concern	Life of Facility
OGCT Perm. Sample. Line	C-276	< 200 hours	N/A	No materials concern	Life of Facility

NOTES

1) It was assumed that the most significant factor on the erosion/corrosion rates for coil assemblies would be amount of time the agitator was in service. For this reason, the "total operating time at inspection" for the coil assemblies was made equivalent to the agitators.
2) The "total operating time at inspection" for the Quencher and MOG lines was assumed to be equal to the OGCT Quencher Pump.
3) The design life for the process pumps and agitators was five years. It is predicted that materials issues will not reduce the life of these components.
4) Several of the process jumpers may be impacted by erosion/corrosion. If acceptable from a process standpoint, the jumpers can be used until failure (i.e. pitting or localized thinning expected). If such failure is not acceptable the jumpers should be inspected at convenient outage after about five years service.

Reviewed by DWPF Materials Committee on 11/13/95

G. T. Chandler, Chairman

11/15/95
DATE

ABLE XIX

PREDICTED SPC EQUIPMENT LIFE

Equipment Description	Materials of Construction	Total Operating Time at Inspection	No. of Process Batch Cycles Com.	Primary Materials Concern to Component	Predicted Additional Service Life
PR Vessel / Fixed Coil	C-276 Alloy	15-18 months	27	Corrosion of steam coils	12 year (Note 1)
PR Agitator	C-276 Alloy	3.3 months	N/A	No materials concern	5 year (Note 2)
PR Sample Pump	C-276 Alloy	450 hours	N/A	No materials concern	5 year (Note 2)
PR Sample Discharge Jumper	*C-276 Alloy*	*450 hours*	*N/A*	*No materials concern*	*Inspect after 5 years (Note 3)*
PRCD Vessel	C-276 Alloy	15-18 months	27	No materials concern	Life of facility
PRFT Vessel	C-276 Alloy	15-18 months	N/A	No materials concern	Life of facility
PRFT Sample Pump	C-276 Alloy	N/A	N/A	No materials concern	5 year (Note 2)
PRFT Transfer Pump	C-276 Alloy	N/A	N/A	No materials concern	5 year (Note 2)
OE Vessel and Coil	C-276 Alloy	15-18 months	27	No materials concern	Life of facility
OECD Vessel	C-276 Alloy	15-18 months	27	No materials concern	Life of facility
OECT Vessel	304L Stainless	15-18 months	27	Possible localized corrosion	Life of facility (Note 4)
PR to PRCD Jumper	C-276 Alloy	N/A	N/A	No materials concern	Inspect after 5 years (Note 3)
PRCD to SCVC Vent Jumper	C-276 Alloy	N/A	N/A	No materials concern	Inspect after 5 years (Note 3)

NOTES

1) **Laboratory coupon data suggests that the general corrosion rate on the fixed Precipitate Reactor (PR) steam coils may be 5 mpy. At this rate, the corrosion allowance on the heated coil would be expended in about twelve years. The PR vessel, however, is expected to last the life of the facility. Thus, the PR may be limited as a result of possible coil failure.**
2) **The design life for the process pumps and agitators was five years. It is predicted that materials issues will not reduce the life of these components.**
3) **Several of the process jumpers may be impacted by erosion/ corrosion. If acceptable from a process standpoint, the jumpers can be used until failure (i.e. pitting or localized thinning expected). If such a failure is not acceptable, the jumpers should be replaced at some predetermined frequency.**
4) **While no evidence of corrosion was noted during the remote visual inspection of the OECT, laboratory data suggests that the 304L stainless steel alloy used for this vessel may be subject to localized corrosion.**

REFERENCE: W. D. Daugherty, " Evaluation of Potential for Materials Degradation of DWPF Safety Class and Safety Significant Components," WSRC-TR-95-0385, September, 1995.

Reviewed by DWPF Materials Committee on 1/30/96

G. T. Chandler, Chairman

2/1/96
DATE

4.0 Photographic Records

During the course of the DWPF inspections, hundreds of pictures were taken to document equipment condition. While a few of these pictures are contained in this document, restraints on space reduced the number of pictures that could be included. To ensure that these pictures can be properly retrieved at a future date, negatives were logged into document control. Appendix 8 provides a complete listing of DWPF and IDMS negative numbers which were used to support the DWPF materials evaluation.

5.0 Acknowledgments:

The authors wish to offer their appreciation to personnel at the Savannah River Site that assisted in the materials evaluation program. Special thanks are given to the personnel at DWPF, A&ID-QC and SRTC who were heavily involved in program support.

APPENDIX 1

FA-04 FIELD COMPLETION REPORTS

APPENDIX 1

DWPF FA-04.02 FIELD COMPLETION REPORT

CHEMICAL PROCESS CELL (CPC)

PROCESS VESSELS EROSION/CORROSION STUDIES

PREPARED BY: J. T. Gee, DWPF-E

DATE PREPARED: NOVEMBER 21, 1995

Summary / Conclusions

Required field work and data collection for the FA-04.02 test program, "Process Vessels Erosion/Corrosion Studies," for the Chemical Process Cell has been completed. Preliminary results indicate that with two exceptions (i.e. SME agitator and coil assemblies) all of the critical equipment will achieve its "design life" and will be acceptable for radioactive operation. The SME and MFT agitator shaft assemblies were replaced with units containing a new blade design with Stellite hard face coating to mitigate lower blade erosive wear. The SME and MFT coil assembly were reworked to eliminate the effects of localized erosion and extend the life of the equipment. With the noted replacement of the agitator shafts and rework of coil assemblies, the installed SME agitator and coil assembly will be suitable for radioactive operation. A final detailed report will be issued next year with combined input from both DWPF and SRTC and will include results from all DWPF materials evaluation testing.

Introduction / Objective

The FA-04.02 test program, Process Vessel Erosion/Corrosion Studies, has been completed for the Chemical Process Cell (CPC). The CPC in this case is defined to include all DWPF equipment outlined in the FA-04.02 test except that found in the Salt Process Cell (SPC). This portion of the inspection program will be reported separately.

The objective of the FA-04.02 test program was to collect process data and perform field inspections on critical DWPF equipment. This test phase is a follow-up to the FA-04.01 evaluation, Process Vessels Erosion/Corrosion - Baseline, reported in 1992. The current inspection data will be used in conjunction with the baseline data to determine the suitability of DWPF equipment for radioactive operation. This work has now been largely completed. This document provides preliminary findings which demonstrate that existing equipment is suitable for radioactive operations. In addition, this report provides objective evidence that the inspection activities defined in the FA-04 Test Plan (i.e. Attachment 1 in the Test Plan) have been performed. A final report will be issued next year (January target) with combined input from both DWPF and SRTC on all materials evaluation studies performed at DWPF (i.e. Test Programs FA-04, FA-05, etc.).

While this report should be construed as preliminary, sufficient review of individual inspection reports and field data has been performed to ensure that existing CPC plant equipment is adequate for radioactive operations.

Objective Evidence that Test Requirements Have Been Completed

The FA-04 Test Plan required that certain equipment field inspections and process data collection be performed. The required work has been completed as outlined in the following paragraphs.

Essentially all of the planned field work for the FA-04.02 test program (CPC portion) has been completed. This is documented in Attachments 1 and 3 for the SRTC materials inspections and NDE inspections respectively. Several planned inspection activities were not performed as outlined in Attachment 4. All of these were low priority inspections (i.e. ranking of "3" in Test Plan, Attachment 1) and the loss of this data is not considered critical.

Collection of equipment run-time and operating speed data was performed for selected process pumps and agitators. PIMS data was not available for all of the FA-04 test phases. Run-time data was based on a combination of manual logs, PIMS data and estimates based on operating logs. Data on equipment operating speed was not available through PIMS, so it was limited to that obtained on manual operating logs during the 1993/1994 test phases. Most of the operating speed data can be obtained or estimated from knowledge of plant operating conditions. For example, most of the agitators operate at fixed rpm. The SRAT, SME, and MFT agitators operate at two speeds (i.e. 65-130 rpm) depending on process requirements. Thus, while the reported run-time data does not differentiate between those two speeds, an estimate can be made (if warranted) as to the number of hours of high and low speed operation.

Chemical data was collected on process streams per the FA-04 test requirements. In regard to addressing the corrosion potential (e.g. aggressive ions, pH, etc.) for the condensate (i.e. SMECT and OGCT) and recycle stream (RCT) data, it was decided to concentrate on the condensate streams. These streams came from a constant source that could be readily monitored. While data on the RCT was collected, it is felt to have lesser value since different waste streams are collected (e.g., SMECT, OGCT, lab drains) and neutralized in this tank. The collected samples could not be traced to a specific feed stream. Therefore, the corrosive characteristics of the SMECT and OGCT process streams (i.e. feed to RCT) were monitored in more detail than the RCT waste material.

Assessment of Predicted Equipment Life

Inspection results indicate that with two exceptions, outlined below, all of the CPC equipment will achieve its "design life" and will be acceptable for radioactive operation. Design life for the subject equipment is defined to be (Ref. 1):

1) Twenty years for permanent piping system (i.e. sample lines, etc.)
2) Twenty years for major process vessels (i.e. tanks, etc.)
3) Five years for replaceable equipment such as pumps, coils and agitators
4) One year (minimum) for replaceable "on-site fabricated equipment" such as process jumpers

Attachment 2 provides a list of all CPC equipment detailing the cumulative service exposure to date and the "predicted additional service life" remaining. Note that these estimates are based on the consensus opinions of members on the DWPF Materials Committee. With the exception of the SME agitator and coil assembly, all of the equipment should match or exceed its design life basis. Even the SME agitator and coil assembly should be completely adequate to initiate radioactive operations. The "predicted additional service life" estimates reported in Attachment 2 take credit for rework to the SME and MFT coil assemblies (Attachment 1, Item of Note, Nos. 3 & 5) and replacement of shaft assemblies for the SME and MFT agitators (Attachment 1, Item of Note, Nos. 4 & 6). Without the rework and noted replacement, the life of the equipment would be significantly below that reported in Attachment 2.

Preliminary Inspection Results

General statements concerning the equipment inspection results are provided in the following paragraphs.

Eight process tanks were inspected for evidence of erosion/corrosion. None of the tanks showed evidence of wall thinning or localized corrosion.

Significant erosion was observed only on equipment directly exposed to glass frit slurry, as expected. The SME coil assembly and agitators (See Attachment 1, Items of Note, Nos. 3 and 4) showed severe localized erosion. The MFT coils and agitators demonstrated similar wear patterns to those observed on the comparable SME equipment, but to a much lesser extent (See Attachment 1, Items of Note, Nos. 5 and 6). While the erosion in this equipment is a concern, it is felt that the impact can be mitigated by relatively simple design changes.

There was a concern that frit particles may erode the entrances to sample lines and change the characteristics of the sample. For this reason, sample line "pickup points" (i.e. sample pump piping) and the Hydragard liquid sampler inlet valves (i.e. sample line entry) for the SME and MFT were inspected using radiography. No evidence of frit erosion was observed.

In general, little evidence of corrosion was noted for the CPC equipment, confirming the appropriate selection of material. The suitability of the materials of construction was confirmed by both direct inspection of the equipment and by evaluation of corrosion coupons. The only significant corrosion was observed in the MOG Line Melter End (i.e. severe pitting in the Inconel 690 piping) as discussed in Attachment 1, Item of Note, No. 8.

No significant evidence of erosion/corrosion was detected by UT on the permanent sample piping lines going to the sample cells. This had been a concern due to the number of sharp bends and elbows (i.e. frit particle erosion).

Problems had been detected earlier with fatigue at welds in the SMECT process pumps. Evaluation determined that it was a problem with the pump design (different pump design, pumps used to mix tank, very high vibration) and harmonics from pump operation. To determine if the problem was isolated to the SMECT pumps, selected welds from seven process pumps were inspected using liquid penetrant (PT). No evidence of fatigue damage at welds was noted.

Analytical testing of the process streams during cold run testing demonstrated that the process chemistry was largely bounded by test solutions used to select materials of construction (Ref. 2). This implies that criteria used to select the materials are still valid.

During inspections for the FA-04.02 test program, problems were discovered with three damaged dip tubes (i.e. two failures as a result of fatigue, one from mechanical damage). Since the dip tubes were not within the scope of the FA-04 test program, this information was provided to Operations. A major program was implemented to inspect dip tube jumpers, perform calculations on design adequacy and determine the presence of in-tank supports. Repair and evaluation of the dip tubes was covered under U-PMT-S-00665.

References:

1) S. M. Nordwick and D. B. Bickford, "Initial Comments and Recommendations for the DWPF Process Vessels Erosion and Corrosion Studies," March 29, 1990.

2) W. D. Daugherty, "Evaluation of Potential for Materials Degradation of DWPF Safety Class and Safety Significant Components," WSRC-TR-95-0385, Rev. 0, September 1995.

ATTACHMENT 1

FA-04.02 EQUIPMENT INSPECTIONS

	INSPECTION ACTIVITIES TO SUPPORT FA-04.02 TEST PROGRAM					
		SRTC MATERIALS INSPECTIONS			NDE	
Equipment Description	Equipment No. (or Jumper No.)	Insp. Date	MTS / MCG Insp. Name / Initials	Method of Inspection Direct / Tape Review	INSPECTIONS (See Attc. 2)	Summary of Inspection Results
LPPP Sludge Tank	S511-010-020-T	11/9/95	Daugherty /	Review of Tape	VT, UT	No evidence of erosion/corrosion
LPPP Precipitate Tank	S511--030-020-T	11/8/95	Daugherty /	Review of Tape	VT, UT	No evidence of erosion/corrosion
PRBT Vessel	S350-195-020-00-T		N/A	N/A	VT, UT	No evidence of erosion/corrosion
PRBT to SRAT Jumper - orifice	ASX(12.1TP)3	10/30/95	Daugherty /	Direct Inspection	VT	No evidence of erosion on orifice plate
SRAT Vessel	S350-150-010-00-T	11/8/95	Daugherty /	Review of Tape	VT, UT	No evidence of erosion/corrosion
SRAT Sample Pump	S350-150-018-00-EV	9/8/95	Imrich /	Direct Inspection	VT,UT,PT,DA	No evidence of erosion/corrosion
SRAT Sample Discharge Jump.	403(9.3SP)2		N/A	N/A	UT	No evidence of erosion/corrosion
SRAT Coupon Racks	N/A	9/8/95	Chandler / MJC	Direct Inspection	VT, UT	See "Items of Note," No. 1
SRAT Coil Assembly	S350-150-010--02-E	11/9/95	Daugherty /	Review of Tape	VT, UT	Slight erosion on lower blades / no concern
SRAT Agitator	S350-150-015-00-AG	9/8/95	Imrich /	Direct Inspection	VT, DA	Slight erosion / no concern to equipment life
SRAT Condenser	S350-150-036-00-E	11/8/95	Daugherty /	Review of Tape	VT	No evidence of corrosion
SRAT Condenser to MWWT Ju.	(9.1C)3(10.2WT)3	11/8/95	Daugherty /	Review of Tape	VT, UT	No evidence of corrosion
SRAT Ammonia Scrubber	S350-150-019-00-V	11/8/95	Daugherty /	Review of Tape	VT	No evidence of corrosion
SRAT Condenser to FAVC Ju.	(9.1C)5-(10.7C)3		N/A	N/A	N/A	Jumper Removed from Process
SMECT Vessel	S350-150-040-00-T	9/10/95	Imrich /	Review of Tape	VT, UT	No evidence of corrosion
SMECT Coil	S350-150-030-02-E	9/12/95	Gee (DWPF-E) /	Direct Inspection	VT, UT	No evidence of corrosion
SME Vessel	S350-150-030-00-EV	9/20/95	Jenkins /	Direct Inspection	VT, UT	See "Items of Note," No. 2
SME Transfer Pump	S350-150-043-60-P		N/A	N/A	PT	No cracking of welds due to fatigue
SME Sample Pump	S350-150-038-00-P	9/11/95	Imrich /	Direct Inspection	VT,UT,PT,DA,RT	Some erosion of impeller / little concern
SME Sample Discharge Jumper	403(11.3SP)2		N/A	N/A	UT	No evidence of erosion/corrosion
SME Coil Assembly	S350-150-030-02-E	9/12/95	Daugherty /	Direct Inspection	VT, UT	See "Items of Note," No. 3
SME Condenser	S350-150-036-00-E	11/8/95	Daugherty /	Review of Tape	VT	No evidence of corrosion
SME Agitator	S350-150-035-00-AG	9/10/95	Imrich /	Direct Inspection	VT, DA	See "Items of Note," No. 4
PFSFT to SME Jumper	501(12)-(11)17		N/A	N/A	UT	No evidence of erosion
MFT Vessel	S350-190-010-00-T		N/A	N/A	VT, UT	No evidence of erosion/corrosion
MFT Sample Pump	S350-190-018-00-P	9/25/95	Chandler / MJC	Direct Inspection	VT,UT,PT,DA,RT	No evidence of erosion/corrosion
MFT Sample Discharge Jumper	404(7.3SP)2		N/A	N/A	UT	No evidence of erosion
Melter Feed Pump No. 1	S350-170-011-00-P	9/27/95	Chandler / MJC	Direct Inspection	VT, PT	Some erosion / little concern to equipment life
MF Loop No. 1 DT Assembly	(7.6DT)	9/25/95	Chandler / MJC	Direct Inspection	VT	No evidence of erosion
#1 MF Loop / Return to Tank	(7.1TP)3Y(7.6DT)1		N/A	N/A	UT	No evidence of erosion
MFT No. 1 Feed Loop Line Str.	(7.1TP)3X North	9/25/95	Chandler / MJC	Direct Inspection	VT	No evidence of erosion

	INSPECTION ACTIVITIES TO SUPPORT FA-04.02 TEST PROGRAM					
		SRTC MATERIALS INSPECTIONS			NDE	
Equipment Description	Equipment No.	Insp. Date	MTS / MCG Insp. Name / Initials	Method of Inspection Direct / Tape Review	INSPECTIONS (See Attc. 2)	Summary of Inspection Results
MFT No. 2 Feed Loop Line Str.	(7.2TP)3X South	9/25/95	Chandler / DJC	Direct Inspection	VT	No evidence of erosion
#2 MF Loop / Return to Tank	(7.2TP)3V(7.6DT)2		N/A	N/A	UT	No evidence of erosion
MFT Coil Assembly	S350-170-010-03-E	11/9/95	Daugherty / WD	Review of Tape	VT, UT	See "Items of Note," No. 5
MFT Agitator	S350-170-015-00-AG	11/21/95	Jenkins / CFJ	Direct Inspection	VT, DA	See "Items of Note," No. 6
Formic Acid Vent Condenser	S350-150-051-00-E		N/A	N/A	N/A	See "Items of Note," No. 7
Process Vessel Vent Header	N/A		N/A	N/A	VT, PT	Welds intact / no evidence of fatigue
RCT Vessel	S395-030-010-00-T		N/A	N/A	VT, UT	No evidence of erosion/corrosion
MOG Line Melter End	(22M)46-(22.24QE)2	10/30/95	Imrich / KJI	Direct Inspection	VT	See "Items of Note," No. 8
MOG Line Quencher End	501(22.24QE)	10/30/95	Imrich / KJI	Direct Inspection	VT, UT	No evidence of erosion/corrosion
OGCT Vessel	S350-190-020-00-T	11/9/95	Daugherty / WD	Review of Tape	VT, UT	No evidence of corrosion
OGCT Sample Pump	S350-190-028-00-P	10/23/95	Gee (DWPF-E) / JTB	Direct Inspection	VT, UT, PT	No evidence of corrosion
OGCT Sample Discharge Jump.	403(6.4SP)2		N/A	N/A	UT	No evidence of corrosion
OGCT Coupon Racks	N/A	11/1/95	Chandler / DJC	Direct Inspection	VT	See "Items of Note," No. 9
SAS Vessel	S350-190-129-00-F		N/A	N/A	VT at IDMS	Used IDMS inspection results
HEME Vessel	S350-190-090-00-T		N/A	N/A	VT at IDMS	Used IDMS inspection results
CDC No. 1 Recirculation Pump	S350-190-020-00-P	11/6/95	Gee (DWPF-E) / JTB	N/A	VT	No evidence of erosion
CDC No. 1 Spray Nozzle Rack	N/A	11/8/95	Gee (DWPF-E) / JTB	N/A	VT	See "Items of Note," No. 10
CDC No. 1 Jumper	359(23CD)11		N/A	N/A	UT	No evidence of erosion
CDC No. 1 Jumper	359(23CD)12		N/A	N/A	UT	No evidence of erosion
CDC No. 1 Jumper	359(23CD)13		N/A	N/A	UT	No evidence of erosion
CDC No. 2 Spray Nozzle Rack	N/A	11/7/95	Gee (DWPF-E) / JTB	N/A	VT	No evidence of erosion
MFT Hydragard Liquid Sampler	N/A		N/A	N/A	RT	No evidence of erosion/corrosion
SME Hydragard Liquid Sampler	N/A	10/16/95	Chandler / DJC	Direct Inspection	VT, RT	No evidence of erosion/corrosion
Evaluation/SME Sample Station	N/A	10/16/95	Chandler / DJC	Direct Inspection	VT, UT	No evidence of erosion/corrosion
Inspect C-276/304L Couplings	N/A		N/A	N/A	VT, UT	No evidence of galvanic corrosion
PR Perm. Sample. Lines	N/A		N/A	N/A	UT	No evidence of erosion/corrosion
SRAT Perm. Sample Lines	N/A		N/A	N/A	UT	No evidence of erosion/corrosion
SME Perm. Sample. Lines	N/A		N/A	N/A	UT	No evidence of erosion/corrosion
MFT Perm. Sample. Lines	N/A		N/A	N/A	UT	No evidence of erosion/corrosion
OGCT Perm. Sample. Line	N/A		N/A	N/A	UT	No evidence of erosion/corrosion

ATTACHMENT 1 - ITEMS OF NOTE

No. 1: SRAT Coupon Racks

Ten corrosion coupons were removed from both the vapor space and the liquid space of the Slurry Receipt Adjustment Tank (SRAT) on 9/8/95 after about 12-18 months process exposure. The coupons consisted of nickel-based alloys C-276, C-22, G30, Inconel 625, and Stellite 6. The types of coupons were flat coupons (with and without autogeneous welds) with Teflon crevice washers, galvanically coupled coupons, and U-bend coupons. Specimens were cleaned and evaluated using ASTM Standard Practice G 1-90.

The examination of the SRAT coupons revealed no evidence of significant general corrosion, localized corrosion, or stress corrosion cracking. The coupons were covered with a thin brown layer after being removed from the SRAT. The layer was easily removed from the liquid space coupons during cleaning, however, a stain remained on the vapor space coupons after cleaning. All measured corrosion rates based on 12 months of exposure for coupons in the liquid space were less than 0.1 mils per year. The maximum measured corrosion rate for the SRAT material of construction, alloy C-276, exposed to liquid was 0.02 mils per year. Slight weight gains were measured for all coupons exposed to the vapor space of the SRAT.

No. 2: SME Vessel

The SME vessel was entered for visual inspection. The condition of the tank bottom and internals were in excellent condition except for one pair of coil supports which had a significant amount of wear on one side. This is thought to be due to misalignment of the coil support structure and is not considered a serious detriment to vessel life. While not part of the FA-04 Test Program, a problem with an internal dip tube (i.e. tube being cut by internal tank deflector plate) was uncovered during the tank inspection. This problem was documented and reported to Operations for corrective action.

No. 3: SME Coil Assembly

Extensive erosion occurred to the bottom coils and downcomer pipe (i.e. cooling water supply) exposed to slurry flow along the bottom of the coil structure. Coil surfaces were polished smooth and the weld beads on the downcomer pipe was worn flush with the adjacent pipe. In worst-case areas of the downcomer pipe, wall thinning of up to 40 % was measured by UT. Additional erosion occurred to the coil supports at the bottom of the coil, with deep grooves in the supports at several locations. No evidence of corrosion was observed.

Due to eroded condition of the SME Coil Assembly, an NCR (95-NCR-05-0215) was issued. It was agreed to repair the SME Coil Assembly and "use-as-is." Repairs included restoring the coil support frame to near the original dimension with C-276 weld metal and applying a Stellite coating to surfaces exposed to direct impact by the frit slurry. Also, process piping (i.e. bottom inner coil near supports, cooling water downcomer pipe) that was eroded was built up with additional C-276 jacket material to increase the expected life. The SME Coil Assembly has been repaired and returned to service.

No. 4: SME Agitator

Erosion has been observed on the lower blades of the SME Agitator. This agitator is a DWPF first generation design. Significant erosion was observed on the back side where the blade is welded to the attachment tab. This tab is then welded to the hub on the shaft. Characteristic wear patterns (approximately 50 % through wall) were seen extending from the corners of the tab on all four blades. These wear patterns were orientated at a 45 degree angle and extended several inches towards the tip of the blades. Other less significant wear scars were observed on the lower edges of the lower blades. No significant wear was observed on the front side of the lower blades or on the shaft. Some erosion was also observed on the edges of the upper hydrofoil blades.

As a result of the erosion damage reported above, the SME Agitator shaft was replaced. The replacement shaft agitator assembly contains redesigned lower blades with Stellite (i.e. hard-face material) overlay coatings to mitigate the erosion concern. The lower blade design for the agitator shaft had been redesigned earlier as a result of erosion encountered at TNX.

No. 5: MFT Coil Assembly

Some evidence of erosion was observed on the bottom coils and downcomer pipe (cooling water supply) which were exposed to frit slurry flow underneath the coil assembly. These surfaces were polished smooth, although weld beads remained proud of the adjacent pipe. No evidence of corrosion was noted.

While the erosion of the MFT Coil Assembly was much less severe than experienced for the SME coil, significant erosion (about 15 % wall thinning) was indicated by UT on the cooling water supply pipe as it extends below the bottom coils. An NCR (95-NCR-05-0221) was written to document these findings. As part of the NCR disposition, the MFT Coil Assembly was to be repaired to extend the life of the component. This included adding additional C-276 jacket material to the area of the downcomer pipe that experienced the erosion. This work has been completed and the MFT Coil Assembly returned to service.

No. 6: MFT Agitator

The MFT Agitator demonstrated nearly identical wear patterns for the lower blades as experienced for the SME Agitator (No. 4), although the severity of the erosion was much reduced (i.e. possibly one-third the penetration depth). While the MFT Agitator could have lasted for an additional 2-3 years of service, it was decided to replace the agitator assembly with the new design with increased Stellite overlay coating. No significant erosion was observed on the upper hydrofoil blades.

No. 7: Formic Acid Vent Condenser (FAVC)

The planned inspection of the FAVC was not performed. The unit was being replaced with a reworked spare. Also, the unit was placed in an area considered inaccessible for inspection. Given the FAVC is considered a very low risk for erosion/corrosion damage, the lack of an inspection of this vessel was not considered a major concern.

No. 8: MOG Line Melter End

Visual inspection of the melter offgas (MOG) line (Inconel 690) showed evidence of pitting attack similar to that observed on the film cooler brush. Pits were observed around the entire circumference of the vertical section of pipe at the inlet to the offgas line. The deepest pits in this section of the pipe were observed just below the film cooler brush and above the top of the 90 degree elbow. Pit depths ranged from approximately 0.025 " to 0.060 " (unofficial for information only). Some pits were observed in the MOG line at the 180 degree bend before the isolation valve. These pits were found during a remote visual inspection performed in April 1995 and did not appear to be very deep. The isolation valve and MOG line after the valve appeared to be in excellent condition.

No. 9: OGCT Coupon Racks

Nine corrosion coupons were removed from both the vapor space and the liquid space of the Off Gas Condensate Tank (OGCT) on 10/23/95 after about 15-18 months process exposure. The coupons consisted of 316L stainless steel and nickel-based alloys C-276, C-22, G30, CW7M, and Inconel 625. The types of coupons were flat coupons (with and without autogeneous welds) with Teflon crevice washers, galvanically coupled coupons, and U-bend coupons. Specimens were cleaned and evaluated using ASTM Standard Practice G 1-90.

The examination of the OGCT coupons revealed no evidence of significant general corrosion, localized corrosion, galvanic corrosion, or stress corrosion cracking. The liquid space coupons were covered with a thin brown layer after being removed from the OGCT. The layer was easily removed from the liquid space coupons during cleaning. Most of the vapor space coupons did not have a coating after being removed from the OGCT. All measured corrosion rates based on 15 months of exposure for coupons in the liquid and vapor space were less than 0.1 mils per year. The maximum measured corrosion rate for the OGCT material of construction, alloy C-276, was 0.05 mils per year in the liquid space.

No. 10: CDC No. 1 Spray Nozzle Rack

In general, the Canister Decon (#1) spray nozzles appeared to be in good condition. Three of the seven boron carbide insert tubes that fit inside the frit feed nozzles (i.e. for blasting canister side walls) had small chips missing at the frit discharge end. This was thought to be from mechanical damage (e.g., installation, bumped by canisters, etc.) but did not appear severe enough to impact the life of the nozzle. All eleven of the rinse nozzles were in good condition. The stainless portion of the ribbon nozzles showed significant erosion/corrosion. Most of this appeared to be crevice and/or other forms of localized corrosion. It is theorized that it occurred as a result of frit being deposited on the stainless steel during cleaning operations, since portions of the stainless steel that should only see air had the noted crevice corrosion. Similar inspections on the CDC No. 2 ribbon nozzle which had a similar service life did not show the crevice corrosion. It is possible that the noted corrosion on the No. 1 ribbon nozzle was a result of a one time improper cleaning after use and may not be a major concern.

ATTACHMENT 2

PREDICTED EQUIPMENT LIFE

Equipment Description	Materials of Construction	Total Operating Time at Inspection	No. of Process Batch Cycles Com.	Primary Materials Concern to Component	Predicted Additional Service Life
LPPP Sludge Tank	304L	12-18 months	N/A	No materials concern	Life of Facility
LPPP Precipitate Tank	304L	12-18 months	N/A	No materials concern	Life of Facility
PRBT Vessel	C-276	12-18 months	17	No materials concern	Life of Facility
SRAT Vessel	C-276	12-18 months	17	No materials concern	Life of Facility
SRAT Sample Pump	C-276	180 hours	N/A	No materials concern	5 year (Note 3)
SRAT Coil Assembly	C-276	10.1 months (Note 1)	17	No materials concern	Life of Facility
SRAT Agitator	C-276	10.1 months	N/A	Slight erosion on lower blades	5 year (Note 3)
SRAT Condenser	C-276	N/A	17	No materials concern	Life of Facility
SRAT Ammonia Scrubber	316L	N/A	N/A	No materials concern	Life of Facility
SMECT Vessel	316L	12-18 months	N/A	No materials concern	Life of Facility
SMECT Coil	316L	N/A	N/A	No materials concern	Life of Facility
SME Vessel	C-276	15-18 months	17	Erosion of tank floor, guides	Life of Facility
SME Transfer Pump	C-276	30 hours	17	Erosion of impeller, piping	5 year (Note 3)
SME Sample Pump	C-276	170 hours	17	Erosion of impeller, piping	5 year (Note 3)
SME Coil Assembly	C-276	14.1 months (Note 1)	17	Erosion of bottom structure	Inspect after 2 years
SME Condenser	C-276	N/A	17	No materials concern	Life of Facility
SME Agitator	C-276	14.1 months	N/A	Erosion of agitator blades	Inspect after 3 years
MFT Vessel	C-276	15-18 months	17	No materials concern	Life of Facility
MFT Sample Pump	C-276	310 hours	17	Erosion of impeller, lines	5 year (Note 3)
Melter Feed Pump No. 1	C-276	3.3 months	17	Erosion of impeller, lines	5 year (Note 3)
MFT Coil Assembly	C-276	14.2 months (Note1)	17	Erosion of bottom structure	5 year (Note 3)
MFT Agitator	C-276	14.2 months	N/A	Erosion of agitator blades	5 year (Note 3)
Process Jumpers - no frit	C-276, 316L	N/A	17	Minimal materials concern	Inspect after 5 years (Note 4)
Process Jumpers - with frit	C-276	N/A	17	Minimal materials concern	Inspect after 5 years (Note 4)
RCT Vessel	C-276	N/A	N/A	No materials concern	Life of Facility
MOG Line Melter End	I690	11.5 months (Note 2)	N/A	Corrosion/pitting on I690 line	Replace after 3 years
MOG Line Quencher End	ALLCORR	11.5 months (Note 2)	N/A	No materials concern	Life of Facility
OGCT Vessel	C-276	15-18 months	N/A	No materials concern	Life of Facility
OGCT Sample Pump	C-276	< 200 hours	N/A	No materials concern	5 year (Note 3)
SAS Vessel	C-276	11.5 months	N/A	No materials concern	Life of Facility
HEME Vessel	C-276	11.5 months	N/A	No materials concern	Life of Facility

ATTACHMENT 2

PREDICTED EQUIPMENT LIFE

Equipment Description	Materials of Construction	Total Operating Time at Inspection	No. of Process Batch Cycles Com.	Primary Materials Concern to Component	Predicted Additional Service Life
CDC No. 1 Recirculation Pump	304L	N/A	about 60 canisters	No materials concern	5 year (Note 3)
CDC No. 1 Spray Nozzle Rack	304L	N/A	about 60 canisters	Crevice corrosion on ribbon nozzle	Inspect ribbon nozzle / 5 years
CDC No. 2 Spray Nozzle Rack	304L	N/A	about 60 canisters	Crevice corrosion on ribbon nozzle	Inspect ribbon nozzle / 5 years
MFT Hydragard Liquid Sampler	C-276	310 hours	N/A	No materials concern	Life of Facility
SME Hydragard Liquid Sampler	C-276	170 hours	N/A	No materials concern	Life of Facility
SME Sample Station	304L	170 hours	N/A	Possible erosion/corrosion of tubing	2 year minimum / run to failure
PR Perm. Sample. Lines	C-276	450 hours	N/A	No materials concern	Life of Facility
SRAT Perm. Sample Lines	C-276	180 hours	N/A	No materials concern	Life of Facility
SME Perm. Sample. Lines	C-276	170 hours	N/A	No materials concern	Life of Facility
MFT Perm. Sample. Lines	C-276	310 hours	N/A	No materials concern	Life of Facility
OGCT Perm. Sample. Line	C-276	< 200 hours	N/A	No materials concern	Life of Facility

NOTES

1) It was assumed that the most significant factor on the erosion/corrosion rates for coil assemblies would be amount of time the agitator was in service. For this reason, the "total operating time at inspection" for the coil assemblies was made equivalent to the agitators.

2) The "total operating time at inspection" for the Quencher and MOG lines was assumed to be equal to the OGCT Quencher Pump.

3) The design life for the process pumps and agitators was five years. It is predicted that materials issues will not reduce the life of these components.

4) Several of the process jumpers may be impacted by erosion/corrosion. If acceptable from a process standpoint, the jumpers can be used until failure (i.e. pitting or localized thinning expected). If such failure is not acceptable the jumpers should be inspected at convenient outage after about five years service.

Reviewed by DWPF Materials Committee on 11/13/95

G. T. Chandler, Chairman

11/15/95
DATE

ATTACHMENT 3

S

Quality Control
Condition Report

AID-QCM- 950127
JOB NO: S950513
Retention: 2 Years
Keywords: Tanks
Jumper
Coils
Pump

Distribution
J. T. Gee, 704-25S
S. F. Piccolo, 704-S
W. D. Kerley, 704-25S
E. J. Freed, 704-25S
K. R. Jones, 704-26S
P. Smock, A&IQ/QC, 730A
W. R. Hinz, A&IQ/QC, 730A
Vlad Cech, A&IQ/QC, 730A
M. W. Trimm, A&IQ/QC, 730A
A. Reynolds, A&IQ/QC, 730A
J. Elder, A&IQ/QC, 730A

D. G. Bevard, A&IQ, 703-A
O. L. Gaston, A&IQ/QC, 730-A
R. E. Sprayberry, A&IQ/QC, 730-A
730-A QC Files

Page: 1 of 12

Date: 11/16/95

Reported By: J. G. Dickinson	Inspectors/Level: R. F. Holmes L-II (VT, PT & UT), J. Elder L-III (UT) L-II (VT & PT), J. McCall L-II (VT, PT & UT) P. Gibbons L-II (VT, PT & UT)
Equipment Examined: See Table 1	
Location: 221-S	IP, IDP, Pipe, Part #: See Table 1
Date of Examination: See Table 1	Time in Service: ~2 Years
Service Condition: NA	Materials of Construction: Stainless Steel Hastelloy
NCR Number (If applicable): NA	
Inspection Procedure (number and title): NDEP 4.1 General Visual, NDEP 6.1 Liquid Penetrant & NDEP 7.1 Ultrasonic Thickness Examination	
Acceptance Criteria/source): NONE PROVIDED BY CUSTOMER	

Inspection Summary:

INTRODUCTION

Administrative & Infrastructure Quality (Formally Site Services Quality), utilized the following nondestructive methods during outage FA-04: liquid penetrant, visual, ultrasonic and radiography. The examination methods, report numbers and inspectors are listed in table 1 of this report. Previous report numbers and results are also provided in table 1. This report is issued as a **"Condition Report"**, since no acceptance criteria was provided. The responsible systems engineer will be required to determine the final acceptability of all items listed in this report. This is the final report, copies of all individual NDE reports were provided to the FA-04.02 Test Coordinator and are also maintained in our files listed under Job # S950513. Radiography test results are contained in Job file numbers S950640, S950641, S950645 and S950646.

RS 11/17/95

Inspection Summary Cont.:

INSPECTION METHODOLOGY

The examinations performed during this outage were done utilizing the same techniques and examination methods during the collection of the base line data. Some examinations were in fact base line data and therefore could not be compared with previous data.

DATA COMPARISON/RESULTS

Small Bore Piping

A comparison of the ultrasonic thickness data from the small diameter piping, obtained during the recent outage, and the baseline data (1990) indicated a decrease in thickness of 0.010 - 0.020". Data point correlation was excellent on both large and small diameter components. The apparent change in thickness prompted an in-depth analysis of the data on the small diameter components. The baseline data reports were reviewed to determine if technique or equipment factors contributed to the difference. The baseline technique and calibrations were reproduced using the same type of equipment used during the baseline examinations. A comparison was then performed where the baseline technique and three currently used techniques were used to measure the same component. The baseline technique consistently provided 0.008 - 0.012" thicker readings.

The differences are attributed to:

* The advancements in ultrasonic transducer technology for specialized applications such as wall thickness measurement of small diameter tubing.

* The refinement of ultrasonic equipment and calibration techniques.

Based on the technique comparison data, we determined that a correction factor of 93% was needed to make the appropriate comparisons to the baseline data. The correction factor was applied to the baseline data in the ultrasonic thickness plots (1 & 2). With the exception of limited areas of the SME coil piping, the remaining piping shows no reduction in wall thickness.

Tanks

Comparison of the process tank data shows virtually no change.

Radiography of Sample Line Components

Radiographs for the SME and MFT (pump) sample line "pick-up points" were compared to similar radiographs taken in 1990. The comparison reveals no apparent erosion /corrosion which would effect the sample characteristics going to the analytical sample cell. Radiographs were also performed for the SME and MFT Hydragard liquid samplers. Results showed no apparent erosion/corrosion which would effect sample characteristics.

Systems Overall Condition

Other than the wall loss in SME coil no significant erosion or corrosion conditions were detected during this outage.

Data collected using several different UT Equipment combinations. The 26DL data was collected in the same manner as the baseline data. The Sonopen, DA312, and 5Mhz Delay tip data were all collected using a USN 50 UT scope (EQ. used in 9/95)
The data was collected on a 1/2" schedule 40. Stainless steel pipe section that included an elbow.
The 26DL (Digital Thickness Gauge) data consistently reads thickner than actual thickness.

FIGURE 1

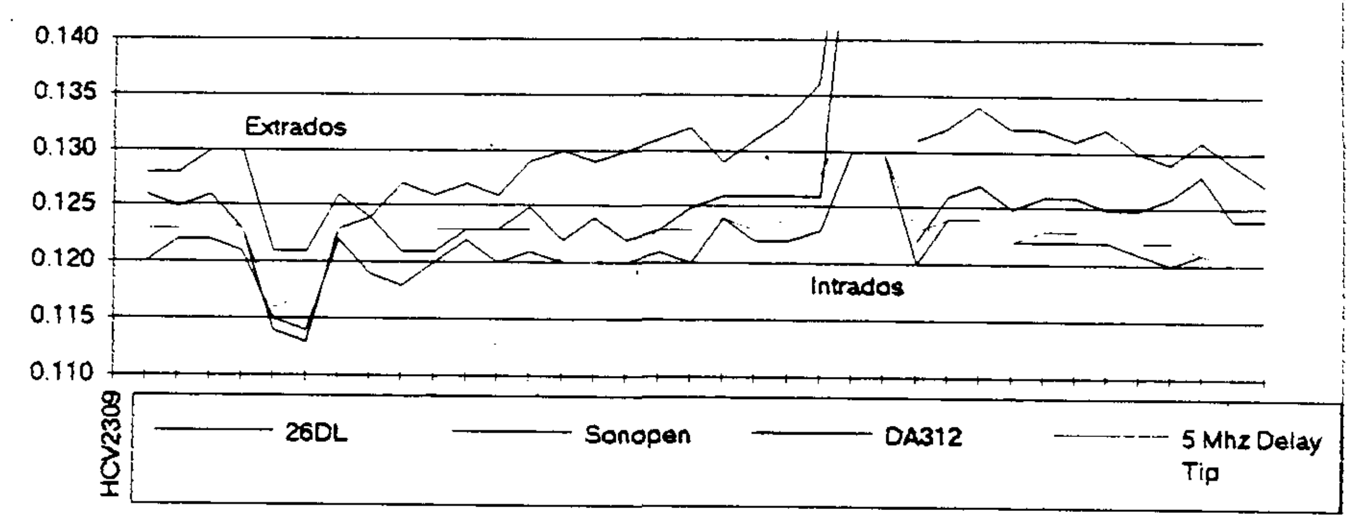
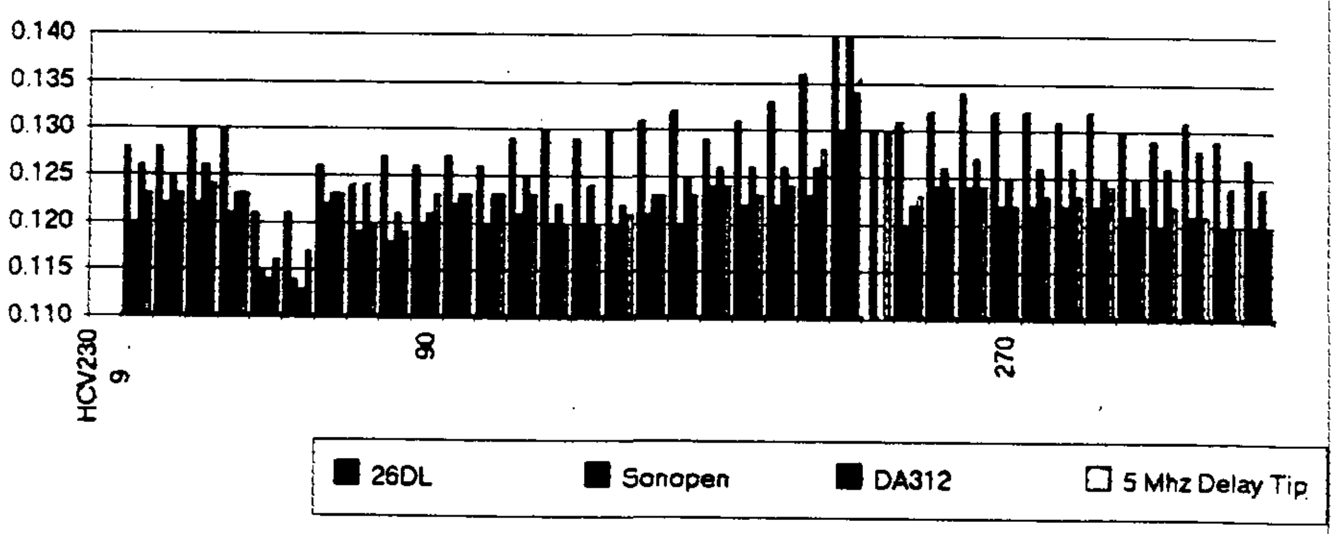


FIGURE 2



DWPF OUTAGE FA-04

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
CDC	Cansiter Decon Cage #1	S360-600-030	95-IR-06-VT-1058	P. Gibbons L-II 11-7-95	No VT indications noted.
CDC	Cansiter Decon Cage #2	S360-600-060	95-IR-06-VT-1059	P. Gibbons L-II 11-7-95	No VT indications noted.
CDC	Recirculation Pump Decon #1	S360-600-033-00-P	95-IR-06-VT-1060 95-IR-06-UT-1061 95-IR-06-PT-1062	P. Gibbons L-II B. Holmes L-II 11-6-95	0.135" to 0.209" 0.430" to 0.452"
CDC	CDC Jumper	358(23CD)12	95-IR-06-VT-1063 95-IR-06-UT-1067	J. Elder L-III B. Holmes L-II 11-2-95	0.100" No VT indications noted.
CDC	CDC Jumper	359(23CD)13	95-IR-06-VT-1064 95-IR-06-UT-1068	J. Elder L-III B. Holmes L-II 11-2-95	0.181" No VT indications noted.
CDC	CDC Jumper	357(23CD)11	95-IR-06-VT-1065 95-IR-06-UT-1066	J. Elder L-III B. Holmes L-II 11-2-95	0.111" No VT indications noted.
LPPP	LPPP Precipitate Tank	S511-030-020-00	95-IR-06-UT-0890 95-IR-06-VT-0891	P Gibbons L-II J. Elder L-II J. McCall L-II 9-9-95	0.471" Baseline No VT indications noted.

DWPF OUTAGE FA-04

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
LPPP	LPPP Sludge Tank	S511-010-020-00-T	95-IR-06-UT-0986 95-IR-06-VT-1069	P Gibbons L-II B. Holmes L-II 10-11-95	0.493" Baseline No VT indications noted.
MFT	Return Loop to Tank Jumper	(7.1TP) 3Y (7.6DT) 1	95-IR-06-VT-0990	B. Holmes L-II P. Gibbons L-II 10-3-95	No VT indications noted.
MFT	Melter Feed Loop #1 DT Assembly	(7.6DT)	95-IR-06-VT-0991 95-IR-06-PT-0992	B. Holmes L-II P. Gibbons L-II 10-3-95	No VT/PT indications noted.
MFT	Sample Pump Discharge Jumper	404(7.3SP)2	95-IR-06-UT-0883	J. B. Elder L-III 9-24-95	0.092"
MFT	Melter Feed #1 Loop Line Strainer	(7.1TP) 3X (North)	95-IR-06-VT-0884	B. Holmes L-II P. Gibbons L-II 9-26-95	Baseline No VT indications noted.
MFT	Melter Feed #2 Loop Line Strainer	(7.1TP) 3X (South)	95-IR-06-VT-0885	B. Holmes L-II P. Gibbons L-II 9-26-95	Baseline No VT indications noted.
MFT	Melter Feed Pump #1	S-350-170-011-00-P	95-IR-06-VT-0994 95-IR-06-UT-0995 95-IR-06-PT-0996	B. Holmes L-II P. Gibbons L-II 9-27-95	Suction Line 0.151" Discharge Line 0.141" Return Line 0.146" Return Line 0.124" Baseline No VT/PT indications noted.

DWPF OUTAGE FA-04

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
MFT	Melter Feed Sample Pump	S-350-170-018-00	95-IR-06-PT-0876 95-IR-06-UT-0877 95-IR-06-VT-0987	P. Gibbons L-II J. Elder L-III 9-22-95	Intake 2" Line 0.144" Return 1 1/2" Line 0.115" Sample Pump Outlet 1/2" line 0.095"
MFT	Melter Feed Cooling Coil	S-350-170-010-03-E	95-IR-06-VT-0880 95-IR-06-UT-0879	B. Holmes L-II P. Gibbons L-II 9-27-95	No VT indications noted. 0.142"
MFT	Melter Feed Agitator	S-350-170-015-00-AG	95-IR-06-VT-0878	B. Holmes L-II 9-25-95	No VT indications noted.
MFT	Melter Feed Line Jumper	257(7.2TP)3	95-IR-06-UT-0881 95-IR-06-VT-0882	P. Gibbons L-II 9-24-95 J. Elder L-II 9-23-95	No VT indications noted. 0.115"
MFT	Melter Feed Return Line Loop to Tank Jumper	(7.2TP)3V (7.6DT0)2	95-IR-06-VT-0989	P. Gibbons L-II B. Holmes L-II 10-3-95	No VT indications noted.
MFT	MFT Sample Lines	SSX-231-P213-1/2A 221-S Nozzle Box & West Canyon wall.(1) SRX-181-P213-1/2B 221-S Nozzle Box & Canyon wall. (2)	95-IR-06-UT-0898	B. Holmes L-II 9-18-95	0.093"
MFT	Tank	S350-170-010-00-T	95-IR-06-UT-0874 95-IR-06-VT-0875	J. B. Elder L-III J. McCall L-II 9-15-95	Tank Bottom 0.747" Shell 0.495"

DWPF OUTAGE FA-04

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
OGCT	Pump	S350-190-028-00	95-IR-06-UT-1046 95-IR-06-PT-1045 95-IR-06-VT-1044	P. Gibbons L-II J. Elder L-II 10-23-95	Intake 0.148" Outlet 0.127" Sample 0.095" No VT/PT indications noted.
OGCT	Tank	S350-190-020-00-T	95-IR-06-UT-0886 95-IR-06-VT-0887	P. Gibbons L-II J. Elder L-II 10-23-95	Tank Bottom 0.751" Shell 0.489" No VT indications noted.
OGCT	Sample Pump Jumper	403(6.4SP)2	95-IR-06-UT-0993	P. Gibbons L-II J. Elder L-II 10-23-95	(1) 0.094" (2) 0.094"
OGCT	OGCT Sample Lines	SSX-187-P213-1/2A 221-S Nozzle Box & West Canyon wall. SRX-137-P213-1/2B 221-S Nozzle Box & Canyon wall	95-IR-06-UT-0898	B. Holmes L-II 9-18-95	0.087"
OGCT	Sample Cell Line Mezz. Level	SSX 137 and SRX 137	95-IR-06-VT-1048 95-IR-06-UT-1049	B. Holmes L-II P. Gibbons L-II 10-16-95	0.102" Baseline No VT indications noted.
PFSFT	PFSFT to SME Jumper	501(12)-(11)-17	95-IR-06-UT-0988	B. Holmes L-II P. Gibbons L-II 10-3-95	0.139"
POGL	Primary Off Gas Line	S350-190-017-01	95-IR-06-VT-1071	P. Gibbons L-II 10-31-95	No VT indications noted.

DWPF OUTAGE FA-04

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
PR	PR Sample Lines	SSX-211-P213-1/2A 221-S Nozzle Box & West Canyon wall. SRX-161-P213-1/2B 221-S Nozzle Box & Canyon wall	95-IR-06-UT-0898	B. Holmes L-II 9-18-95	(1) 0.093" (2) 0.093"
PR	Sample Cell Line Mezz. Level	SSX 117 and SRX 161	95-IR-06-VT-1048 95-IR-06-UT-1049	B. Holmes L-II P. Gibbons L-II 10-16-95	0.097" Baseline
PRBT	PRBT to SRAT Feed Jumper	ASX(12.1TP)3	95-IR-06-VT-1037	J. ELDER L-II P. Gibbons L-II 10-3-95	No VT indications noted.
PRBT	PRBT Tank	S999-395-030-10-T (RCT Spare Tank)	95-IR-06-UT-0892 95-IR-06-VT-0893	J. Elder L-III J. McCall L-II 9-14-95	0.493" Base Line No VT indications noted.
PVV	PVV Header Piping	#129	95-IR-06-PT-0894 95-IR-06-VT-0895 North & South Piping Welds	J. McCall L-II J. Elder L-II	No VT/PT indications noted.
Quencher	Primary Quencher	S350-190-017-02	95-IR-06-UT-1038 95-IR-06-VT-1039	J. Elder L-III P Gibbons L-II 10-31-95	0.376" No VT indications noted.
RCT	RCT Tank	S350-150-010-00-E	95-IR-06-UT-0888 95-IR-06-VT-0889 95-IR-06-VT-1047 Internals	J. Elder L-III J. McCall L-II 9-12-95 B. Holmes L-II P. Gibbons L-II 10-17-95	0.772" No VT indications noted.

DWPF OUTAGE FA-04

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
SME	Sample Cell Line Mezz. Level	SSX 121 and SRX 171	95-IR-06-VT-1048 95-IR-06-UT-1049	B. Holmes L-II P. Gibbons L-II 10-16-95	0.097" No VT indications noted.
SME	SME Tank	S350-150-030-00-EV	95-IR-06-UT-0855 95-IR-06-VT-0856 95-IR-06-VT-0857 Internals 95-IR-06-VT-1051 After Dip Tube Repair	J. Elder L-III J. McCall L-II 9-14-95	Lower Head 0.745" Shell 0.491" No VT indications noted.
SME	SME Transfer Pump	S350-150-043-60	95-IR-06-PT-0858	P. Gibbons L-II 9-19-95	No PT indications noted.
SME	SME Condenser	S350-150-036-00-E	95-IR-06-UT-0863 95-IR-06-VT-0864	P. Gibbons L-II J. ELDER L-II 9-13-95	0.196" No VT indications noted.
SME	SME Cooling Coil	S350-150-030-02-E	95-IR-06-VT-0865 95-IR-06-UT-0866	P. Gibbons L-II B. Holmes 9-12-95	0.088" lowest area Rpt.'d and area was repaired. No VT indications noted.
SME	SME Jumper	403(11.3SP)2	95-IR-06-UT-0867	J. Elder L-III 9-10-95	Left 0.091" Right 0.094"
SME	For SME Coil U-Bend & Elbow Comparsion Test, U-Bend Representative of SME & SRAT	NA	95-IR-06-UT-0998	P. Gibbons L-II B. Holmes 9-12-95	0.137"

DWPF OUTAGE FA-04

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
SME	SME Sample Pump	S350-150-038-00-P	95-IR-06-UT-0859 95-IR-06-VT-0860 95-IR-06-PT-0861	B. Holmes L-II P. Gibbons L-II J. Elder L-II J. McCall L-II 9-14-95	0.093" On Sample 1/2" Line No VT/PT indications noted.
SME	SME Agitator Blades	S350-150-035-00-AG	95-IR-06-UT-0862	B. Holmes L-II J. McCall L-II 9-12-95	0.033" Lower blade "A" item has been repaired.
SME	SME Sample Lines	SSX-221-P213-1/2A 221-S Nozzle Box& West Canyon wall.(1) SRX-171-P213-1/2B 221-S Nozzle Box & Canyon wall (2)	95-IR-06-UT-0898	B. Holmes L-II 9-18-95	(1) 0.085" to 0.118" (2) 0.097" to 0.106"
SMECT	SMECT Tank	S350-150-040-00-T	95-IR-06-UT-0868 95-IR-06-VT-0870 95-IR-06-VT-0869 95-IR-06-VT-1052 After Dip Tube Repair	J. Elder L-III J. McCall L-II 9-10-95	Tank Bottom 0.862" Shell 0.511"
SMECT	SMECT Transfe Pump	S350-150-045-00-P	95-IR-06-PT-0871	P. Gibbons L-II 9-19-95	No PT indications noted.
SMECT	SMECT Cooling Coil	S350-150-040-02-E	95-IR-06-PT-0872 95-IR-06-UT-0873 95-IR-06-VT-1070	B. Holmes L-II 9-19-95	0.139" No VT/PT indications noted.
SRAT	SRAT Sample Lines	SSX-229-P213-1/2A 221-S Nozzle Box & West Canyon wall.(1) SRX-179-P213-1/2B 221-S Nozzle Box & Canyon wall (2)	95-IR-06-UT-0898	B. Holmes L-II 9-18-95	(1) 0.080" to 0.120" (2) 0.097" to 0.112"

DWPF OUTAGE FA-04

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
SRAT	SRAT Cooling Coil	S350-150-010-02-E	95-IR-06-VT-1050 95-IR-06-UT-0851	P. Gibbons L-II J. Elder L-III 9-9-95	0.140" No VT indications noted.
SRAT	SRAT Condenser Jumper	(9.1C)3-(10.2WT)3	95-IR-06-VT-0853 95-IR-06-UT-0852	P. Gibbons L-II J. Elder L-III 9-11-95	0.107" to 0.103" No VT indications noted.
SRAT	SRAT Condenser Jumper	403 (9.3SP)2	95-IR-06-VT-0854	J. Elder L-III 9-11-95	Left 0.098" Right 0.097" No VT indications noted.
SRAT	SRAT Condenser T Section on SRAT Condenser	(9.1C)3-(10.2WT)3	95-IR-06-UT-0849	P. Gibbons L-II 9-12-95	0.195"/0.191" BASE LINE
SRAT	SRAT Condenser	S350-150-016-00-E	95-IR-06-VT-0850	P. Gibbons L-II J. Elder L-II 9-12-95	No VT indications noted.
SRAT	SRAT Sample Pump	S350-150-018-00	95-IR-06-VT-0847 95-IR-06-PT-0845 95-IR-06-UT-0846	B. Holmes L-II J. McCall L-II J. Elder L-II 9-10-95	Sample Line 0.103" Outlet 0.137" Suction 0.154" No VT/PT indications noted.
SRAT	SRAT Tank	S350-150-010-00-EV	95-IR-06-UT-0842 95-IR-06-VT-0843 (Int.) 95-IR-06-VT-0844	B. Holmes L-II J. McCall L-II J. Elder L-II 9-10-95	Tank Bottom 0.758" Shell 0.472" No VT indications noted.

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DWPF OUTAGE FA-04

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
SRAT	SRAT Agitator	Blades	95-IR-06-VT-0848	P Gibbons L-II 9-8-95	No VT indications noted.
SRAT	SRAT Ammonia Scrubber	S350-150-019-00-V	95-IR-06-VT-0997	B. Holmes L-II P Gibbons L-II 9-8-95	No VT indications noted.
SRAT	Sample Cell Line Mezz. Level	SSX 221 and SRX 179	95-IR-06-VT-1048 95-IR-06-UT-1049	B. Holmes L-II P. Gibbons L-II 10-16-95	0.102" No VT indications noted.

ATTACHMENT 4

INTER-OFFICE MEMORANDUM
SAVANNAH RIVER SITE

OPS-DTE-950145
Key words: DWPF

TO: W. D. Kerley, 704-25S

FROM: J. T. Gee J. T. Gee, 704-25S

CC: S. F. Piccolo, 704-S
E. J. Freed, 704-25S

DATE: November 17, 1995

SUBJECT: Removal of Test Inspection Requirements from the FA-04 Test Plan (U)

Per the FA-04 Test Plan, you are authorized to delete the requirements of inspection activities that are ranked "3" (i.e. "non-intent change to test plan"). Based on review of Attachment I of the FA-04 Test Plan (i.e. "Inspection Activities to Support FA-04"), several activities with a ranking of "3" could not be performed. These inspection activities are listed below along with an explanation as to why these activities were not performed. If you agree with removing these activities from the FA-04 inspection requirements, please sign the concurrence block at the end of this letter.

1) SRAT Condenser to FAVC Vent Jumper

Technical Justification: The subject jumper is no longer in the process.

2) SRAT Ammonia Scrubber (UT data not performed)

Technical Justification:

Remote video inspection of the SRAT scrubber indicated that the vessel walls were in excellent condition with no evidence of localized corrosion. The scrubber is fabricated from 316L stainless steel which has excellent resistance to dilute nitric acid as expected in the SRAT scrubber (Reference: ASM Handbook of Corrosion Data, page 378) service environment. For these reasons, it was concluded that there was no need to perform the UT on the vessel walls. Given the low expected corrosion rates, wall thinning would not be measurable. UT data was collected on the SMECT sample pump and vessel which are also fabricated from 316L stainless steel and have a similar chemistry to the scrubber. The elimination of the UT data would prevent the need to remove the SRAT ammonia scrubber from service.

3) Formic Acid Vent Condenser (FAVC)

Technical Justification:

The FAVC was removed from service and replaced with a reworked spare unit. It was concluded that a formal inspection of the vessel was not justified. This was based largely on the short exposure of the equipment (i.e. about 6 months) and the low risk of corrosion for the FAVC. The FAVC is fabricated from 316L stainless steel which has excellent resistance to formic acid at all concentrations up to ambient temperatures and up to 5 % formic at atmospheric boiling (Reference: ASM Handbook of Corrosion Data, page 277). Given the low temperatures and formic concentrations expected in the condenser, corrosion should not be an issue and the need for the inspection could be waived.

4) SAS Vessel / HEME Vessel

Technical Justification:

To minimize the cost and schedule impact to DWPF, Management requested that credit be taken for IDMS inspection activities wherever technically justified. DWPF-E personnel concluded that recent inspection of the IDMS SAS and HEME equipment could be used in lieu of DWPF planned inspections. This approach was approved by the DWPF Materials Committee.

The IDMS inspections downstream of the quencher confirmed that corrosion was insignificant. This was based on both visual inspections and review of coupons placed in the IDMS SAS and HEME vessels. Given the longer service exposure for the IDMS components and the lack of corrosion evidence, it was concluded that there was no need to perform the inspections at DWPF.

Taking credit for the IDMS off-gas inspections eliminated the need at DWPF to either remove equipment for inspection or build access scaffolding. This saved both cost and schedule impact, without significant loss of technical information.

Concurrence By:

W. D. Kerley

W. D. Kerley, DWPF-E

11/17/95

DATE

APPENDIX 1

DWPF FA-04.03 FIELD COMPLETION REPORT

SALT PROCESS CELL (SPC)

PROCESS VESSELS EROSION/CORROSION STUDIES

PREPARED BY: J. T. Gee, DWPF-E

DATE PREPARED: February 1, 1996

Summary / Conclusions

Required field work and data collection for the FA-04.03 test program, "Process Vessels Erosion/Corrosion Studies," for the Salt Process Cell (SPC) has been completed. Test results indicate that erosion/corrosion of SPC process equipment is not a concern and the existing SPC equipment, with two exceptions (i.e. PR and PRFT sample pump dip tube assemblies), will achieve its "design life" and will be acceptable for radioactive operation. This is based on evaluation of corrosion coupon data removed from the Precipitate Reactor (PR) as well as UT and VT data obtained on various components of SPC plant equipment. A final detailed report will be issued next two months with combined input from both DWPF and SRTC and will include results from all DWPF materials evaluation testing.

Introduction / Objective

The FA-04.03 test program, Process Vessel Erosion/Corrosion Studies, has been completed for the Salt Process Cell (SPC). An earlier report was issued for the Chemical Process Cell which included all non-SPC equipment included in the test program.

The objective of the FA-04.03 test program was to collect process data and perform field inspections on critical SPC equipment. This test phase is a follow-up to the FA-04.01 evaluation, Process Vessels Erosion/Corrosion - Baseline, reported in 1992. The current inspection data will be used in conjunction with the baseline data to determine the suitability of DWPF equipment for radioactive operation. This work has now been largely completed. This document provides preliminary findings which demonstrate that existing equipment is suitable for radioactive operations. In addition, this report provides objective evidence that the inspection activities defined in the FA-04 Test Plan (i.e. Attachment 1 in the Test Plan) have been performed. A final report will be issued by April '96 with combined input from both DWPF and SRTC on all materials evaluation studies performed at DWPF (i.e. Test Programs FA-04, FA-05, etc.).

While this is not a final report with all of the supporting data, sufficient review of individual inspection reports and field data has been performed to ensure that existing SPC plant equipment is adequate for radioactive operations.

Objective Evidence that Test Requirements Have Been Completed

The FA-04 Test Plan required that certain equipment field inspections and process data collection be performed. The required work has been completed as outlined in the following paragraphs.

All of the planned field work for the FA-04.03 test program has been completed. This is documented in Attachments 1 and 3 for the SRTC materials inspections and NDE inspections respectively.

Collection of equipment run-time and operating speed data was performed for selected process pumps and agitators. Run-time data was based on a combination of manual logs, PIMS data and estimates based on operating logs. This is due to recent PIMS upgrades. Some PIMS historical data was available. Data on equipment operating speed was not available through PIMS, so it was limited to that obtained on manual operating logs during the 1993/1994 test phases. Most of the operating speed data can be obtained or estimated from knowledge of plant operating conditions. For example, the PR and PRFT agitators operate at fixed rpm, so speed is readily known.

Chemical data was collected on process streams per the FA-04 test requirements. In regard to the SPC, this included the PR feed and PR product. Since the primary concern was for corrosion, the solution pH and level of aggressive ions was monitored.

Assessment of Predicted Equipment Life

Inspection results indicate that with two exceptions, outlined below, all of the SPC equipment will achieve its "design life" and will be acceptable for radioactive operation. Design life for the subject equipment is defined to be (Ref. 1):

1) Twenty years for permanent piping system (i.e. sample lines, etc.)
2) Twenty years for major process vessels (i.e. tanks, etc.)
3) Five years for replaceable equipment such as pumps, coils and agitators
4) One year (minimum) for replaceable "on-site fabricated equipment" such as process jumpers

Attachment 2 provides a list of all SPC equipment detailing the cumulative service exposure to date and the "predicted additional service life" remaining. Note that these estimates are based on the consensus opinions of members on the DWPF Materials Committee. With the exception of the PR and PRFT sample pump dip tube assemblies, all of the equipment should match or exceed its design life basis. The "predicted additional service life" estimates reported in Attachment 2 take credit for rework to the dip tube assemblies (Attachment 1, Item of Note, No 1). This required rework would likely include additional supports or cross braces between the dip tube piping. Without the rework the life of the equipment would be significantly below that reported in Attachment 2.

Preliminary Inspection Results

General statements concerning the equipment inspection results are provided in the following paragraphs.

Six process tanks were inspected for evidence of corrosion. None of the tanks showed evidence of localized corrosion. This was based on remote visual inspections of the tank interior. Measurements on wall thinning could not be performed due to double wall tank design for these vessels.

Corrosion of the SPC equipment was found to be negligible, confirming the appropriate selection of material. The suitability of the materials of construction was confirmed by both direct inspection of the equipment and by evaluation of corrosion coupons.

Analytical testing of the process streams during cold run testing demonstrated that the process chemistry was largely bounded by test solutions used to select materials of construction (Ref. 2). This implies that criteria used to select the materials are still valid.

Problems had been detected earlier with mechanical fatigue at welds in the SMECT process pumps. While the SMECT pumps are of a different design than used for the SPC process pumps, several critical welds on the PR sample pump were examined to determine if fatigue damage had occurred. PT testing confirmed that four of the eight welds showed reportable indications . For this reason, the PRFT sample pump (identical) and the PRFT transfer pump were pulled for weld inspections. PT testing on the PRFT sample pump confirmed reportable indications on two of eight welds. (All of the indications were on welds contained in the dip tube assemblies.) None of the five welds examined on the PRFT transfer pumps had a positive indication from the PT testing. An NCR (96-NCR-05-0030) was issued to track the repair of the dip tube assemblies.

As a result of concern over possible mechanical fatigue damage, Operations requested that PT examinations be performed on four themowells and two dip tube jumpers (listed on Attachment 1). The connecting weld between the block and the extending member (i.e. dip tube or thermowell) was examined by PT and there were no reportable indications.

References: 1) S. M. Nordwick and D. B. Bickford, "Initial Comments and Recommendations for the DWPF Process Vessels Erosion and Corrosion Studies," March 29, 1990.

2) W. D. Daugherty, "Evaluation of Potential for Materials Degradation of DWPF Safety Class and Safety Significant Components," WSRC-TR-95-0385, Rev. 0, September 1995.

	INSPECTION ACTIVITIES TO SUPPORT FA-04.03 TEST PROGRAM					
		SRTC MATERIALS INSPECTIONS			NDE	
Equipment Description	Equipment No. (or Jumper No.)	Insp. Date	MTS / MCG Insp. Name / Initials	Method of Inspection Direct / Tape Review	INSPECTIONS (See Attc. 2)	Summary of Inspection Results
PR Vessel / Fixed Coil	S355-150-020-00-T	12/31/95	K. Imrich /	Review of Tape	VT	No evidence of erosion/corrosion
PR Agitator	S355-150-025-00-AG	12/29/95	K. Imrich /	Direct Inspection	VT, DA	No significant evidence of erosion/corrosion
PR Sample Pump	S355-150-028-00-P	12/28/95	K. Imrich /	Direct Inspection	VT, UT, PT	See "Items of Note," No. 1
PR Sample Discharge Jumper	401(16.4SP)2	12/30/95	N/A	Direct Inspection	VT, UT	No evidence of erosion/corrosion
PR Coupon Racks	N/A	12/30/95	G. Chandler /	Direct Inspection	N/A	See "Items of Note," No. 2
PRCD Vessel	S355-150-026-00-E	12/31/95	K. Imrich /	Review of Tape	VT	No evidence of corrosion
PRFT Vessel	S355-150-060-00-T	12/31/95	K. Imrich /	Review of Tape	VT	No evidence of erosion/corrosion
PRFT Sample Pump	S355-150-068-00-P	12/30/95	J. Gee /	Direct Inspection	VT, PT	See "Items of Note," No. 1
PRFT Transfer Pump	S355-150-061-00-P	12/30/95	J. Gee /	Direct Inspection	VT, PT	No evidence of erosion/corrosion
OE Vessel and Coil	S355-150-030-00-T	12/31/95	K. Imrich /	Review of Tape	VT	No evidence of corrosion
OECD Vessel	S355-150-036-00-E	12/31/95	K. Imrich /	Review of Tape	VT	No evidence of corrosion
OECT Vessel	S355-150-050-00-T	12/31/95	K. Imrich /	Review of Tape	VT	No evidence of corrosion
PR to PRCD Jumper	(15.1C)3-(16)7	12/29/95	K. Imrich /	Review of Tape	VT, UT	No evidence of corrosion
PRCD to SCVC Vent Jumper	(15.1C)12-(14.1C)4	12/29/95	K. Imrich /	Review of Tape	VT, UT	No evidence of corrosion
Thermowell	(13TW)	12/28/95	N/A	N/A	VT, PT	No PT indication at block weld
Thermowell	(14TW)	12/28/95	N/A	N/A	VT, PT	No PT indication at block weld
Thermowell	(15TW)	12/28/95	N/A	N/A	VT, PT	No PT indication at block weld
Thermowell	(16TW)	12/28/95	N/A	N/A	VT, PT	See "Items of Note," No. 3
Dip Tube	403(14.3TK)10	12/28/95	N/A	N/A	VT, PT	No PT indication at block weld
Dip Tube	403(15.2EV)12	12/28/95	N/A	N/A	VT, PT	No PT indication at block weld

ATTACHMENT 1 - ITEMS OF NOTE

No. 1: PR and PRFT Sample Pumps

During PT and VT (NDE) inspections performed on the Precipitate Reactor (PR) and Precipitate Reactor Feed Tank (PRFT) Sample pumps, evidence of fatigue damage at welds was discovered in the dip tube assemblies. PT indications were noted on 4 of 8 welds on the PR sample pump and 2 of 8 welds on the PRFT sample pump. An NCR, 96-NCR-05-0030, was issued to track repair or replacement of the dip tube assemblies.

No. 2: PR Coupon Racks

Corrosion coupons were removed from the vapor space and the liquid space of the Precipitate Reactor Tank (PR) after 12-18 months of exposure during cold runs and mercury runs. The coupons consisted of nickel-based alloys C-276, C22, G30, Inconel 625, and Stellite 6. The types of coupons were flat coupons with Teflon crevice washers, galvanically coupled coupons, and U-bend coupons. Several coupons contained autogeneous welds. Specimens were cleaned and evaluated using ASTM standard practice G 1-90.

The examination of the corrosion coupons from the PR tank revealed no evidence of significant general corrosion, localized corrosion, galvanic corrosion, or stress corrosion cracking. The coupons were coated with a thin brown layer after being removed from the tanks. The layer was easily removed from most of the coupons during cleaning, however, a heavy stain remained after cleaning on the coupons exposed in the liquid space. Corrosion rates for all coupons based on 12 months exposure were less than 0.1 mils per year (mpy). The maximum corrosion rate measured for the material of construction for the PR tank, alloy C-276, in the liquid and vapor region was 0.02 and 0.1 mpy, respectively.

No. 3: Thermowell (16TW)

Inspection of one of the C-276 dip tubes, 403(15.2EV)12, revealed a pronounced bend in the lower assembly. This bend in the dip tube occurred as a result of mechanical damage. The block connecting weld was examined by PT and no indications were found. It was suggested that the dip tube could be reworked by "cold straightening." No reduction in service life for the component is expected.

ATTACHMENT 2

PREDICTED SPC EQUIPMENT LIFE

Equipment Description	Materials of Construction	Total Operating Time at Inspection	No. of Process Batch Cycles Com.	Primary Materials Concern to Component	Predicted Additional Service Life
PR Vessel / Fixed Coil	C-276 Alloy	15-18 months	27	Corrosion of steam coils	12 year (Note 1)
PR Agitator	C-276 Alloy	3.3 months	N/A	No materials concern	5 year (Note 2)
PR Sample Pump	C-276 Alloy	450 hours	N/A	No materials concern	5 year (Note 2)
PR Sample Discharge Jumper	C-276 Alloy	450 hours	N/A	No materials concern	Inspect after 5 years (Note 3)
PRCD Vessel	C-276 Alloy	15-18 months	27	No materials concern	Life of facility
PRFT Vessel	C-276 Alloy	15-18 months	N/A	No materials concern	Life of facility
PRFT Sample Pump	C-276 Alloy	N/A	N/A	No materials concern	5 year (Note 2)
PRFT Transfer Pump	C-276 Alloy	N/A	N/A	No materials concern	5 year (Note 2)
OE Vessel and Coil	C-276 Alloy	15-18 months	27	No materials concern	Life of facility
OECD Vessel	C-276 Alloy	15-18 months	27	No materials concern	Life of facility
OECT Vessel	304L Stainless	15-18 months	27	Possible localized corrosion	Life of facility (Note 4)
PR to PRCD Jumper	C-276 Alloy	N/A	N/A	No materials concern	Inspect after 5 years (Note 3)
PRCD to SCVC Vent Jumper	C-276 Alloy	N/A	N/A	No materials concern	Inspect after 5 years (Note 3)

NOTES

1) Laboratory coupon data suggests that the general corrosion rate on the fixed Precipitate Reactor (PR) steam coils may be 5 mpy. At this rate, the corrosion allowance on the heated coil would be expended in about twelve years. The PR vessel, however, is expected to last the life of the facility. Thus, the PR may be limited as a result of possible coil failure.
2) The design life for the process pumps and agitators was five years. It is predicted that materials issues will not reduce the life of these components.
3) Several of the process jumpers may be impacted by erosion/ corrosion. If acceptable from a process standpoint, the jumpers can be used until failure (i.e. pitting or localized thinning expected). If such a failure is not acceptable, the jumpers should be replaced at some predetermined frequency.
4) While no evidence of corrosion was noted during the remote visual inspection of the OECT, laboratory data suggests that the 304L stainless steel alloy used for this vessel may be subject to localized corrosion.

REFERENCE: W. D. Daugherty, " Evaluation of Potential for Materials Degradation of DWPF Safety Class and Safety Significant Components," WSRC-TR-95-0385, September, 1995.

Reviewed by DWPF Materials Committee on 1/30/96

G. T. Chandler, Chairman

2/1/96
DATE

ATTACHMENT 3

S

Quality Control
Condition Report

AID-QCM-960011
JOB NO: S950807
Retention: 2 Years
Keywords: Tanks
Jumper
Agitator
Pump

Distribution
J. T. Gee, 704-25S **
S. F. Piccolo, 704-S
W. D. Kerley, 704-25S
E. J. Freed, 704-25S
K. R. Jones, 704-26S
P. Smock, A&IQ/QC, 730A
W. R. Hinz, A&IQ/QC, 730A
Vlad Cech, A&IQ/QC, 730A
M. W. Trimm, A&IQ/QC, 730A
A. Reynolds, A&IQ/QC, 730A
J. Elder, A&IQ/QC, 730A
D. G. Bevard, A&IQ, 703-A
O. L. Gaston, A&IQ/QC, 730-A
R. E. Sprayberry, A&IQ/QC, 730-A
730-A QC Files

Page: 1 of 3

Date: 1/11/96

Reported By: J. G. Dickinson	Inspectors/Level: J. Elder L-III (UT) L-II (VT & PT), P. Gibbons L-II (VT, PT & UT)
Equipment Examined: Jumpers, Tanks, Pumps, Agitator Blades, see attached pages 2 and 3	
Location: 221-S	IP, IDP, Pipe, Part #: See attached pages 2 and 3
Date of Examination: See attached pages 2 and 3	Time in Service: ~2 Years
Service Condition: NA	Materials of Construction: Stainless Steel Hastelloy
NCR Number (if applicable): NA	
Inspection Procedure (number and title): NDEP 4.1 General Visual, NDEP 6.1 Liquid Penetrant & NDEP 7.1 Ultrasonic Thickness Examination	
Acceptance Criteria/source): **NONE PROVIDED BY CUSTOMER**	

Inspection Summary:

Administration & Infrastructure Quality (Formally Site Services Quality), utilized the following nondestructive examination methods during outage FA-04-Phase 2: liquid penetrant, visual and ultrasonic thickness. The examination methods, report numbers and inspectors are listed in table 1 of this report. The examinations performed during this outage utilized the same techniques and examination methods during the collection of the base line data. Variations in the baseline data and this report are attributed to the refinement of ultrasonic equipment, calibration techniques and the advancements in ultrasonic transducer technology for specialized applications such as wall thickness measurement of small diameter tubing. No significant erosion or corrosion conditions were detected during this outage. This report is issued as a **"Condition Report"**, since no acceptance criteria was provided. The responsible systems engineer will be required to determine the final acceptability of all items listed in this report. Copies of all individual NDE reports were provided to the FA-04 Test Coordinator with copies maintained in our files listed under Job # S950807.

**** Attachments**

JS 1/11/96

DWPF OUTAGE FA-04-P2

JOB # S950807

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
MFT	MFT Agitator	S999-170-015-00AG	95-IR-06-VT-1118 95-IR-06-PT-1117	M. Trimm L-III 11-29-95 J. B. Elder L-II 11-29-95	Linear indications, wear & physical damage noted during (VT) visual examination. Linear indications detected during VT examination, area repaired and passed PT.
OE	OE Vessel (Internals)	S355-150-030-00-T	95-IR-06-VT-1178 Video Tape # FA-04-#4	P. Gibbons L-II J. B. Elder L-II 12-31-95	No indications noted during (VT) Visual examination.
OECD	OCED Vessel (Internals)	S355-150-036-00-E	95-IR-06-VT-1185 Video Tape # FA-04-#4	P. Gibbons L-II J. B. Elder L-II 12-31-95	No indications noted during (VT) Visual examination.
OECT	OECT Vessel (Internals)	S355-150-050-00-T	95-IR-06-VT-1179 Video Tape # FA-04-#4	P. Gibbons L-II J. B. Elder L-II 12-31-95	No indications noted during (VT) Visual examination.
PR	PR Sample Pump	S-355-150-028-00-P	95-IR-06-VT-1173 95-IR-06-PT-1174 95-IR-06-UT-1175	P. Gibbons L-II J. B. Elder L-II/III 12-28-95 & 12-29-95	No indications noted during (VT) Visual or (PT) liquid penetrtant examination. No evidence of wall thinning noted
PR	PR Sample Discharge Jumper	401(16.4SP)2	95-IR-06-VT-1191 95-IR-06-UT-1192 Video Tape # FA-04-#4	P. Gibbons L-II J. B. Elder L-II/III 12-30-95	No indications noted during (VT) Visual or apparent wall thickness loss during (UT) ultrasonic thickness examination. Readings 0.010" higher than base line data.
PR	PR to SCVC Jumper	(15.1C)12-(14.1C)4	95-IR-06-VT-1189 95-IR-06-UT-1190 Video Tape # FA-04-#4	P. Gibbons L-II J. B. Elder L-II/III 12-29-95	No indications noted during (VT) Visual or apparent wall thickness loss during (UT) ultrasonic thickness examination. Sample lines not inspected due to accessibility.

DWPF OUTAGE FA-04-P2

JOB # S950807

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
PR	PR to PRCD Jumper	(15.1C)3-(16)7	95-IR-06-VT-1187 95-IR-06-UT-1188 Video Tape # FA-04-#4	P. Gibbons L-II J. B. Elder L-II/III 12-29-95	No indications noted during (VT) Visual or apparent wall thickness loss during (UT) ultrasonic thickness examination.
PR	PR Agitator	S355-150-025-00AG	95-IR-06-VT-1176	P. Gibbons L-II 12-29-95	No indications noted during (VT) Visual examination.
PR	PR Vessel (Internals)	S355-150-020-00-T	95-IR-06-VT-1177 Video Tape # FA-04-#4	P. Gibbons L-II J. B. Elder L-II 12-31-95	No indications noted during (VT) Visual examination.
PRCD	PRCD Vessel (Internals)	S355-150-026-00-E	95-IR-06-VT-1186	P. Gibbons L-II J. B. Elder L-II 12-31-95	No indications noted during (VT) Visual examination.
PRFT	PRFT Sample Pump	S-355-150-068-00-P	95-IR-06-VT-1181 95-IR-06-PT-1182	P. Gibbons L-II J. B. Elder L-II 12-30-95	Linear indications noted during (PT) liquid penetrant examination. System Eng. Notified of condition, unsure of course of action, NCR, repair etc.
PRFT	PRFT Transfer Pump	S-355-150-061-00-P	95-IR-06-VT-1183 95-IR-06-PT-1184	P. Gibbons L-II J. B. Elder L-II 12-30-95	No indications noted during (VT) Visual or (PT) liquid penetrant examination.
PRFT	PRFT Vessel (Internals)	S355-150-060-00-T	95-IR-06-VT-1180 Video Tape # FA-04-#4	P. Gibbons L-II J. B. Elder L-II 12-31-95	No indications noted during (VT) Visual examination.

APPENDIX 2

NDE SUMMARY REPORTS

APPENDIX 2

S

Quality Control
Condition Report

AID-QCM-950127
JOB NO: S950513
Retention: 2 Years
Keywords: Tanks
Jumper
Coils
Pump

Distribution

J. T. Gee, 704-25S
S. F. Piccolo, 704-S
W. D. Kerley, 704-25S
E. J. Freed, 704-25S
K. R. Jones, 704-26S
P. Smock, A&IQ/QC, 730A
W. R. Hinz, A&IQ/QC, 730A
Vlad Cech, A&IQ/QC, 730A
M. W. Trimm, A&IQ/QC, 730A
A. Reynolds, A&IQ/QC, 730A
J. Elder, A&IQ/QC, 730A

D. G. Bevard, A&IQ, 703-A
O. L. Gaston, A&IQ/QC, 730-A
R. E. Sprayberry, A&IQ/QC, 730-A
730-A QC Files

Page: 1 of 12

Date: 11/16/95

Reported By: J. G. Dickinson	Inspectors/Level: R. F. Holmes L-II (VT, PT & UT), J. Elder L-III (UT) L-II (VT & PT), J. McCall L-II (VT, PT & UT) P. Gibbons L-II (VT, PT & UT)
Equipment Examined: See Table 1	
Location: 221-S	IP, IDP, Pipe, Part #: See Table 1
Date of Examination: See Table 1	Time in Service: ~2 Years
Service Condition: NA	Materials of Construction: Stainless Steel Hastelloy
NCR Number (If applicable): NA	
Inspection Procedure (number and title): NDEP 4.1 General Visual, NDEP 6.1 Liquid Penetrant & NDEP 7.1 Ultrasonic Thickness Examination	
Acceptance Criteria/source): NONE PROVIDED BY CUSTOMER	

Inspection Summary:

INTRODUCTION

Administrative & Infrastructure Quality (Formally Site Services Quality), utilized the following nondestructive methods during outage FA-04: liquid penetrant, visual, ultrasonic and radiography. The examination methods, report numbers and inspectors are listed in table 1 of this report. Previous report numbers and results are also provided in table 1. This report is issued as a **"Condition Report"**, since no acceptance criteria was provided. The responsible systems engineer will be required to determine the final acceptability of all items listed in this report. This is the final report, copies of all individual NDE reports were provided to the FA-04.02 Test Coordinator and are also maintained in our files listed under Job # S950513. Radiography test results are contained in Job file numbers S950640, S950641, S950645 and S950646.

PS 11/17/95

Inspection Summary Cont.:

INSPECTION METHODOLOGY

The examinations performed during this outage were done utilizing the same techniques and examination methods during the collection of the base line data. Some examinations were in fact base line data and therefore could not be compared with previous data.

DATA COMPARISON/RESULTS

Small Bore Piping

A comparison of the ultrasonic thickness data from the small diameter piping, obtained during the recent outage, and the baseline data (1990) indicated a decrease in thickness of 0.010 - 0.020". Data point correlation was excellent on both large and small diameter components. The apparent change in thickness prompted an in-depth analysis of the data on the small diameter components. The baseline data reports were reviewed to determine if technique or equipment factors contributed to the difference. The baseline technique and calibrations were reproduced using the same type of equipment used during the baseline examinations. A comparison was then performed where the baseline technique and three currently used techniques were used to measure the same component. The baseline technique consistently provided 0.008 - 0.012" thicker readings.

The differences are attributed to:

* The advancements in ultrasonic transducer technology for specialized applications such as wall thickness measurement of small diameter tubing.

* The refinement of ultrasonic equipment and calibration techniques.

Based on the technique comparison data, we determined that a correction factor of 93% was needed to make the appropriate comparisons to the baseline data. The correction factor was applied to the baseline data in the ultrasonic thickness plots (1 & 2). With the exception of limited areas of the SME coil piping, the remaining piping shows no reduction in wall thickness.

Tanks

Comparison of the process tank data shows virtually no change.

Radiography of Sample Line Components

Radiographs for the SME and MFT (pump) sample line "pick-up points" were compared to similar radiographs taken in 1990. The comparison reveals no apparent erosion /corrosion which would effect the sample characteristics going to the analytical sample cell. Radiographs were also performed for the SME and MFT Hydragard liquid samplers. Results showed no apparent erosion/corrosion which would effect sample characteristics.

Systems Overall Condition

Other than the wall loss in SME coil no significant erosion or corrosion conditions were detected during this outage.

Data collected using several different UT Equipment combinations. The 26DL data was collected in the same manner as the baseline data. The Sonopen, DA312, and 5Mhz Delay tip data were all collected using a USN 50 UT scope (EQ. used in 9/95)
The data was collected on a 1/2" schedule 40. Stainless steel pipe section that included an elbow.
The 26DL (Digital Thickness Gauge) data consistently reads thickner than actual thickness.

FIGURE 1

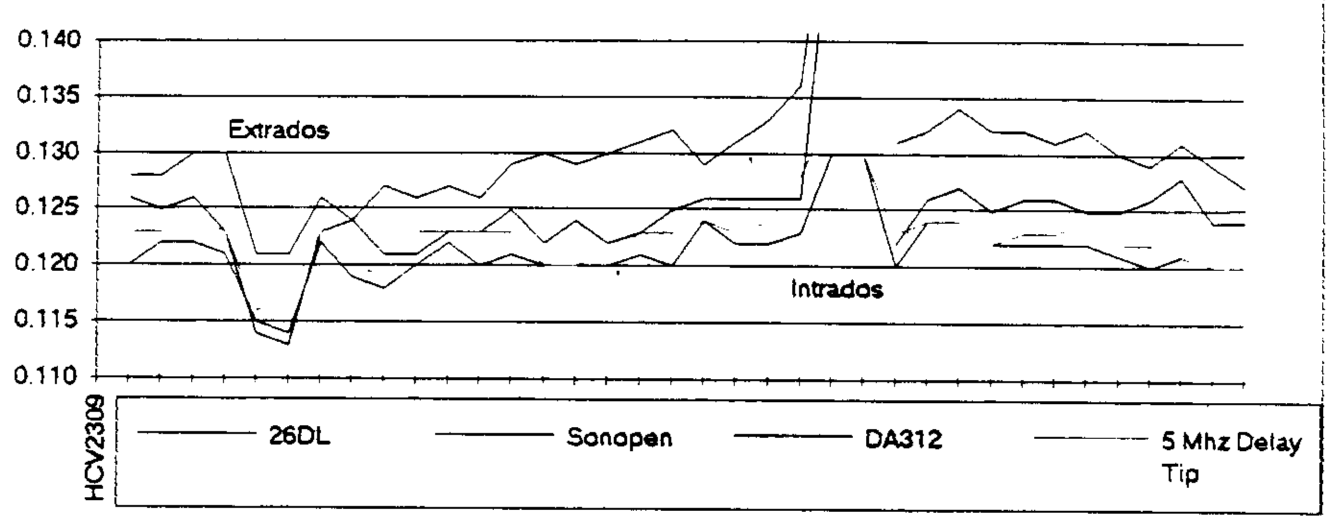
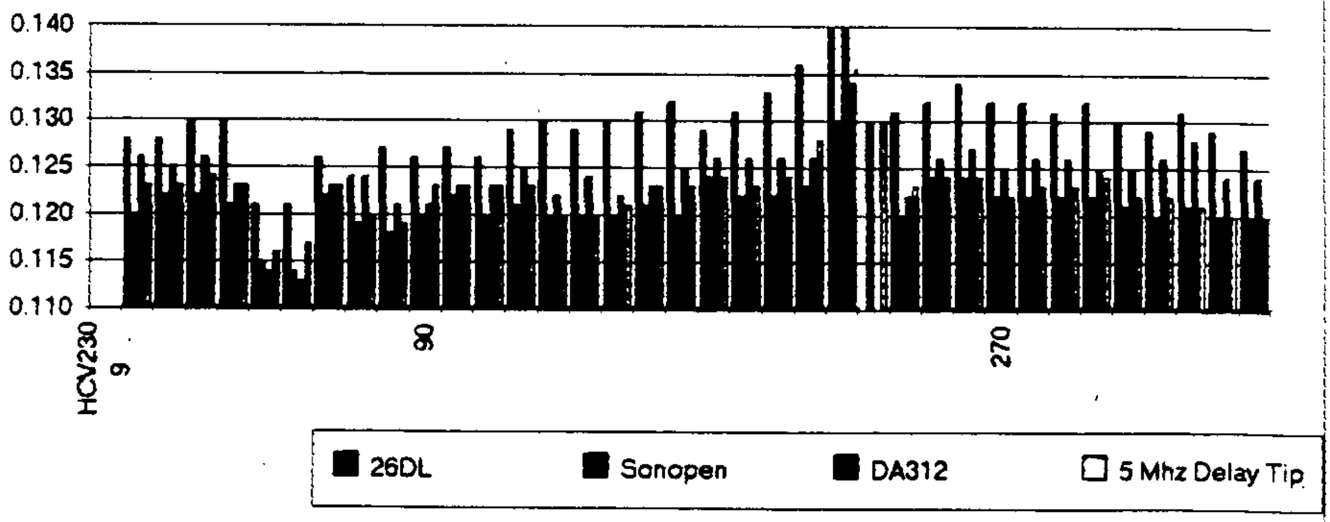


FIGURE 2



DWPF OUTAGE FA-04

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
CDC	Cansiter Decon Cage #1	S360-600-030	95-IR-06-VT-1058	P. Gibbons L-II 11-7-95	No VT indications noted.
CDC	Cansiter Decon Cage #2	S360-600-060	95-IR-06-VT-1059	P. Gibbons L-II 11-7-95	No VT indications noted.
CDC	Recirculation Pump Decon #1	S360-600-033-00-P	95-IR-06-VT-1060 95-IR-06-UT-1061 95-IR-06-PT-1062	P. Gibbons L-II B. Holmes L-II 11-6-95	0.135" to 0.209" 0.430" to 0.452"
CDC	CDC Jumper	358(23CD)12	95-IR-06-VT-1063 95-IR-06-UT-1067	J. Elder L-III B. Holmes L-II 11-2-95	0.100" No VT indications noted.
CDC	CDC Jumper	359(23CD)13	95-IR-06-VT-1064 95-IR-06-UT-1068	J. Elder L-III B. Holmes L-II 11-2-95	0.181" No VT indications noted.
CDC	CDC Jumper	357(23CD)11	95-IR-06-VT-1065 95-IR-06-UT-1066	J. Elder L-III B. Holmes L-II 11-2-95	0.111" No VT indications noted.
LPPP	LPPP Precipitate Tank	S511-030-020-00	95-IR-06-UT-0890 95-IR-06-VT-0891	P Gibbons L-II J. Elder L-II J. McCall L-II 9-9-95	0.471" Baseline No VT indications noted.

AID-QCM-950127
JOB # 950513
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11/6/95

DWPF OUTAGE FA-04

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
LPPP	LPPP Sludge Tank	S511-010-020-00-T	95-IR-06-UT-0986 95-IR-06-VT-1069	P Gibbons L-II B. Holmes L-II 10-11-95	0.493" Baseline No VT indications noted.
MFT	Return Loop to Tank Jumper	(7.1TP) 3Y (7.6DT) 1	95-IR-06-VT-0990	B. Holmes L-II P. Gibbons L-II 10-3-95	No VT indications noted.
MFT	Melter Feed Loop #1 DT Assembly	(7.6DT)	95-IR-06-VT-0991 95-IR-06-PT-0992	B. Holmes L-II P. Gibbons L-II 10-3-95	No VT/PT indications noted.
MFT	Sample Pump Discharge Jumper	404(7.3SP)2	95-IR-06-UT-0883	J. B. Elder L-III 9-24-95	0.092"
MFT	Melter Feed #1 Loop Line Strainer	(7.1TP) 3X (North)	95-IR-06-VT-0884	B. Holmes L-II P. Gibbons L-II 9-26-95	Baseline No VT indications noted.
MFT	Melter Feed #2 Loop Line Strainer	(7.1TP) 3X (South)	95-IR-06-VT-0885	B. Holmes L-II P. Gibbons L-II 9-26-95	Baseline No VT indications noted.
MFT	Melter Feed Pump #1	S-350-170-011-00-P	95-IR-06-VT-0994 95-IR-06-UT-0995 95-IR-06-PT-0996	B. Holmes L-II P. Gibbons L-II 9-27-95	Suction Line 0.151" Discharge Line 0.141" Return Line 0.146" Return Line 0.124" Baseline No VT/PT indications noted.

DWPF OUTAGE FA-04

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
MFT	Melter Feed Sample Pump	S-350-170-018-00	95-IR-06-PT-0876 95-IR-06-UT-0877 95-IR-06-VT-0987	P. Gibbons L-II J. Elder L-III 9-22-95	Intake 2" Line 0.144" Return 1 1/2" Line 0.115" Sample Pump Outlet 1/2" line 0.095"
MFT	Melter Feed Cooling Coil	S-350-170-010-03-E	95-IR-06-VT-0880 95-IR-06-UT-0879	B. Holmes L-II P. Gibbons L-II 9-27-95	No VT indications noted. 0.142"
MFT	Melter Feed Agitator	S-350-170-015-00-AG	95-IR-06-VT-0878	B. Holmes L-II 9-25-95	No VT indications noted.
MFT	Melter Feed Line Jumper	257(7.2TP)3	95-IR-06-UT-0881 95-IR-06-VT-0882	P. Gibbons L-II 9-24-95 J. Elder L-II 9-23-95	No VT indications noted. 0.115"
MFT	Melter Feed Return Line Loop to Tank Jumper	(7.2TP)3V (7.6DT0)2	95-IR-06-VT-0989	P. Gibbons L-II B. Holmes L-II 10-3-95	No VT indications noted.
MFT	MFT Sample Lines	SSX-231-P213-1/2A 221-S Nozzle Box & West Canyon wall.(1) SRX-181-P213-1/2B 221-S Nozzle Box & Canyon wall. (2)	95-IR-06-UT-0898	B. Holmes L-II 9-18-95	0.093"
MFT	Tank	S350-170-010-00-T	95-IR-06-UT-0874 95-IR-06-VT-0875	J. B. Elder L-III J. McCall L-II 9-15-95	Tank Bottom 0.747" Shell 0.495"

DWPF OUTAGE FA-04

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
OGCT	Pump	S350-190-028-00	95-IR-06-UT-1046 95-IR-06-PT-1045 95-IR-06-VT-1044	P. Gibbons L-II J. Elder L-II 10-23-95	Intake 0.148" Outlet 0.127" Sample 0.095" No VT/PT indications noted.
OGCT	Tank	S350-190-020-00-T	95-IR-06-UT-0886 95-IR-06-VT-0887	P. Gibbons L-II J. Elder L-II 10-23-95	Tank Bottom 0.751" Shell 0.489" No VT indications noted.
OGCT	Sample Pump Jumper	403(6.4SP)2	95-IR-06-UT-0993	P. Gibbons L-II J. Elder L-II 10-23-95	(1) 0.094" (2) 0.094"
OGCT	OGCT Sample Lines	SSX-187-P213-1/2A 221-S Nozzle Box & West Canyon wall. SRX-137-P213-1/2B 221-S Nozzle Box & Canyon wall	95-IR-06-UT-0898	B. Holmes L-II 9-18-95	0.087"
OGCT	Sample Cell Line Mezz. Level	SSX 137 and SRX 137	95-IR-06-VT-1048 95-IR-06-UT-1049	B. Holmes L-II P. Gibbons L-II 10-16-95	0.102" Baseline No VT indications noted.
PFSFT	PFSFT to SME Jumper	501(12)-(11)-17	95-IR-06-UT-0988	B. Holmes L-II P. Gibbons L-II 10-3-95	0.139"
POGL	Primary Off Gas Line	S350-190-017-01	95-IR-06-VT-1071	P. Gibbons L-II 10-31-95	No VT indications noted.

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DWPF OUTAGE FA-04

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
PR	PR Sample Lines	SSX-211-P213-1/2A 221-S Nozzle Box & West Canyon wall. SRX-161-P213-1/2B 221-S Nozzle Box & Canyon wall	95-IR-06-UT-0898	B. Holmes L-II 9-18-95	(1) 0.093" (2) 0.093"
PR	Sample Cell Line Mezz. Level	SSX 117 and SRX 161	95-IR-06-VT-1048 95-IR-06-UT-1049	B. Holmes L-II P. Gibbons L-II 10-16-95	0.097" Baseline
PRBT	PRBT to SRAT Feed Jumper	ASX(12.1TP)3	95-IR-06-VT-1037	J. ELDER L-II P. Gibbons L-II 10-3-95	No VT indications noted.
PRBT	PRBT Tank	S999-395-030-10-T (RCT Spare Tank)	95-IR-06-UT-0892 95-IR-06-VT-0893	J. Elder L-III J. McCall L-II 9-14-95	0.493" Base Line No VT indications noted.
PVV	PVV Header Piping	#129	95-IR-06-PT-0894 95-IR-06-VT-0895 North & South Piping Welds	J. McCall L-II J. Elder L-II	No VT/PT indications noted.
Quencher	Primary Quencher	S350-190-017-02	95-IR-06-UT-1038 95-IR-06-VT-1039	J. Elder L-III P Gibbons L-II 10-31-95	0.376" No VT indications noted.
RCT	RCT Tank	S350-150-010-00-E	95-IR-06-UT-0888 95-IR-06-VT-0889 95-IR-06-VT-1047 Internals	J. Elder L-III J. McCall L-II 9-12-95 B. Holmes L-II P. Gibbons L-II 10-17-95	0.772" No VT indications noted.

DWPF OUTAGE FA-04

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
SME	Sample Cell Line Mezz. Level	SSX 121 and SRX 171	95-IR-06-VT-1048 95-IR-06-UT-1049	B. Holmes L-II P. Gibbons L-II 10-16-95	0.097" No VT indications noted.
SME	SME Tank	S350-150-030-00-EV	95-IR-06-UT-0855 95-IR-06-VT-0856 95-IR-06-VT-0857 Internals 95-IR-06-VT-1051 After Dip Tube Repair	J. Elder L-III J. McCall L-II 9-14-95	Lower Head 0.745" Shell 0.491" No VT indications noted.
SME	SME Transfer Pump	S350-150-043-60	95-IR-06-PT-0858	P. Gibbons L-II 9-19-95	No PT indications noted.
SME	SME Condenser	S350-150-036-00-E	95-IR-06-UT-0863 95-IR-06-VT-0864	P. Gibbons L-II J. ELDER L-II 9-13-95	0.196" No VT indications noted.
SME	SME Cooling Coil	S350-150-030-02-E	95-IR-06-VT-0865 95-IR-06-UT-0866	P. Gibbons L-II B. Holmes 9-12-95	0.088" lowest area Rpt.'d and area was repaired. No VT indications noted.
SME	SME Jumper	403(11.3SP)2	95-IR-06-UT-0867	J. Elder L-III 9-10-95	Left 0.091" Right 0.094"
SME	For SME Coil U-Bend & Elbow Comparsion Test, U-Bend Representative of SME & SRAT	NA	95-IR-06-UT-0998	P. Gibbons L-II B. Holmes 9-12-95	0.137"

DWPF OUTAGE FA-04

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
SME	SME Sample Pump	S350-150-038-00-P	95-IR-06-UT-0859 95-IR-06-VT-0860 95-IR-06-PT-0861	B. Holmes L-II P. Gibbons L-II J. Elder L-II J. McCall L-II 9-14-95	0.093" On Sample 1/2" Line No VT/PT indications noted.
SME	SME Agitator Blades	S350-150-035-00-AG	95-IR-06-UT-0862	B. Holmes L-II J. McCall L-II 9-12-95	0.033" Lower blade "A" item has been repaired.
SME	SME Sample Lines	SSX-221-P213-1/2A 221-S Nozzle Box& West Canyon wall.(1) SRX-171-P213-1/2B 221-S Nozzle Box & Canyon wall (2)	95-IR-06-UT-0898	B. Holmes L-II 9-18-95	(1) 0.085" to 0.118" (2) 0.097" to 0.106"
SMECT	SMECT Tank	S350-150-040-00-T	95-IR-06-UT-0868 95-IR-06-VT-0870 95-IR-06-VT-0869 95-IR-06-VT-1052 After Dip Tube Repair	J. Elder L-III J. McCall L-II 9-10-95	Tank Bottom 0.862" Shell 0.511"
SMECT	SMECT Transfer Pump	S350-150-045-00-P	95-IR-06-PT-0871	P. Gibbons L-II 9-19-95	No PT indications noted.
SMECT	SMECT Cooling Coil	S350-150-040-02-E	95-IR-06-PT-0872 95-IR-06-UT-0873 95-IR-06-VT-1070	B. Holmes L-II 9-19-95	0.139" No VT/PT indications noted.
SRAT	SRAT Sample Lines	SSX-229-P213-1/2A 221-S Nozzle Box & West Canyon wall.(1) SRX-179-P213-1/2B 221-S Nozzle Box & Canyon wall (2)	95-IR-06-UT-0898	B. Holmes L-II 9-18-95	(1) 0.080" to 0.120" (2) 0.097" to 0.112"

DWPF OUTAGE FA-04

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
SRAT	SRAT Cooling Coil	S350-150-010-02-E	95-IR-06-VT-1050 95-IR-06-UT-0851	P. Gibbons L-II J. Elder L-III 9-9-95	0.140" No VT indications noted.
SRAT	SRAT Condenser Jumper	(9.1C)3-(10.2WT)3	95-IR-06-VT-0853 95-IR-06-UT-0852	P. Gibbons L-II J. Elder L-III 9-11-95	0.107" to 0.103" No VT indications noted.
SRAT	SRAT Condenser Jumper	403 (9.3SP)2	95-IR-06-VT-0854	J. Elder L-III 9-11-95	Left 0.098" Right 0.097" No VT indications noted.
SRAT	SRAT Condenser T Section on SRAT Condenser	(9.1C)3-(10.2WT)3	95-IR-06-UT-0849	P. Gibbons L-II 9-12-95	0.195"/0.191" BASE LINE
SRAT	SRAT Condenser	S350-150-016-00-E	95-IR-06-VT-0850	P. Gibbons L-II J. Elder L-II 9-12-95	No VT indications noted.
SRAT	SRAT Sample Pump	S350-150-018-00	95-IR-06-VT-0847 95-IR-06-PT-0845 95-IR-06-UT-0846	B. Holmes L-II J. McCall L-II J. Elder L-II 9-10-95	Sample Line 0.103" Outlet 0.137" Suction 0.154" No VT/PT indications noted.
SRAT	SRAT Tank	S350-150-010-00-EV	95-IR-06-UT-0842 95-IR-06-VT-0843 (Int.) 95-IR-06-VT-0844	B. Holmes L-II J. McCall L-II J. Elder L-II 9-10-95	Tank Bottom 0.758" Shell 0.472" No VT indications noted.

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Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
SRAT	SRAT Agitator	Blades	95-IR-06-VT-0848	P Gibbons L-II 9-8-95	No VT indications noted.
SRAT	SRAT Ammonia Scrubber	S350-150-019-00-V	95-IR-06-VT-0997	B. Holmes L-II P Gibbons L-II 9-8-95	No VT indications noted.
SRAT	Sample Cell Line Mezz. Level	SSX 221 and SRX 179	95-IR-06-VT-1048 95-IR-06-UT-1049	B. Holmes L-II P. Gibbons L-II 10-16-95	0.102" No VT indications noted.

APPENDIX 2

S

Quality Control
Condition Report

AID-QCM-960011
JOB NO: S950807
Retention: 2 Years
Keywords: Tanks
Jumper
Agitator
Pump

Distribution
J. T. Gee, 704-25S **
S. F. Piccolo, 704-S
W. D. Kerley, 704-25S
E. J. Freed, 704-25S
K. R. Jones, 704-26S
P. Smock, A&IQ/QC, 730A
W. R. Hinz, A&IQ/QC, 730A
Vlad Cech, A&IQ/QC, 730A
M. W. Trimm, A&IQ/QC, 730A
A. Reynolds, A&IQ/QC, 730A
J. Elder, A&IQ/QC, 730A

D. G. Bevard, A&IQ, 703-A
O. L. Gaston, A&IQ/QC, 730-A
R. E. Sprayberry, A&IQ/QC, 730-A
730-A QC Files

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Date: 1/11/96

Reported By: J. G. Dickinson	Inspectors/Level: J. Elder L-III (UT) L-II (VT & PT), P. Gibbons L-II (VT, PT & UT)
Equipment Examined: Jumpers, Tanks, Pumps, Agitator Blades, see attached pages 2 and 3	
Location: 221-S	IP, IDP, Pipe, Part #: See attached pages 2 and 3
Date of Examination: See attached pages 2 and 3	Time in Service: ~2 Years
Service Condition: NA	Materials of Construction: Stainless Steel Hastelloy
NCR Number (if applicable): NA	
Inspection Procedure (number and title): NDEP 4.1 General Visual, NDEP 6.1 Liquid Penetrant & NDEP 7.1 Ultrasonic Thickness Examination	
Acceptance Criteria/source): **NONE PROVIDED BY CUSTOMER**	

Inspection Summary:

Administration & Infrastructure Quality (Formally Site Services Quality), utilized the following nondestructive examination methods during outage FA-04-Phase 2: liquid penetrant, visual and ultrasonic thickness. The examination methods, report numbers and inspectors are listed in table 1 of this report. The examinations performed during this outage utilized the same techniques and examination methods during the collection of the base line data. Variations in the baseline data and this report are attributed to the refinement of ultrasonic equipment, calibration techniques and the advancements in ultrasonic transducer technology for specialized applications such as wall thickness measurement of small diameter tubing. No significant erosion or corrosion conditions were detected during this outage. This report is issued as a **"Condition Report"**, since no acceptance criteria was provided. The responsible systems engineer will be required to determine the final acceptability of all items listed in this report. Copies of all individual NDE reports were provided to the FA-04 Test Coordinator with copies maintained in our files listed under Job # S950807.

**** Attachments**

s 1/11/96

DWPF OUTAGE FA-04-P2

JOB # S950807

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
MFT	MFT Agitator	S999-170-015-00AG	95-IR-06-VT-1118 95-IR-06-PT-1117	M. Trimm L-III 11-29-95 J. B. Elder L-II 11-29-95	Linear indications, wear & physical damage noted during (VT) visual examination. Linear indications detected during VT examination, area repaired and passed PT.
OE	OE Vessel (Internals)	S355-150-030-00-T	95-IR-06-VT-1178 Video Tape # FA-04-#4	P. Gibbons L-II J. B. Elder L-II 12-31-95	No indications noted during (VT) Visual examination.
OECD	OCED Vessel (Internals)	S355-150-036-00-E	95-IR-06-VT-1185 Video Tape # FA-04-#4	P. Gibbons L-II J. B. Elder L-II 12-31-95	No indications noted during (VT) Visual examination.
OECT	OECT Vessel (Internals)	S355-150-050-00-T	95-IR-06-VT-1179 Video Tape # FA-04-#4	P. Gibbons L-II J. B. Elder L-II 12-31-95	No indications noted during (VT) Visual examination.
PR	PR Sample Pump	S-355-150-028-00-P	95-IR-06-VT-1173 95-IR-06-PT-1174 95-IR-06-UT-1175	P. Gibbons L-II J. B. Elder L-II/III 12-28-95 & 12-29-95	No indications noted during (VT) Visual or (PT) liquid penetrant examination. No evidence of wall thinning noted
PR	PR Sample Discharge Jumper	401(16.4SP)2	95-IR-06-VT-1191 95-IR-06-UT-1192 Video Tape # FA-04-#4	P. Gibbons L-II J. B. Elder L-II/III 12-30-95	No indications noted during (VT) Visual or apparent wall thickness loss during (UT) ultrasonic thickness examination. Readings 0.010" higher than base line data.
PR	PR to SCVC Jumper	(15.1C)12-(14.1C)4	95-IR-06-VT-1189 95-IR-06-UT-1190 Video Tape # FA-04-#4	P. Gibbons L-II J. B. Elder L-II/III 12-29-95	No indications noted during (VT) Visual or apparent wall thickness loss during (UT) ultrasonic thickness examination. Sample lines not inspected due to accessibility.

DWPF OUTAGE FA-04-P2

JOB # S950807

Module	Component	Part #	Exam. Method Rpt.#	Inspector Date	Thick(s) This Outage
PR	PR to PRCD Jumper	(15.1C)3-(16)7	95-IR-06-VT-1187 95-IR-06-UT-1188 Video Tape # FA-04-#4	P. Gibbons L-II J. B. Elder L-II/III 12-29-95	No indications noted during (VT) Visual or apparent wall thickness loss during (UT) ultrasonic thickness examination.
PR	PR Agitator	S355-150-025-00AG	95-IR-06-VT-1176	P. Gibbons L-II 12-29-95	No indications noted during (VT) Visual examination.
PR	PR Vessel (Internals)	S355-150-020-00-T	95-IR-06-VT-1177 Video Tape # FA-04-#4	P. Gibbons L-II J. B. Elder L-II 12-31-95	No indications noted during (VT) Visual examination.
PRCD	PRCD Vessel (Internals)	S355-150-026-00-E	95-IR-06-VT-1186	P. Gibbons L-II J. B. Elder L-II 12-31-95	No indications noted during (VT) Visual examination.
PRFT	PRFT Sample Pump	S-355-150-068-00-P	95-IR-06-VT-1181 95-IR-06-PT-1182	P. Gibbons L-II J. B. Elder L-II 12-30-95	Linear indications noted during (PT) liquid penetrant examination. System Eng. Notified of condition, unsure of course of action, NCR, repair etc.
PRFT	PRFT Transfer Pump	S-355-150-061-00-P	95-IR-06-VT-1183 95-IR-06-PT-1184	P. Gibbons L-II J. B. Elder L-II 12-30-95	No indications noted during (VT) Visual or (PT) liquid penetrant examination.
PRFT	PRFT Vessel (Internals)	S355-150-060-00-T	95-IR-06-VT-1180 Video Tape # FA-04-#4	P. Gibbons L-II J. B. Elder L-II 12-31-95	No indications noted during (VT) Visual examination.

APPENDIX 3

SUMMARY OF INSPECTED EQUIPMENT

APPENDIX 3

FA-04 02 EQUIPMENT INSPECTIONS

Equipment Description	INSPECTION ACTIVITIES TO SUPPORT FA-04.02 TEST PROGRAM				NDE	Summary of Inspection Results
		SRTC MATERIALS INSPECTIONS				
	Equipment No. (or Jumper No.)	Insp. Date	MTS / MCG Insp. Name / Initials	Method of Inspection Direct / Tape Review	INSPECTIONS (See Attc. 2)	
LPPP Sludge Tank	S511-010-020-T	11/9/95	Daugherty /	Review of Tape	VT, UT	No evidence of erosion/corrosion
LPPP Precipitate Tank	S511--030-020-T	11/8/95	Daugherty /	Review of Tape	VT, UT	No evidence of erosion/corrosion
PRBT Vessel	S350-195-020-00-T		N/A	N/A	VT, UT	No evidence of erosion/corrosion
PRBT to SRAT Jumper - orifice	ASX(12.1TP)3	10/30/95	Daugherty /	Direct Inspection	VT	No evidence of erosion on orifice plate
SRAT Vessel	S350-150-010-00-T	11/8/95	Daugherty /	Review of Tape	VT, UT	No evidence of erosion/corrosion
SRAT Sample Pump	S350-150-018-00-EV	9/8/95	Imrich /	Direct Inspection	VT,UT,PT,DA	No evidence of erosion/corrosion
SRAT Sample Discharge Jump.	403(9.3SP)2		N/A	N/A	UT	No evidence of erosion/corrosion
SRAT Coupon Racks	N/A	9/8/95	Chandler /	Direct Inspection	VT, UT	See "Items of Note," No. 1
SRAT Coil Assembly	S350-150-010--02-E	11/9/95	Daugherty /	Review of Tape	VT, UT	Slight erosion on lower blades / no concern
SRAT Agitator	S350-150-015-00-AG	9/8/95	Imrich /	Direct Inspection	VT, DA	Slight erosion / no concern to equipment life
SRAT Condenser	S350-150-036-00-E	11/8/95	Daugherty /	Review of Tape	VT	No evidence of corrosion
SRAT Condenser to MWWT Ju.	(9.1C)3(10 2WT)3	11/8/95	Daugherty /	Review of Tape	VT, UT	No evidence of corrosion
SRAT Ammonia Scrubber	S350-150-019-00-V	11/8/95	Daugherty /	Review of Tape	VT	No evidence of corrosion
SRAT Condenser to FAVC Ju	(9.1C)5-(10.7C)3		N/A	N/A	N/A	Jumper Removed from Process
SMECT Vessel	S350-150-040-00-T	9/10/95	Imrich /	Review of Tape	VT, UT	No evidence of corrosion
SMECT Coil	S350-150-030-02-E	9/12/95	Gee (DWPF-E) /	Direct Inspection	VT, UT	No evidence of corrosion
SME Vessel	S350-150-030-00-EV	9/20/95	Jenkins /	Direct Inspection	VT, UT	See "Items of Note," No. 2
SME Transfer Pump	S350-150-043-60-P		N/A	N/A	PT	No cracking of welds due to fatigue
SME Sample Pump	S350-150-038-00-P	9/11/95	Imrich /	Direct Inspection	VT,UT,PT,DA,RT	Some erosion of impeller / little concern
SME Sample Discharge Jumper	403(11.3SP)2		N/A	N/A	UT	No evidence of erosion/corrosion
SME Coil Assembly	S350-150-030-02-E	9/12/95	Daugherty /	Direct Inspection	VT, UT	See "Items of Note," No. 3
SME Condenser	S350-150-036-00-E	11/8/95	Daugherty /	Review of Tape	VT	No evidence of corrosion
SME Agitator	S350-150-035-00-AG	9/10/95	Imrich /	Direct Inspection	VT, DA	See "Items of Note," No. 4
PFSFT to SME Jumper	501(12)-(11)17		N/A	N/A	UT	No evidence of erosion
MFT Vessel	S350-190-010-00-T		N/A	N/A	VT, UT	No evidence of erosion/corrosion
MFT Sample Pump	S350-190-018-00-P	9/25/95	Chandler /	Direct Inspection	VT,UT,PT,DA,RT	No evidence of erosion/corrosion
MFT Sample Discharge Jumper	404(7 3SP)2		N/A	N/A	UT	No evidence of erosion
Melter Feed Pump No 1	S350-170-011 00-P	9/27/95	Chandler /	Direct Inspection	VT, PT	Some erosion / little concern to equipment life
MF Loop No 1 DT Assembly	(7 6DT)	9/25/95	Chandler /	Direct Inspection	VT	No evidence of erosion
#1 MF Loop./ Return to Tank	(7 1TP)3Y(7 6DT)1		N/A	N/A	UT	No evidence of erosion
MFT No 1 Feed Loop Line Str	(7 1TP)3X North	9/25/95	Chandler /	Direct Inspection	VT	No evidence of erosion

Equipment Description	INSPECTION ACTIVITIES TO SUPPORT FA-04.02 TEST PROGRAM						Summary of Inspection Results
		SRTC MATERIALS INSPECTIONS			NDE		
	Equipment No.	Insp. Date	MTS / MCG Insp. Name / Initials	Method of Inspection Direct / Tape Review	INSPECTIONS (See Attc. 2)		
MFT No. 2 Feed Loop Line Str	(7.2TP)3X South	9/25/95	Chandler /	Direct Inspection	VT		No evidence of erosion
#2 MF Loop / Return to Tank	(7.2TP)3V(7.6DT)2		N/A	N/A	UT		No evidence of erosion
MFT Coil Assembly	S350-170-010-03-E	11/9/95	Daugherty /	Review of Tape	VT, UT		See "Items of Note," No. 5
MFT Agitator	S350-170-015-00-AG	11/21/95	Jenkins /	Direct Inspection	VT, DA		See "Items of Note," No. 6
Formic Acid Vent Condenser	S350-150-051-00-E		N/A	N/A	N/A		See "Items of Note," No. 7
Process Vessel Vent Header	N/A		N/A	N/A	VT, PT		Welds intact / no evidence of fatigue
RCT Vessel	S395-030-010-00-T		N/A	N/A	VT, UT		No evidence of erosion/corrosion
MOG Line Melter End	(22M)46-(22.24QE)2	10/30/95	Imrich /	Direct Inspection	VT		See "Items of Note," No. 8
MOG Line Quencher End	501(22.24QE)	10/30/95	Imrich /	Direct Inspection	VT, UT		No evidence of erosion/corrosion
OGCT Vessel	S350-190-020-00-T	11/9/95	Daugherty /	Review of Tape	VT, UT		No evidence of corrosion
OGCT Sample Pump	S350-190-028-00-P	10/23/95	Gee (DWPF-E) /	Direct Inspection	VT, UT, PT		No evidence of corrosion
OGCT Sample Discharge Jump.	403(6.4SP)2		N/A	N/A	UT		No evidence of corrosion
OGCT Coupon Racks	N/A	11/1/95	Chandler /	Direct Inspection	VT		See "Items of Note," No. 9
SAS Vessel	S350-190-129-00-F		N/A	N/A	VT at IDMS		Used IDMS inspection results
HEME Vessel	S350-190-090-00-T		N/A	N/A	VT at IDMS		Used IDMS inspection results
CDC No. 1 Recirculation Pump	S350-190-020-00-P	11/6/95	Gee (DWPF-E) /	N/A	VT		No evidence of erosion
CDC No. 1 Spray Nozzle Rack	N/A	11/8/95	Gee (DWPF-E)	N/A	VT		See "Items of Note," No. 10
CDC No. 1 Jumper	359(23CD)11		N/A	N/A	UT		No evidence of erosion
CDC No. 1 Jumper	359(23CD)12		N/A	N/A	UT		No evidence of erosion
CDC No 1 Jumper	359(23CD)13		N/A	N/A	UT		No evidence of erosion
CDC No. 2 Spray Nozzle Rack	N/A	11/7/95	Gee (DWPF-E)	N/A	VT		No evidence of erosion
MFT Hydragard Liquid Sampler	N/A		N/A	N/A	RT		No evidence of erosion/corrosion
SME Hydragard Liquid Sampler	N/A	10/16/95	Chandler /	Direct Inspection	VT, RT		No evidence of erosion/corrosion
Evaluation/SME Sample Station	N/A	10/16/95	Chandler /	Direct Inspection	VT, UT		No evidence of erosion/corrosion
Inspect C-276/304L Couplings	N/A		N/A	N/A	VT, UT		No evidence of galvanic corrosion
PR Perm Sample Lines	N/A		N/A	N/A	UT		No evidence of erosion/corrosion
SRAT Perm. Sample Lines	N/A		N/A	N/A	UT		No evidence of erosion/corrosion
SME Perm Sample Lines	N/A		N/A	N/A	UT		No evidence of erosion/corrosion
MFT Perm Sample Lines	N/A		N/A	N/A	UT		No evidence of erosion/corrosion
OGCT Perm Sample Line	N/A		N/A	N/A	UT		No evidence of erosion/corrosion

APPENDIX 3 (Cont.)

FA-04.03 EQUIPMENT INSPECTIONS

	INSPECTION ACTIVITIES TO SUPPORT FA-04.03 TEST PROGRAM					
		SRTC MATERIALS INSPECTIONS			NDE	
Equipment Description	Equipment No. (or Jumper No.)	Insp. Date	MTS / MCG Insp. Name / Initials	Method of Inspection Direct / Tape Review	INSPECTIONS (See Attc. 2)	Summary of Inspection Results
PR Vessel / Fixed Coil	S355-150-020-00-T	12/31/95	K. Imrich /	Review of Tape	VT	No evidence of erosion/corrosion
PR Agitator	S355-150-025-00-AG	12/29/95	K. Imrich /	Direct Inspection	VT, DA	No significant evidence of erosion/corrosion
PR Sample Pump	S355-150-028-00-P	12/28/95	K. Imrich /	Direct Inspection	VT, UT, PT	See "Items of Note," No. 1
PR Sample Discharge Jumper	401(16.4SP)2	12/30/95	N/A	Direct Inspection	VT, UT	No evidence of erosion/corrosion
PR Coupon Racks	N/A	12/30/95	G. Chandler /	Direct Inspection	N/A	See "Items of Note," No. 2
PRCD Vessel	S355-150-026-00-E	12/31/95	K. Imrich /	Review of Tape	VT	No evidence of corrosion
PRFT Vessel	S355-150-060-00-T	12/31/95	K. Imrich /	Review of Tape	VT	No evidence of erosion/corrosion
PRFT Sample Pump	S355-150-068-00-P	12/30/95	J. Gee /	Direct Inspection	VT, PT	See "Items of Note," No 1
PRFT Transfer Pump	S355-150-061-00-P	12/30/95	J. Gee /	Direct Inspection	VT, PT	No evidence of erosion/corrosion
OE Vessel and Coil	S355-150-030-00-T	12/31/95	K. Imrich /	Review of Tape	VT	No evidence of corrosion
OECD Vessel	S355-150-036-00-E	12/31/95	K. Imrich /	Review of Tape	VT	No evidence of corrosion
OECT Vessel	S355-150-050-00-T	12/31/95	K. Imrich /	Review of Tape	VT	No evidence of corrosion
PR to PRCD Jumper	(15.1C)3-(16)7	12/29/95	K. Imrich /	Review of Tape	VT, UT	No evidence of corrosion
PRCD to SCVC Vent Jumper	(15.1C)12-(14.1C)4	12/29/95	K. Imrich /	Review of Tape	VT, UT	No evidence of corrosion
Thermowell	(13TW)	12/28/95	N/A	N/A	VT, PT	No PT indication at block weld
Thermowell	(14TW)	12/28/95	N/A	N/A	VT, PT	No PT indication at block weld
Thermowell	(15TW)	12/28/95	N/A	N/A	VT, PT	No PT indication at block weld
Thermowell	(16TW)	12/28/95	N/A	N/A	VT, PT	See "Items of Note," No 3
Dip Tube	403(14.3TK)10	12/28/95	N/A	N/A	VT, PT	No PT indication at block weld
Dip Tube	403(15.2EV)12	12/28/95	N/A	N/A	VT, PT	No PT indication at block weld

APPENDIX 4

INSPECTION: INTERIOR OF SME TANK

Westinghouse Savannah River Company
APPLIED SCIENCE & ENGINEERING TECHNOLOGY
Materials Consultation

SRT-MTS-965106

June 28, 1996

TO: J. Gee, 704-25S
DWPF Engineering

FROM: C.F. Jenkins, 730-A C.F. Jenkins
Materials Consultation

INSPECTION: INTERIOR OF SME TANK

SUMMARY

The interior of the Slurry Mix Evaporator Tank was visually inspected after removal of the internal components and deinventory of the test feeds from the melter. Condition of the tank bottom and walls was excellent - erosion, reported for the bottom turns of the coil assembly and an attached downcomer, had not affected the vessel bottom and walls. One set of coil guides on the vessel floor exhibited significant abrasive wear on one side. This probably resulted from misalignment of the coil support structure and it should not seriously affect vessel life. No other wear was noted on the tank proper. An internal dip tube near the wall was found damaged by a deflector plate attached to framework at the same location. A hole in the pipe had resulted from contact and vibration created by the agitated slurry mixture.

BACKGROUND

Because of erosion observed in internal components of the TNX full scale SRAT/SME, it was imperative to be able to inspect the interior of the DWPF SME vessel after an extended use. The coil and agitator assemblies from the SME showed wear similar to that observed in the TNX scale versions of the feed equipment. Localized areas on the tank bottom which experience flow disruptions, such as those in the vicinity of the coil bumper guides, and the area near the central bearing location, are prone to development of erosion. The guides and other internal components are also susceptible to abrasive wear which may be exaggerated by the presence of the glass frit.

INSPECTION

Although the tank was empty, it was not clean. The tank bottom is slightly sloped towards a sump in the north direction, as situated in Building 221-S. The floor was covered with a ~1 inch deep "mud" soup. The sidewalls and attachments within the vessel were also caked with the mud, though it was relatively dry away from the bottom. Inspection of the metal surface did require wiping the deposit or soup away.

There were no indications of corrosion and no wear was evident on the floor. Original grinding marks could be seen in several places. This is actually as expected based on prior experience at TNX. During agitation, flow parallels the bottom and stays above the surface, which apparently is protected by the quiet mud so that erosion does not proceed. Wear was also not evident near the center bearing, which receives and houses the end of the agitator shaft during service. This area of the floor might be expected to suffer abrasion under some conditions, but it did not experience the effect here.

Inspection of the coil guides, which are fixed to the floor, revealed wear on the guide at the north orientation. The wear existed over nearly the full inside face on one side of one guide only. It is not certain why this occurred, but it probably relates to the fit of the foot which is attached to the coil assembly at the location, and to coil alignment or misalignment with the guide in question. The upstream inside edges of the guides on the short radius side (nearest tank center) exhibit surface polishing as a result of the fluid flow, but the degree of metal loss is small and negligible at the guides.

A 2-inch downcomer pipe or dip tube had a wedge-shaped hole cut into the pipe as a result of contact with a stationary 1/4-inch thick deflector plate attached to an adjacent downcomer support. The contact location is on the east side of the vessel, about 3-feet above the bottom. The pipe is used for frit additions, and is subject to vibration as a result of agitator action on the slurry mix. The cut extends around 1/3 the circumference of the pipe. The deflector should be reoriented, the contact eliminated, and the pipe repaired before the tank is restored to service.

CONCLUSIONS

Results of inspection of the SME vessel interior following non-radioactive trial tests indicated that erosion within the vessel was minimal and not of concern. Damage to a frit feed tube had occurred as a result of contact with a misplaced deflector plate. The tube was repaired and the plate repositioned before the tank was closed. Abrasive wear due to contact on one of the fixed coil guides suggested possible misalignment, so that only one foot was in contact with its guide at any time. Note that all surfaces of the guides and positioning feet are overlaid with STELLITE. Wear will continue until a second foot contacts its guide and the total load is divided. The situation is not expected to affect vessel life significantly.

cc: R.L. Bickford, 730-A
W.L. Daugherty, 730-A

APPENDIX 5

VISUAL EXAMINATION OF DWPF MELTER TOP HEAD AND OFF GAS COMPONENTS

WSRC-TR-95-0234
Revision 0

MATERIAL PERFORMANCE OF DWPF MELTER TOP HEAD AND OFF GAS COMPONENTS (U)

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SAVANNAH RIVER TECHNOLOGY CENTER

Publication Date: August 12, 1996

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MATERIAL PERFORMANCE OF DWPF MELTER TOP HEAD AND OFF GAS COMPONENTS (U)

Kenneth J. Imrich

Issued: August 12, 1996

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SRTC SAVANNAH RIVER TECHNOLOGY CENTER, AIKEN, SC 29808
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TITLE: MATERIAL PERFORMANCE OF DWPF MELTER TOP HEAD AND OFF GAS COMPONENTS (U)

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Material Performance of DWPF Melter Top Head and Off Gas Components (U)

Summary

Results of the visual inspections of the DWPF top head and off gas components indicated that most of the components will perform satisfactorily for their two year design life. The following components showed no evidence of degradation or only minor attack: the level probe, the side, center and vapor space thermowells, the primary quencher, the primary and melter off gas (MOG) line isolation valves (isolation valves are part of the MOG lines), the backup MOG line, the backup film cooler, and the backup film cooler brush. The primary off gas film cooler and the primary MOG line showed signs of moderate attack, however, they will perform satisfactorily for two years.

The following components experienced significant degradation which could result in failure prior to their two year design life.

- Borescope outer housing (extend life by applying Cr/Al duplex coating)

  Severe pitting on the borescope housing outer diameter and oxidation around the orifice were observed. The Cr/Al coating applied on a replacement borescope outer housing dramatically improved its corrosion resistance. A visual inspection of this housing after approximately 2 months of service indicated no evidence of significant attack. Application of the duplex Cr/Al coating on spare (including borescopes from melter 2) and new borescope outer housings is recommended. Aluminum containing alloys such as VDM 602 CA should also be considered as a replacement material for this component.

- Primary film cooler brush (install when required)

  Degradation of the primary film cooler brush Hastelloy X (alloy contains 9 wt% molybdenum) bristles resulted from oxidation of molybdenum. The resulting MoO_3, a corrosive gas, contributed to pitting of the brush block and further degradation of the bristles. The backup film cooler brush performed satisfactorily; however, similar degradation would be expected if the backup system was used continuously. Service life of the brushes can be extended by installing them only when they are needed. The brushes should be removed immediately after each use to minimize oxidation and exposure to hot corrosive gases. Hastelloy X will not perform satisfactorily in this environment and therefore, Inconel 690, Inconel 690 modified with 3 wt% Al, or VDM 602 CA should be used to fabricate the bristles. Service life of this component can also be extended by eliminating the thin bristles and using a scraper with a thicker cross-section. Current blue prints should be changed to show that the film cooler brush shaft is actually fabricated from Inconel X-750.

- Feed tubes (extend life by weld overlaying)

  Degradation of the original feed tube was characterized by severe pitting around the entire beveled region of the core end piece and was attributed to end grain attack. The degraded region was ground and weld overlayed with Inconel 690 filler material. A visual inspection of the repaired feed tubes was performed prior to radioactive runs (approximately five months of service) and showed only minor attack in the beveled region. Weld overlaying of all the spare feed tubes with Inconel 690 filler material is recommended. Weld repaired feed tubes should perform satisfactorily for their intended design life. The core end piece of new feed tubes should also be overlayed to avoid this type of attack.

Backup off gas components have seen only limited service. Components from the backup off gas system would be expected to perform similar to that of the primary off gas components if they are used continuously. The backup film cooler brush should be installed on the melter only when required. Although the backup quencher, which was fabricated from Hastelloy C-276, was not inspected, performance of this material should be satisfactory. This assessment is based on the August 1995 visual inspection of the Hastelloy C-276 quencher from the Integrated DWPF Melter System (IDMS). This inspection showed no evidence of degradation after approximately seven years of continuous operation.

To extend the service life of the melter top head and off gas components, a program should be initiated to develop and evaluate new engineered materials and alloys with improved oxidation and high temperature corrosion resistance. This program should evaluate the effects of mixed gases, containing chlorides and sulfates, on the stability of the protective oxide layers. Further evaluation of aluminum containing alloys such as, Inconel 690 modified with 3 wt% Al and VDM alloy 602 CA, should also be performed. Testing should be performed in both controlled laboratory systems and in an actual melter such as the IDMS.

Several discrepancies have been identified between materials specified on blue prints and actual materials of construction. Therefore, alloy composition of the off gas and top head components from melter 2 should be verified using the portable Texas Nuclear Alloy Analyzer. In addition to verifying alloy compositions, material identification is necessary to understand the corrosion observed in components from melter 1.

Background

The Materials Technology Section (MTS) of the Savannah River Technology Center (SRTC) was requested by Defense Waste Processing Facility to visually inspect various off gas and top head components from the DWPF melter in April 1995 and during the FA-04.02/FA-05 test plan inspection. The former inspection included all melter top head components: two melter borescopes, dip tube bubbler (level probe), two feed tubes, center, side and vapor space thermowells; primary off gas components: film cooler, film cooler brush, off gas line up to and including the isolation valve, and quencher; and backup off gas system: film cooler, film cooler brush, off gas line up to and including the isolation valve. The backup quencher was not inspected during either the April 1995 or the FA-04.02/FA-05 inspections.

All components were fabricated from Inconel 690 except the isolation valve and the primary quencher, which were fabricated from CW7M, a cast version of Hastelloy C-276, and Allcorr, respectively. A report summarizing results of metallurgical evaluations of the borescope will be issued at a later date. A remote visual inspection of the primary off gas line before and after cleaning was performed and video taped by Administration and Infrastructure Quality/Quality Control (A&IQ/QC) Group. Results of the field inspections performed by A&IQ/QC during this program are in Reference 1.

The melter has been in service for approximately eight months with over 85% of the time spent in idle mode (melter not being fed). Air is being injected into the melter through the borescopes and the backup film cooler to control off gas fumability. Melter vapor space temperatures have ranged from 650°C during feeding to 900°C while the melter is idled. Temperatures are lower during feeding because a cold cap (unmelted feed material) forms on top of the melt. Temperatures in the off gas line are lowered to approximately 350 °C by the addition of air and steam though the film cooler and the dilution air system. Finally the temperature is lowered to approximately 90 °C at the primary quencher.

Visual and Metallurgical Examination Results

Melter Top Head Components

Borescopes

The borescopes were in service for three to five months when they were inspected in April of 1995. A detailed report summarizing the results of the failure analysis can be found in reference 1. These components were previously replaced due to a camera failure resulting from over heating. Visual examination of borescope 26 A (EP S-350-185-15-30B) indicated the presence of heavy oxide deposits and deep pits around the outer diameter of the Inconel 690 outer housing (Figure 1). The largest pit near the bottom of the outer housing was approximately 3 inches in diameter and as much as 0.188 inches deep (nominal wall thickness 0.375 inches). Chloride and sulfate containing salts i.e., sodium chloride and potassium sodium sulfate were removed from the surface and identified by X-ray Diffraction (XRD). Sulfate and chloride concentrations were quantified by Ion Chromatography (IC) and approached 20,000 ppm and 9,000 ppm, respectively. Numerous small pits were observed along the entire length of the outer housing. The orifice below the camera lens, where the air exits, was also covered with a thick scale. In some areas the scale had spalled off revealing the metal substrate. Radial cracks in the substrate emanated outward from the inner diameter of the orifice in all directions (Figure 2). Point scans performed with Energy Dispersive Spectroscopy (EDS) indicated a severe depletion of chromium in the near surface region around the orifice. Internal void formation characteristic of high temperature oxidation was also evident in this region. The inner diameter of this tube, except for the portion around the orifice, did not show any signs of oxidation (spalling or chrome depletion) or corrosion. The original machining marks were still visible on this surface. The second borescope, 25 A (no EP number available), was only visually inspected and appeared to be in similar condition.

The inner Type 304 L camera optics housing was in excellent condition (Figure 3). A thin brown deposit was observed on the lower portion of the tube (last eight inches) and on the optics assembly cover. A slight discoloration (bluing due to elevated temperature exposure) was also observed in this piece of the borescope.

Center Melter Thermowell

Visual inspection of the center melter thermowell was performed several hours after its removal from the melter (Figure 4). The 0.125 inch thick glass coating, which extend from the bottom of the thermowell several feet to the melt line, had almost entirely spalled off during cooling. The Inconel 690 surface below the glass coating appeared to have a crystalline appearance consistent with an intergranular attack (IGA). The attack was more severe at the end of the tube where end grains are exposed. Similar attack has been observed in other melter components in TNX. The tube was generally silver/gray in color; however, gold and blue spots (possibly resulting from an oxide of titanium) were observed in several locations. There appeared to be some minor attack at the glass - air interface. Above the melt line a thin black coating was observed on several regions of the sheath. No degradation, pitting or oxidation, was observed in the vapor space region of this component.

Vapor Space Thermowell

Initially this Inconel 690 melter top head component could not be removed from the melter. However, after fabrication of a Type 304 stainless steel collar and air quenching, the thermowell was extracted from the melter (Figure 5). Vertical scratches were evident on opposing sides of the Inconel 690 collar but they did not seem to be very deep. A thin black glassy coating initially covered most of the thermowell, but upon cooling, this layer spalled off. No significant degradation was evident on this component.

Side Thermowell

The side thermowell appeared to be in better shape than any of the other thermowells. Little or no melt line attack was observed (Figure 6). Discoloration, like that noted on the center thermowell, was not observed. There was a slight roughening of the surface which contacted the molten glass but was not as severe as that observed on the center thermowell.

Dip Tube Bubbler (Level Probe)

The dip tube bubbler appeared to be in excellent condition. The surface of the tube was similar in condition to that of the center thermowell (Figure 7). The tip was covered with a thick coating of glass. The tip, area around the bottom hole, approximately 1 inch in diameter, was not inspected because the component was still extremely hot and glass was spalling off. This component was placed back into the melter before this region could be inspected again.

Feed Tubes

Two feed tubes, labeled A (S-999-350-50-40) and B (no EP No. available), were visually examined and documented. Glass deposits and scale had to be chipped away to expose the metal substrate of the core end piece. Severe degradation of the beveled edge at the bottom of the core end piece was observed on both feed tubes (Figure 8). Material loss in this region appeared to be significant, approximately 0.090 in. Several small metallurgical pieces were removed from outer housing and the bottom area around the orifice adjacent to the bevel on the core end piece. Specimens were not removed from the beveled region to avoid penetrating the water jacket. Metallurgical examination of these specimens revealed a pitting type of attack. Pits were broad and covered most of the beveled surface. No evidence of intergranular attack was observed in either of the specimens (Figure 9). The area surrounding the feed outlet was in excellent condition. No material loss or pitting was apparent in this region. Similarly, the entire length of outer Inconel 690 tube appeared to be in excellent condition. No evidence of corrosion was observed above this weld joining the beveled portion to the outer tube.

Primary Off Gas System

Film Cooler

Visual inspection of the primary film cooler showed oxidation of the lower portion of the outer lip (Figure 10). Oxidation was most severe in a region encompassing approximately 1/3 of the circumference of the outer lip (Figure 11). This area was oriented toward what was believed to be the north east side (middle) of the melter. The scale was removed using light tapping with a screwdriver. Most of metal underneath the scale was oxidized especially around the edge. Internal components including the baffles and second lip were in good condition. A thin grayish black film was observed on the inner surfaces and contained mainly sulfates. No chloride containing salts were found in this region. The outer diameter of the film cooler was in excellent condition i.e., free of pitting or general corrosion, with only light deposits observed. Air passages, intended for flushing the region between the film cooler and the refractory were clean and free of any obstructions. No degradation of the flange was observed.

Film Cooler Brush

Visual examination of the Inconel 690 film cooler brush indicated severe pitting of the bristle holder and corrosion/oxidation of the bristles (Figure 12). Approximately 25 percent of the bristles from the four holders were missing. The remaining bristles were corroded, severely thinned, very brittle and /or partially broken. X-ray Fluorescence (XRF) analyses of a bristle from the failed primary film cooler brush indicated a composition of 54 wt% Ni, 25.78 Fe, 12.75 Cr, 2.71 Cu, 2.94 Mn, and 1.40 Co. The brush was covered with a grayish black deposit. Sodium chloride and potassium sulfate salts were identified by XRD. Concentrations of the salts were found to be approximately 4000 and 21000 ppm, respectively. Metallography revealed a characteristic wrought structure with some grain growth. Large broad pits were observed in both the brush block and in weld fusion zones which attached the bristle holders to the brush block (Figure 13). Very little scale formation was observed on this component. Evidence of intergranular attack was not noted. Degradation of the flange face which mates to the off gas line was not observed. XRF analyses were also performed on the brush block and brush shaft and revealed that these components were fabricated from Inconel 690 and X-750 (73 wt% Ni, 16 Cr, 7 Fe, and 3 Ti), respectively. The shaft showed only minor pitting attack.

Off Gas Line

The melter off gas (MOG) line from the film cooler to the isolation valve was visually inspected, both directly and remotely (using a video probe), for evidence of degradation and deposit build up (Figure 14). The isolation valve is part of the MOG line. Severe pitting was observed in the 8 inch diameter Inconel 690 pipe just below the film cooler brush flange (Figure 15). The pits were numerous but generally less than 0.0625 inches deep. The metal surface in this region was covered with a very thin, light gray deposit. Metallic scrapings taken in this region were analyzed using XRF and indicated a chromium concentration of 12 wt%. This is a significant decrease in chromium concentration from that specified (30 wt%) for the DWPF melter Inconel 690 components. Deposits from this region were analyzed by XRD and again were found to contain high amounts of chloride and sulfate bearing salts. No significant change in pit depths in the region below the film cooler brush was observed during the April and the FA-04.02/FA-05 inspections.

The lower portion of this pipe between the film cooler flange and the 90 degree elbow was covered by a heavy (~ 0.375" thick) multi-colored (gray, black, and some yellow) deposit. A 3" diameter portion of this deposit was removed for analyses. XRD analysis indicated the presence of various chloride and sulfate containing salts. Chloride and sulfate concentrations were approximately 4000 ppm and 21000 ppm, respectively. Pitting was not observed beneath this deposit. The film cooler, film cooler brush, and quencher MOG line flange faces were in excellent condition.

Remote visual examination from the MOG line beginning at the 90 degree elbow and continuing to the isolation valve was performed using a video probe during both the April and FA-04.02/FA-05 inspections. Initially the surface of the pipe was covered with thick gray deposits and the pipe could not be viewed. However, following cleaning (April inspection only) with water, remote visual examination revealed pitting throughout the entire length of the MOG line up to the isolation valve. The isolation valve (fabricated from CW7M, a cast version of Hastelloy C-276) including the casting and the ball were in excellent condition, exhibiting no evidence of pitting attack or corrosive attack. Deposits collected from the off gas line outlet contained chlorides and sulfates concentrations in excess of 9000 and 28000 ppm respectively. The pipe was not cleaned during the FA-04.02/FA-05 so the inner diameter surface between 90 degree elbow and the isolation valve was not viewed with the video probe.

Primary Quencher

The primary quencher was the only off gas component fabricated from Teledyne Allvac Allcorr. Visual examination in April 1995 included the inlet region, the nozzle, and the center of the quencher including several welds; however, during the FA-04.02/FA-05 inspection the entire quencher, including piping before and after the quencher, was visually examined. Evidence of general and localized corrosion was not observed during either inspection. A black loosely adhering deposit was sampled from the inlet region of the quencher and a white crystalline deposit was scraped from the bottom of the outlet pipe. The black deposits contained both sodium chloride and sodium sulfate while the white deposits sampled from the outlet contained only sodium chloride.

Backup Off Gas System

Film Cooler

Visual examination of the backup film cooler was performed and indicated no signs of significant corrosion. A rough black deposit was observed covering the lower portion of the film cooler (Figure 16). The Inconel 690 material beneath this tenaciously bound deposit did not show any evidence of degradation. Deposits from the film cooler contained approximately 3000 ppm chlorides and 11000 ppm sulfates. The backup off gas system has only been in service for approximately one month or 10 % of the time the melter has been operated (from initial start-up through the April 1995 inspection). No feeding or glass pouring was performed while the backup off gas system was operative. During the remaining 90% of the time this system was used to inject air into the melter (~ 430 lb/hr). The design of this component is significantly different from the primary off gas film cooler. Air vents run vertically up the film cooler rather than circumferentially (Figure 17).

Film Cooler Brush

The film cooler brush was coated with a thick off white/pale yellow deposit. Analysis of this deposit revealed significant amounts of lead chloride (> 1 wt%). Examination of the brush did not indicate any pitting of the brush block or bristle holders. Some thinning of the bristles was observed but was not as extensive as that observed in the primary system. A number of the bristles were missing with some appearing to have been pulled out from the holder while others had broken off flush with the holders (Figure 18).

Off Gas Line

The inlet and outlet regions of the off gas line were visually inspected (Figure 19). Remote video inspection was not performed. Both the inlet and outlet ends were covered with a very fine yellowish white deposit which was found to contain high concentrations of sodium and lead chloride along with some sulfate containing salts. This deposit was also observed beyond the isolation valve and was easily removed with a soft brush. Pitting attack was not observed in any portion of the backup MOG line. The Inconel 690 pipe and Hastelloy C-276 ball in the isolation valve did not show any signs of corrosion.

Discussion

Top Head Components

Varying degrees of degradation were observed on top head and primary off gas components. More severe attack occurred in the hotter regions of the melter vapor space and off gas system. Chloride and sulfate bearing compounds i.e., sodium sulfate, and sodium chloride, present in the off gas condense and concentrate on the colder top head and off gas components. These compounds break down the protective chromium oxide layer resulting in severe degradation of the metal substrate. Generally degradation was more severe in the higher temperature regions of the melter and off gas system.

Results from the metallurgical evaluation indicate that the spalling noted around the orifice of the borescope resulted from high temperature oxidation [2]. Normally this alloy would form a stable chromium oxide (Cr_2O_3) layer which would protect the metal from further oxidation or corrosion. However, thermal fluctuations caused by frequent purges of steam (once every half hour) and the constant flow of air around the orifice, accelerated spalling of the protective chromium oxide layer and resulted in further oxidation of the substrate. Chloride and sulfate containing salts also contributed to the degradation of the protective oxide layer. Spalling of the oxide layer exposes fresh metal and results in the formation of a new Cr_2O_3 layer and metal wastage. Furthermore, elevated temperatures, approaching 850°C in the vapor space during idle mode, accelerate the diffusion of chromium from deep within the metal substrate to the surface.

Oxidation around the orifice of the borescopes may be minimized by reducing the amount of purge air passed through the orifice, by minimizing the frequency of steam purging, or by cooling the Inconel 690 sheath. These solutions would require redesign of the borescope. Oxidation in this region could be eliminated completely by using an inert gas purge such as argon but the effects of the gas on the glass chemistry, off gas, and system integrity would need to be evaluated. If these are not viable options, an alternate material (ceramic or alloy), which could be used as an insert around the orifice, or surface treatment should be considered.

The large pit observed on the side of the outer housing near the core end piece resulted from Type II hot corrosion. The morphology in this region was dramatically different than that observed around the orifice only inches away. This type of corrosion results in a non-uniform pitting attack with little or no chromium depletion from the metal substrate [3]. Here internal void formation was minimal indicating that only the chromium close to the surface had enough time to diffuse to the surface and combine with oxygen to form Cr_2O_3 before it spalled off.). A corrosion rate in excess of 300 mils/yr was estimated. The extremely high concentrations of chloride and sulfate bearing salts combined with thermal cycling of the outer tube contributed to the degradation of the protective oxide. Formation of nickel sulfides in the metal substrate, characteristic of sulfidation, was not observed in this region.

The role of the chlorides on the degradation of the borescope is unknown; however, chlorides are known to cause severe "breakaway" corrosion in other chromium and nickel based alloys [4]. Additions of small amounts of aluminum to Ni/Cr alloys have been shown to increase the chlorination and oxidation resistance of nickel base alloys [5, 6]. Therefore, a recommendation was made by the DWPF Materials Committee in June to apply a duplex chromium and aluminum diffusion coating to one of the replacement borescope outer housings [7] (work packages BGKRL and BGKRM). An inspection was performed after approximately two months of service (Figure 20a and b). A thin loosely adhering scale was scraped from the side of the housing and XRF analysis of this scale detected the presence of aluminum which indicates corrosion of the coating had occurred. However, corrosive attack was minimal and application of the Cr/Al coating has dramatically extended the life of the outer housing [8]. The service life of the coated borescopes was conservatively estimated at one year; however; a visual inspection should be performed after one year of service (this will include some time during radioactive operations) to assess their condition and extend their service life to two years. Alternate alloys containing 2 to 3 wt% aluminum or silicon (VDM alloys 602 CA and 45 TM and Inconel 690 modified with 3 wt% Al) have also performed well in IDMS and incinerator coupon tests [9, 10, 11] and should be considered for use on this and other DWPF melter components.

Degradation of the feed tube core end piece resulted from pitting attack of the beveled region between to the main outer tube and the bottom flat orifice plate. No significant attack was observed in the outer tube or around the orifice. Metallurgical specimens sectioned from the orifice plate and the main tube adjacent to the beveled region revealed no evidence of intergranular attack. It is speculated that exposed end grains in the beveled region may have contributed to the observed localized attack; however, the metallurgical evaluation was not conclusive. The detail print (no. D188452 rev. 16) did not specify the form of material i.e., bar, plate or round stock, from which this portion of the component was to be fabricated. Therefore, if it was machined from a piece round stock end grains would have been present. Attack of the region around the orifice would be less likely since it is closer to the cooling water jacket. Columnar grains shown in the photo micrograph resulted from directional cooling of the weld. Weld repair of the feed tubes was recommended [12]. The core end piece of new feed tubes should also be overlayed to avoid this type of attack.

A visual inspection of a weld repaired feed tube (S999-350-50-40) was performed and indicated a significant improvement in performance (Figure 21). One small region of shallow pitting was observed on the weld repair area. Service time was not determined but was estimated at approximately five months.

The three thermowells and the dip tube bubbler were in good condition. Only a minor intergranular attack below the melt line was observed. This type of attack was observed in similar components in IDMS. Since these components are reasonably thick, this attack should not affect their operability. In addition, degradation of these components in the vapor space does not seem to be a significant concern. This may be attributed to the lack of chloride and sulfate salt deposits. These salts appear to condense on the cooler components such as the film cooler (air cooled), the feed tubes (water cooled) and the borescopes (steam and air cooled). The absence of significant corrosive attack may also be attributed the thin glassy deposits which have been observed on these components above the melt line.

Primary Off Gas System

Failure of the primary film cooler brush bristles resulted from oxidation of the Hastelloy X. Although it was initially thought that the bristles were fabricated from Inconel 690 weld wire, the blue print (M-DCP-S-92010 Rev. 2) specified Hastelloy X (a nickel base alloy containing 9 wt% molybdenum). Bristles taken from spare film cooler brushes were positively identified as Hastelloy X. Molybdenum reacts with the oxygen to form corrosive liquid phase at 795 °C or a volatile corrosive gas (MoO_3) at slightly higher temperatures [13]. Temperature data from the film cooler region was not available; however, data obtained from a thermocouple mounted on the end of the IDMS film cooler indicated that vapor space temperatures during idle mode ranged between 800 and 900 °C. Temperatures near the film cooler brush should be slightly lower since air injected into the film cooler mixes with and cools the hot exhaust gases. Temperatures were still high enough to completely oxidize the Mo from the bristles.

In addition to the degradation caused by the MoO_3, chloride and sulfate salts that deposited on the brush also contribute to the corrosion of the bristles and brush block. Laboratory tests have shown that the chloride and sulfate salts will adversely affect the stability of the protective oxide layers at lower temperatures [4]. The acidic nature of the salts fluxes away the protective Cr_2O_3 layer exposing fresh metal which then repassivates. The breakdown of the protective oxide layer can occur very fast resulting in catastrophic corrosion. In the case of the film cooler brush block, degradation was in the form of deep broad pits. Pitting attack was also observed on the borescope outer housing and in the inlet of the primary off gas line. Although high concentrations of sulfate containing salts were present on the surface of the film cooler brush, evidence of sulfidation i.e., sulfide formation at the scale-metal interface, was not observed. Sulfidation can occur when temperatures exceed the melting point of the various sulfate salts (825 to 980 °C).

The film cooler brush shaft was to be constructed from Inconel 690 per WSRC Print M-DCP-S-92010 Rev. 2. Material identification revealed that the shaft was fabricated from Inconel X-750, a precipitation-hardenable alloy. Inconel X-750 has good oxidation resistance and high temperature strength; however, it contains less chromium than Inconel 690, 14 to 17 wt% Cr and 27 - 31 wt%, respectively. Chromium provides corrosion resistance especially to the chloride and sulfate salts present in the DWPF melter. Furthermore, Inconel X-750 does not contain Al or rare earth elements which increase the corrosion resistance of the protective oxide layer. Therefore, this alloy would be less resistant to corrosive attack than Inconel 690. The minor pitting attack experienced by the shaft may have occurred because the shaft was out of the direct flow of exhaust gases. Thereby, reducing metal temperatures and minimizing chloride and sulfate salt deposition. The brush block was also identified and found to be Inconel 690. This is consistent with the print.

Due to discrepancies with the print and actual material of construction, alloy composition off gas and top head components from melter 2 should be evaluated using to portable Texas Nuclear Alloy Analyze. This analysis would aid in the understanding of the corrosion observed in components from melter 1.

Severe oxidation of the Hastelloy X film cooler brush bristles is anticipated. Degradation will accelerate with increasing temperature such as that experienced during idle mode. Changes in the brush design, operation and material of construction should be considered. From a operational stand point, the brush should be installed only when it is needed, otherwise it should be removed and the port sealed with a blind flange. The bristle material should be changed to Inconel 690 or an alloy with a higher aluminum content such as VDM 602 CA or the modified Inconel 690 (3 wt% Al). The print (M-DCP-S-92010 Rev. 2) should be changed to reflect this material substitution. These two changes should dramatically extend the life of this component. An evaluation should be conducted determine the feasibility, of using a scraper to clean the film cooler. Increased cross -sectional area may aid in increasing component service life.

Degradation observed on the end of the film cooler most likely resulted from a combination type II corrosion and oxidation. Metallurgical sections were not removed from this component and therefore, the exact corrosion mechanism could not be determined. Approximately 30% of the bottom edge of the film cooler was affected; however, the degradation was not severe enough to warrant removal at this time.

The off gas line from the 90 degree elbow up to the isolation valve showed some evidence of pitting attack. Pits were observed throughout the entire length of this pipe (up to the isolation valve). Pit depths did not seem deep enough to compromise the structural integrity of the off gas line. Continued use of this component is therefore recommended.

Both the isolation valve and the primary quencher were in excellent condition and adequate for continued operation.

Backup Off Gas System

The backup off gas system components were in excellent condition; however, operating time on this system was limited. The high chloride and sulfate containing deposits observed throughout this system may pose a serious corrosion problem if this system is used for extended periods of time. The absence of any degradation i.e., pitting attack, indicates that the corrosion is temperature dependent. Since air is injected through this system the temperature would be expected to be much lower than that in the primary side where pitting attack was observed.

Although the DWPF backup quencher, which was fabricated from Hastelloy C-276, was not inspected, it is expected to perform satisfactorily. This is based on the performance of the IDMS quencher visually inspected in August 1995 [14, 15]. Corrosive attack of this component was not observed after approximately seven years of continuous operation.

Conclusions

The following is an assessment of the current condition of the various top head and off gas components from the DWPF melter following inspections in the spring and fall of 1995. Component performance was based on the current operating mode and melter environment. Changes in the operating conditions and/or feed chemistry may affect component service life.

The following components showed no significant evidence of degradation and will perform satisfactorily for their current two year design life:

- Thermowells (vapor space, center, and side)
- Level probe
- Primary and backup MOG line isolation valves
- Primary quencher
- Backup MOG line
- Backup film cooler and film cooler brush

The following components showed evidence of moderate degradation but are expected to perform satisfactorily for their two year design life:

- Weld repaired feed tubes (pitting attack on beveled region of core end piece)
- Primary film cooler (oxidation and corrosion on lower edge, no repair required)
- Primary off gas line (significant pitting attack in inlet region, moderate pitting up to the isolation valve, no repair required)

The following components experienced significant degradation and are not expected to survive the two year service life as currently designed:

- Borescope outer housing (extend life by applying Cr/Al duplex coating)
- Primary film cooler brush (install when required)
- Original feed tubes (extend life by weld overlaying)

The following recommendations were made to extend the lives of these components to approximately two years.

Borescope outer housings experienced significant oxidation around the orifice and breakaway corrosion on the side of the outer housing. Minimal pitting was observed on the duplex Cr/Al coated outer housing after approximately two months of service. Future housings should be coated with this diffusion layer. Aluminum containing alloys such as, VDM 602 CA or the modified Inconel 690 with 3 wt% Al, should be considered as candidate materials for future housings. To ensure the stability of the protective oxide layer, the air being passed through the borescope should be reduced or eliminated (possibly using an inert gas such as argon). In addition, the frequency of steam purges should also be reduced to minimize thermal cycling of the housing. The service life of the borescopes was conservatively estimated at one year; however; a visual inspection should be performed after one year of service (this will include some time during radioactive operations) to assess their condition and extend their service life to two years.

Primary and backup film cooler brush bristles were fabricated from Hastelloy X. Degradation of the primary film cooler brush bristles resulted from oxidation of molybdenum. Chloride and sulfate salts also contributed to the degradation by attacking the protective oxide layer. The backup system performed satisfactorily, showing only minor attack, because air injected through this system lowered the temperatures and because it was used infrequently as an off gas system. However, similar degradation would be expected if the backup system were used continuously. Service life of the brushes can be extended by installing them only when they are needed. The brushes should be removed immediately after each use to minimize oxidation and exposure to hot corrosive gasses. Hastelloy X will not perform satisfactorily in this environment and therefore, Inconel 690, Inconel 690 modified with 3 wt% Al, or VDM 602 CA should be used to fabricate the bristles. Service life of the component can also be extended by eliminating the thin bristles and using a scraper with a thicker cross-section. Current blue prints should be changed to show that the film cooler brush shaft is fabricated from Inconel X-750.

Feed tubes experienced severe degradation in the beveled region of the core end piece. The degradation was most likely due to end grain attack. A visual inspection of the weld repaired feed tubes was performed prior to radioactive runs and showed only minor attack. Buttering of the core end piece of damaged and spare feed tubes with Inconel 690 weld filler metal was recommended. Weld repaired feed tubes should perform satisfactorily for their intended design life. The core end piece of new feed tubes should also be overlayed to avoid this type of attack.

Several discrepancies have been identified between materials specified on blue prints and actual materials of construction. Therefore, alloy composition of the off gas and top head components from melter 2 should be evaluated using a portable Texas Nuclear Alloy Analyzer. This analysis would verify materials of construction and aid in the understanding of the corrosion observed in components from melter 1.

Path Forward

Most of the DWPF melter top head and off gas components will perform satisfactorily for their two year design life. The components that suffered significant attack were the borescopes, primary film cooler brush, and feed tubes. Changes in the operation of the film cooler brush and design modifications to the feed tubes and borescopes is expected to extend their service lives to two years. A two year life is adequate but should be extended because; 1) the melter design life is 2 years butmay be extended, 2) remote handling in a radioactive environment is difficult, 3) outages for component replacement results in unnecessary production downtime, 4) long term disposition of radioactively contaminated components is costly, 5) high alloy materials are

are expensive, and 6) procurement and fabrication lead times are long. Therefore, a program should be initiated to develop and evaluate new engineered materials and alloys with improved oxidation and high temperature corrosion resistance. This program would explore the effects chloride and sulfate gases on the stability of the protective oxide layers. Testing should be performed in both controlled laboratory systems and in an actual melter systems such as the IDMS.

Acknowledgments

The authors wish to offer appreciation to the personnel who have assisted with inspections and metallurgical evaluation, including J.T. Gee, D.C. Iverson, G.T. Chandler, C.F. Jenkins, T.L. Reown and A.R. Jurgensen.

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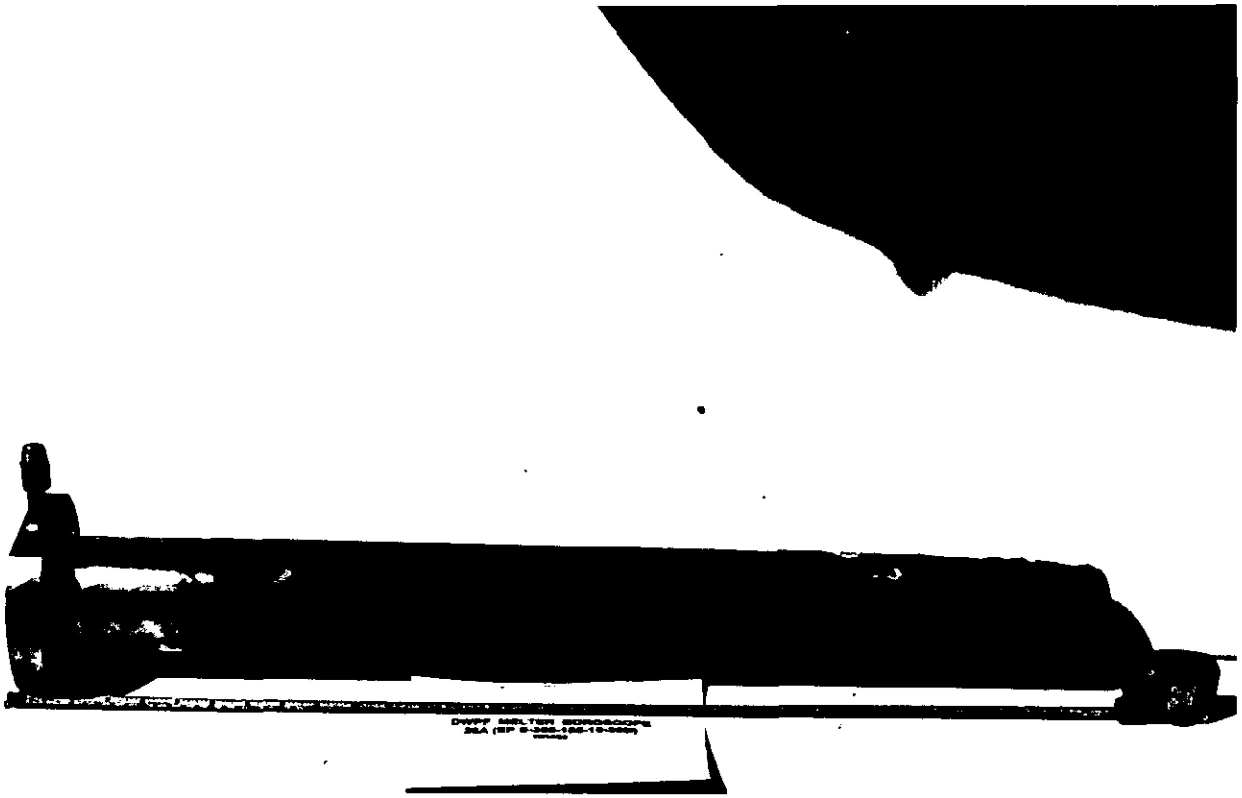


Figure 1. Borescope Outer Housing (WSRC-FM-95-0050-63).

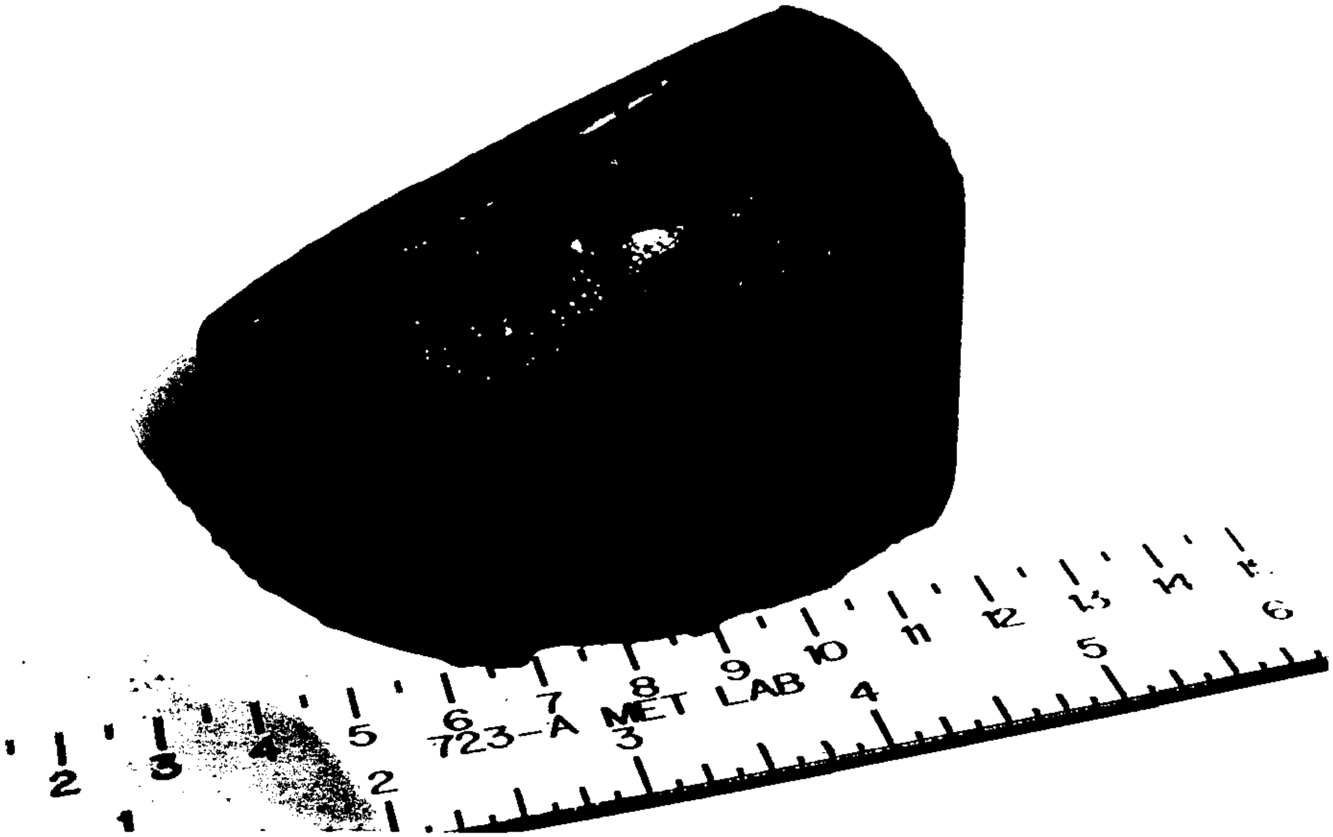


Figure 2a. Large pit on the side of the borescope outer housing (WSRC-FM-95-0050-05).

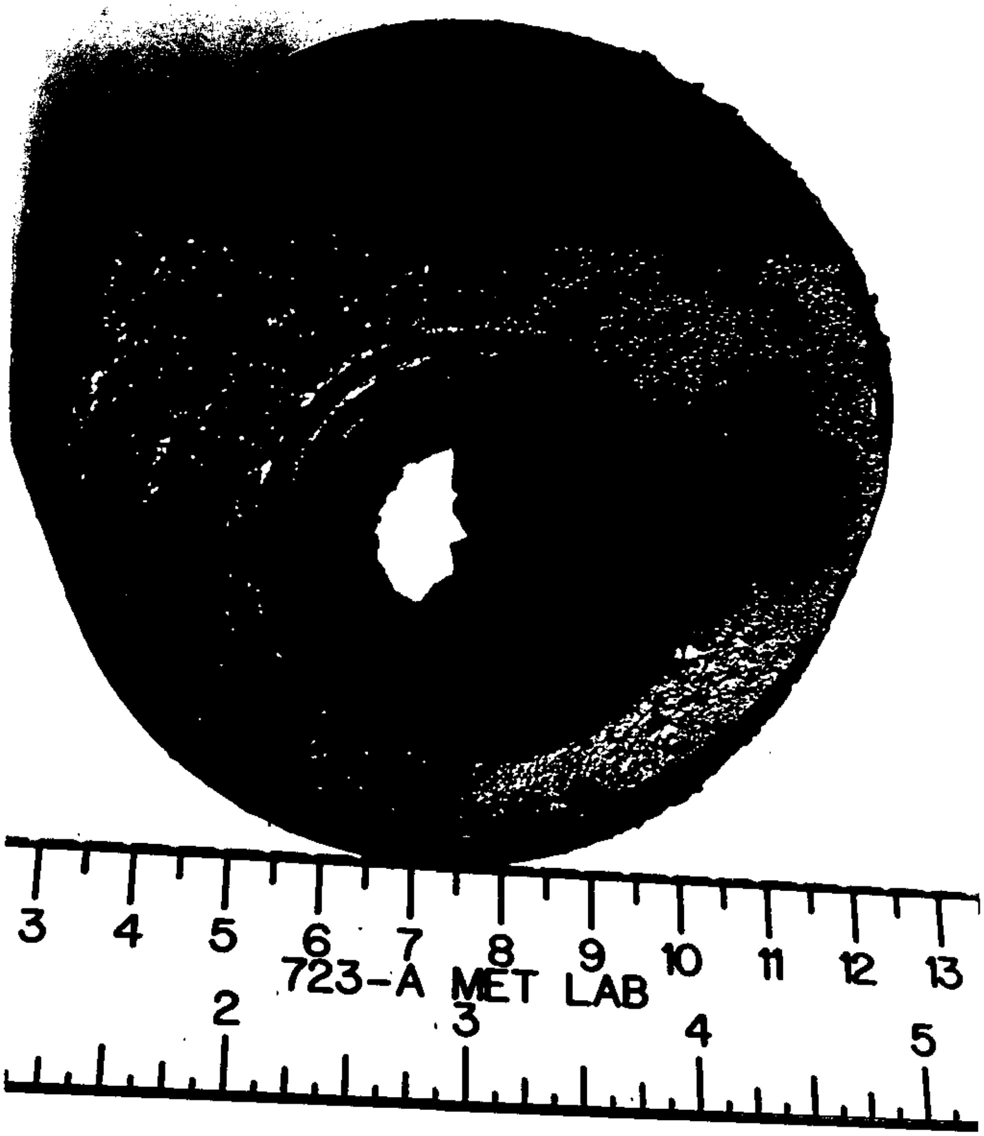


Figure 2b. Borescope orifice (WSRC-FM-95-0050-12).

Figure 3a. Borescope camera assembly (WSRC-FM-95-0050-48).

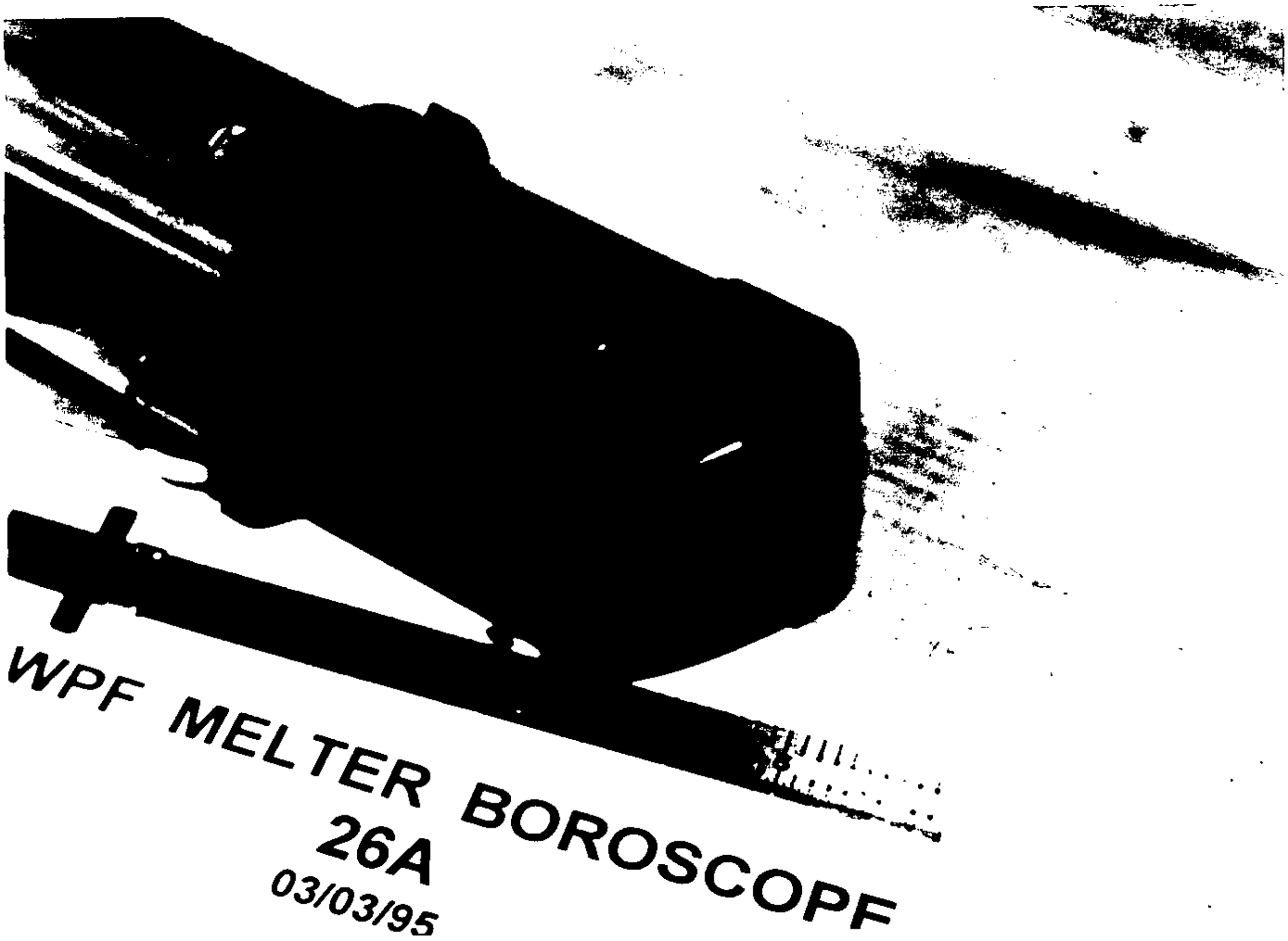


Figure 3b. End of the borescope camera assembly (WSRC-FM-95-0050-45).

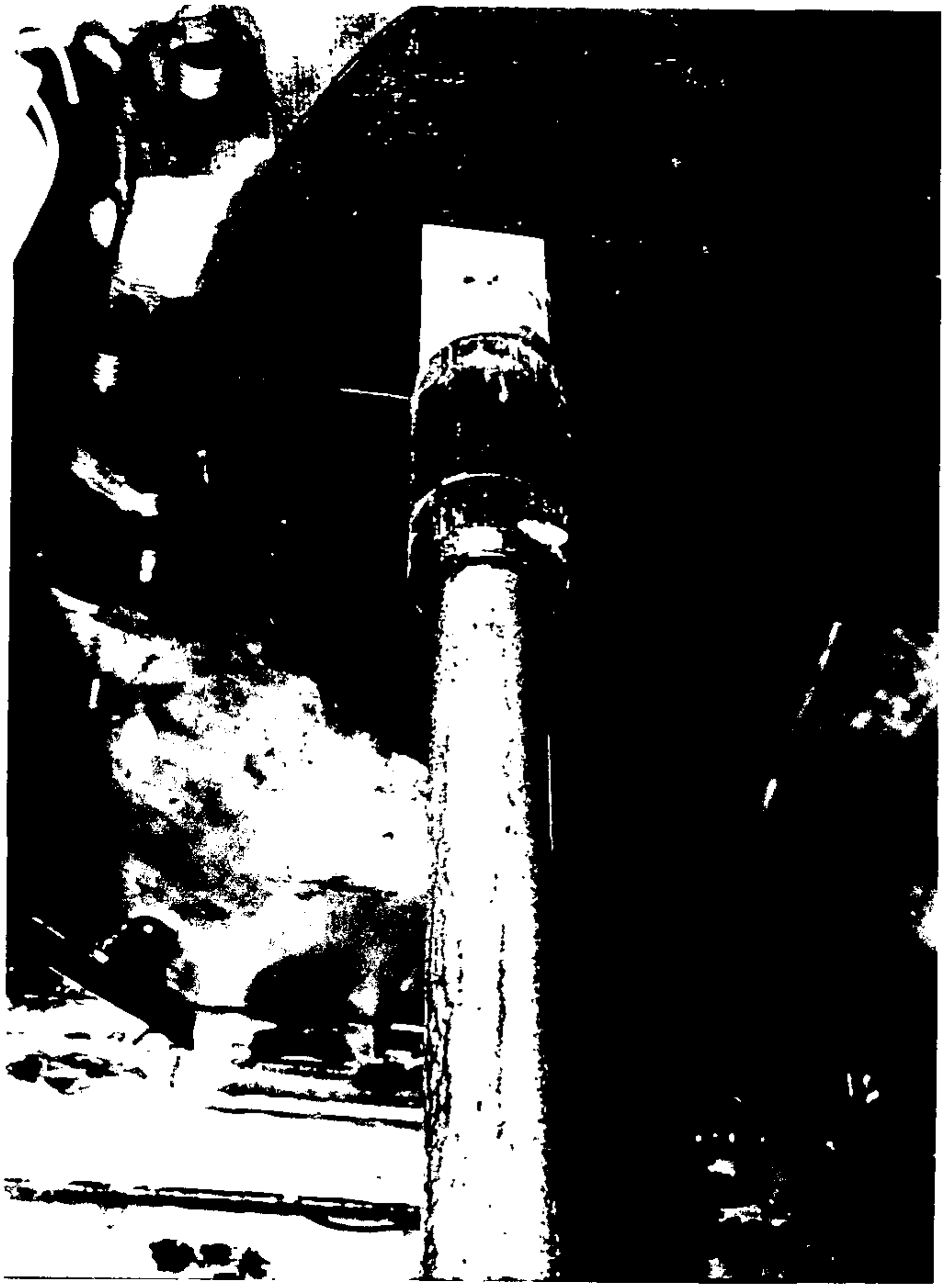


Figure 4a. Center thermowell - Inconel 690 collar below alumina insulator (WSRC-FM-95-0049-90).

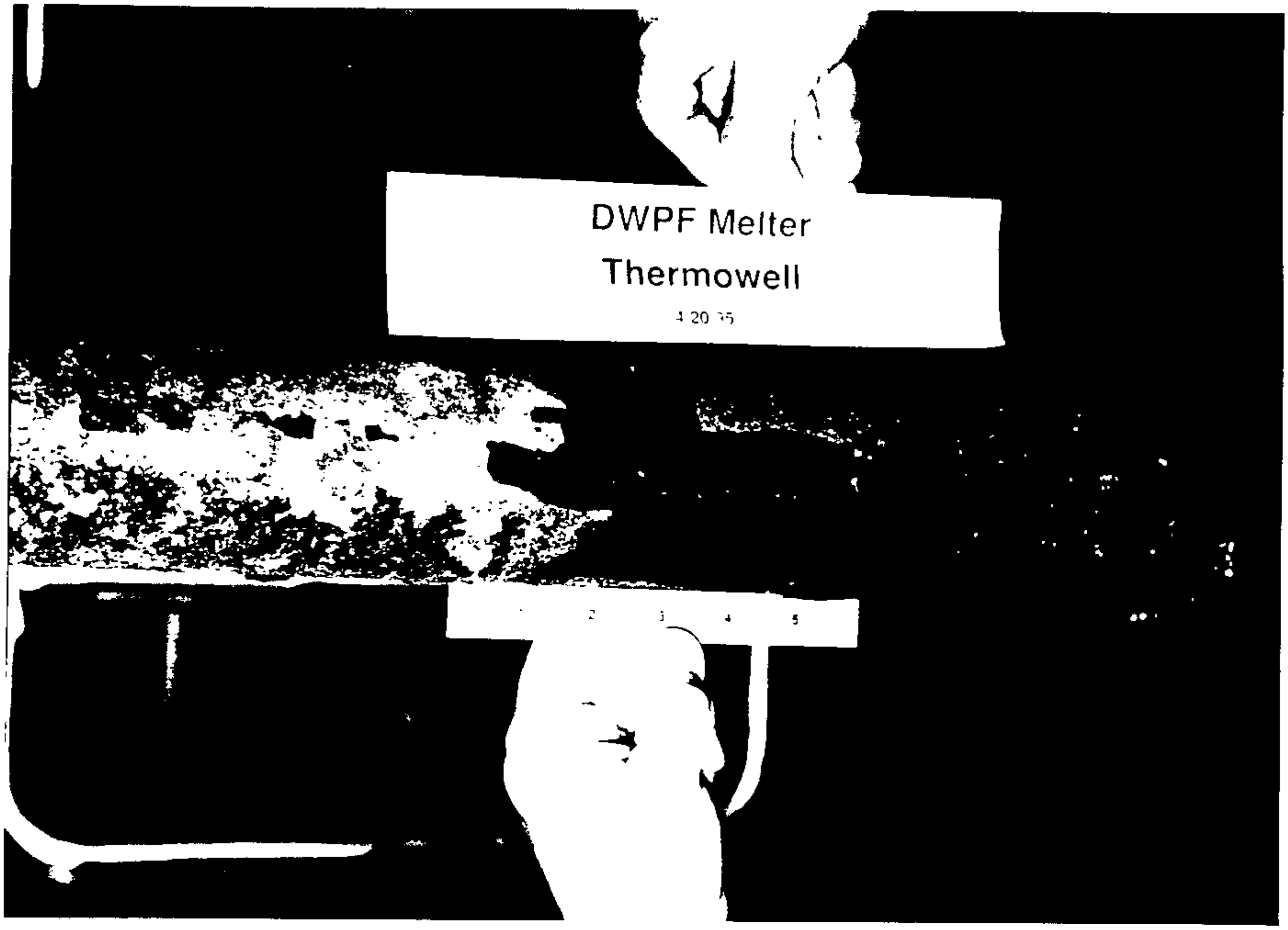


Figure 4b. Center thermowell - bottom region (WSRC-FM-95-0049-97).

Figure 5a. Vapor space thermowell - lower portion (WSRC-FM-95-0049-115).

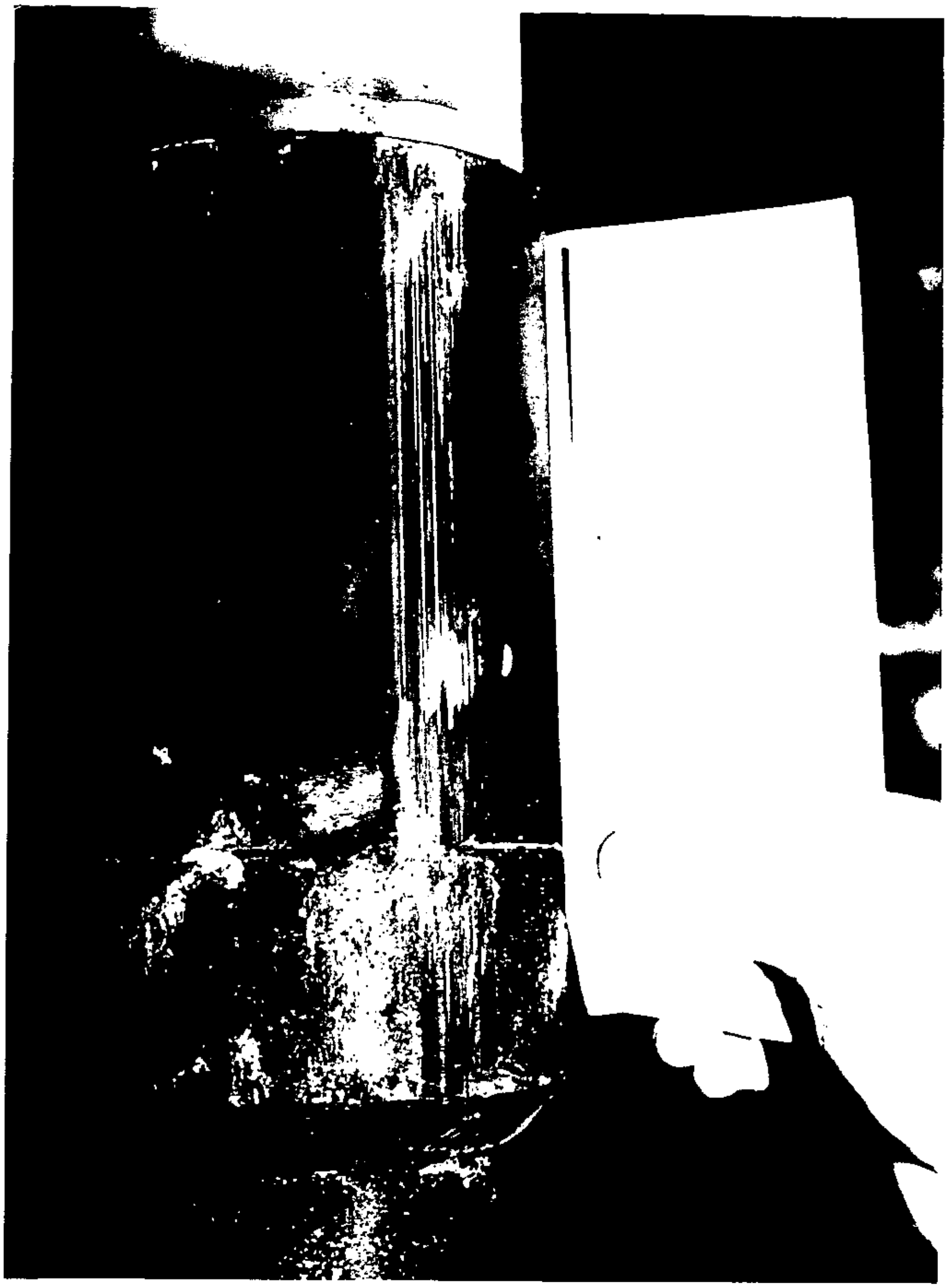


Figure 5b. Vapor space thermowell - scratch on collar and alumina insulator (WSRC-FM-95-0049-113).

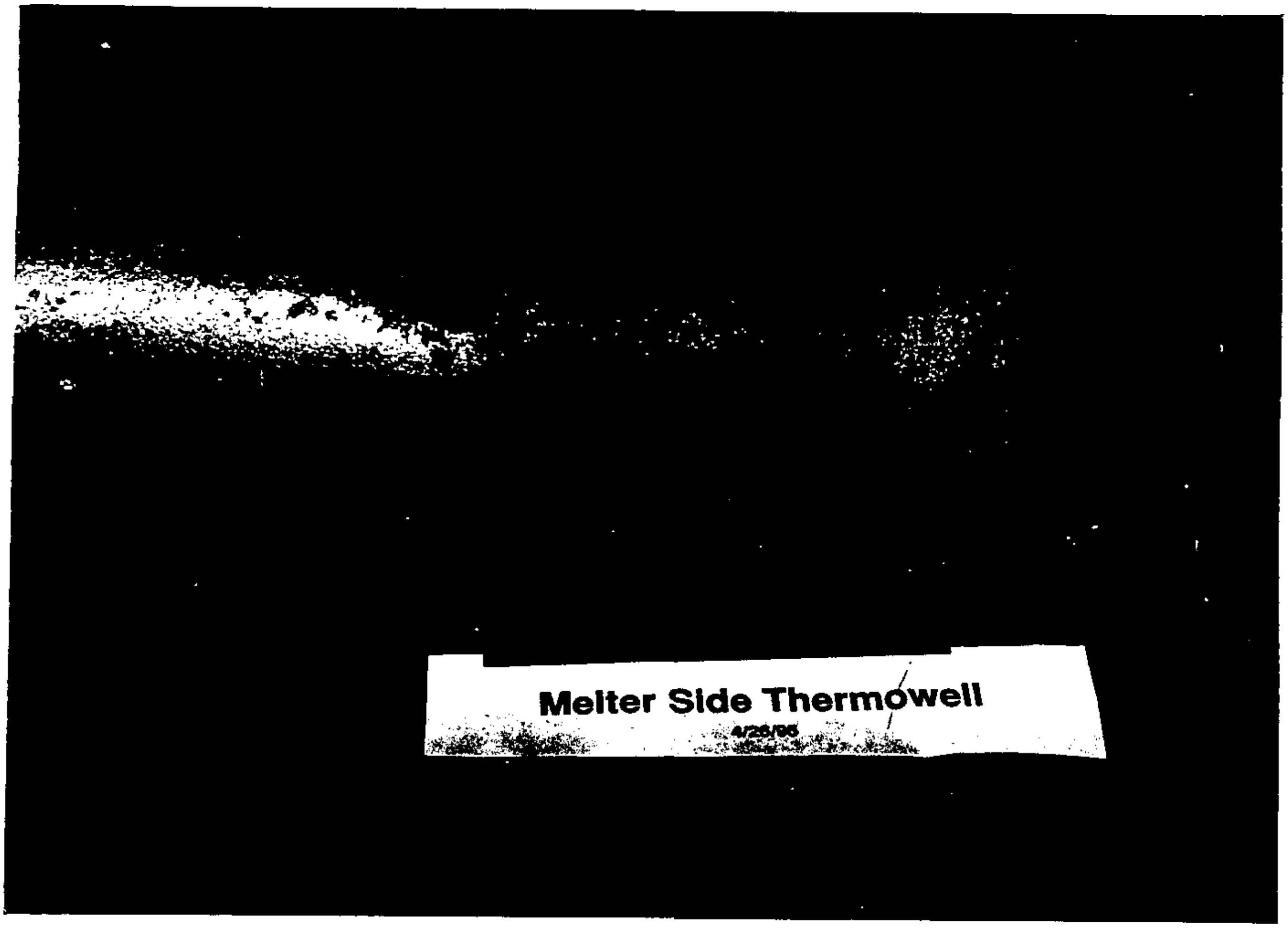


Figure 6a. Side thermowell - tip (WSRC-FM-95-0049-88).

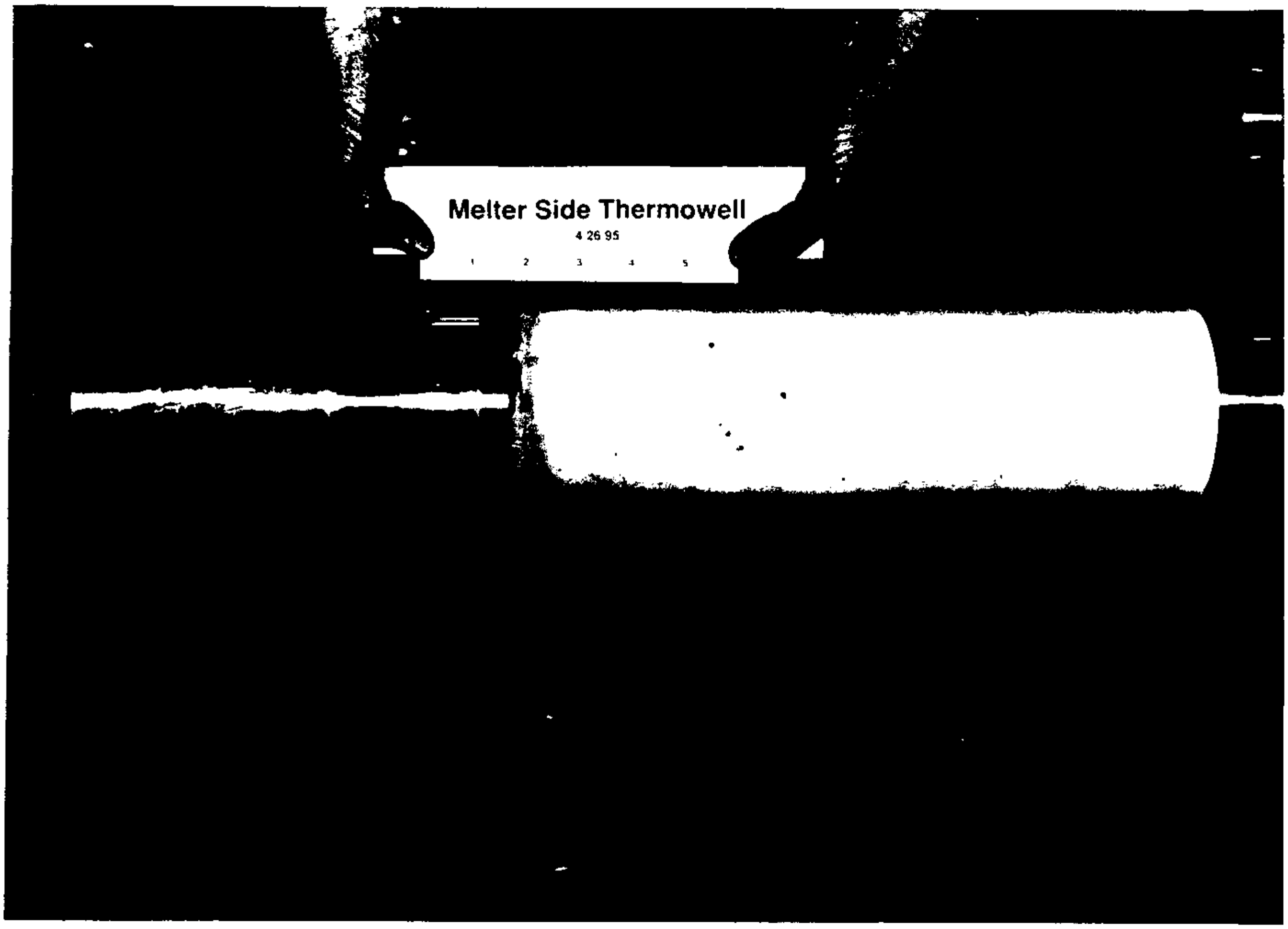


Figure 6b. Side thermowell - Inconel 690 collar and alumina insulator (WSRC-FM-95-0049-86).

Figure 7. Level Probe (WSRC-FM-95-0049-29).

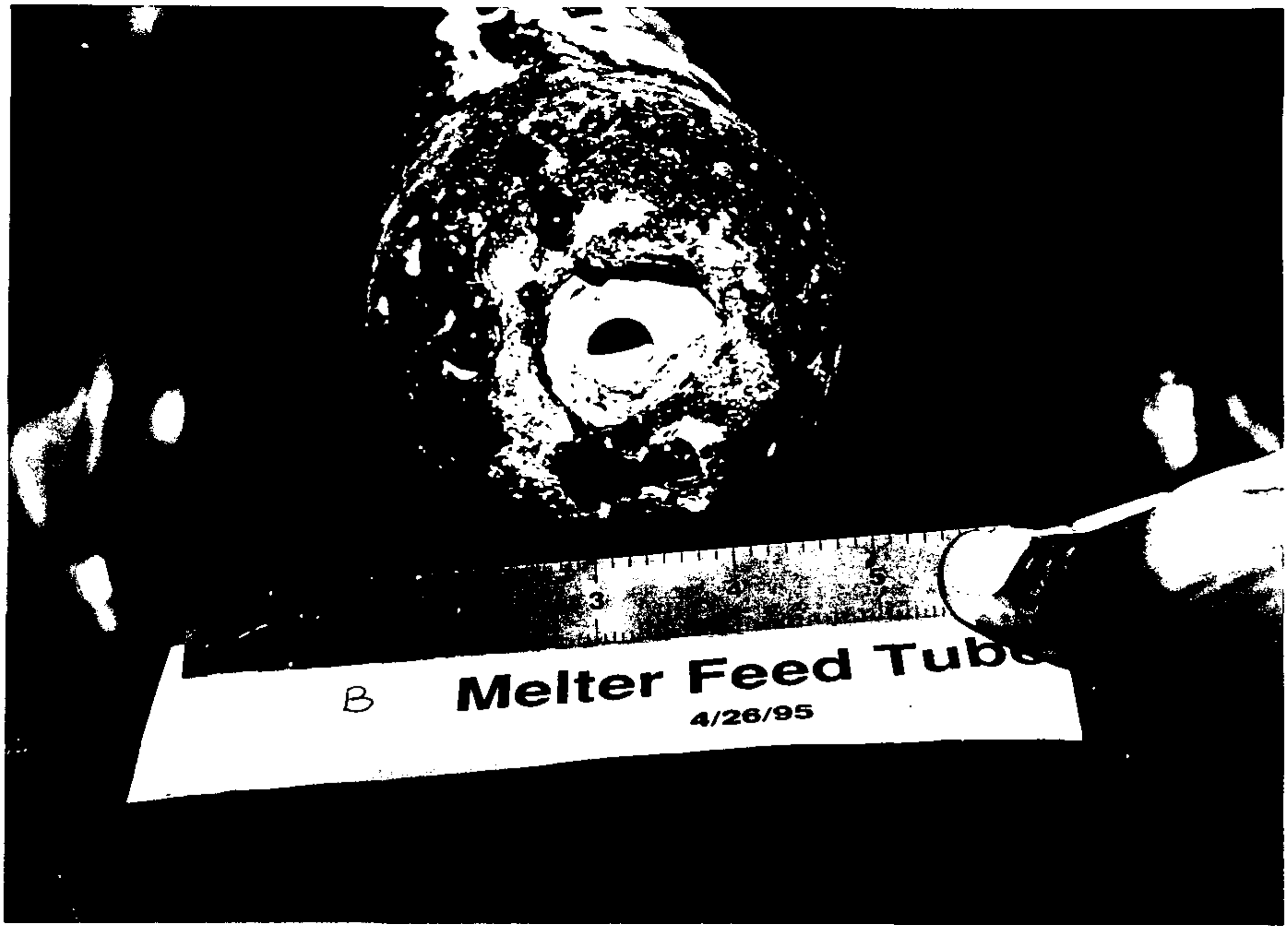


Figure 8a. Feed tube - before cleaning (WSRC-FM-95-0049-80).

Figure 8b. Feed tube - after cleaning (WSRC-FM-95-0049-76).

Figure 9. Photomicrograph of material removed from feed tube (EE 54035 A). Pitting is evident along external surfaces in both the weld fusion (f) zone and in the base (b) material (arrows indicate pits). No intergranular attack was observed. Magnification 200X.

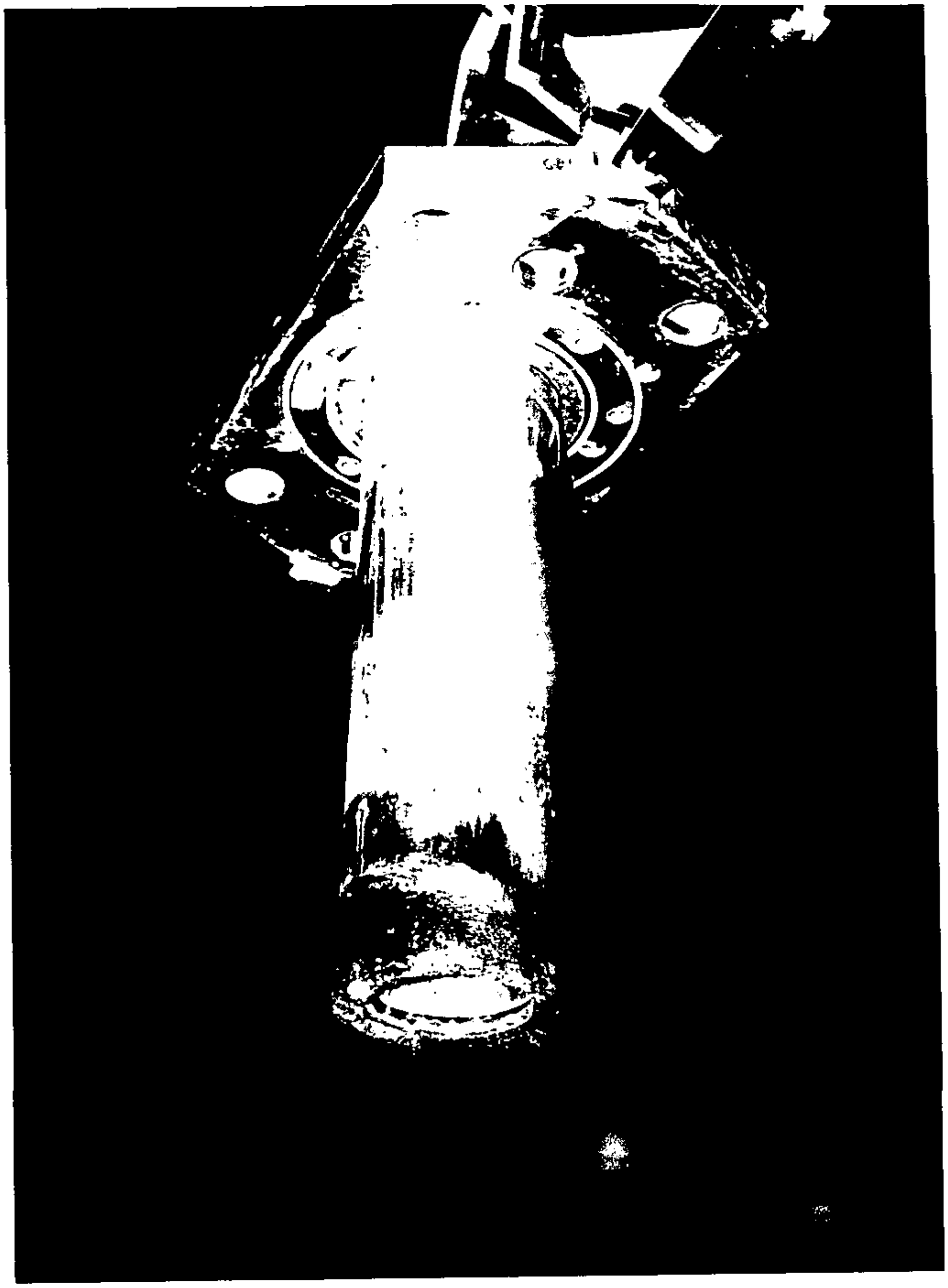


Figure 10. Primary film cooler immediately after removal (WSRC-FM-95-0049-12).

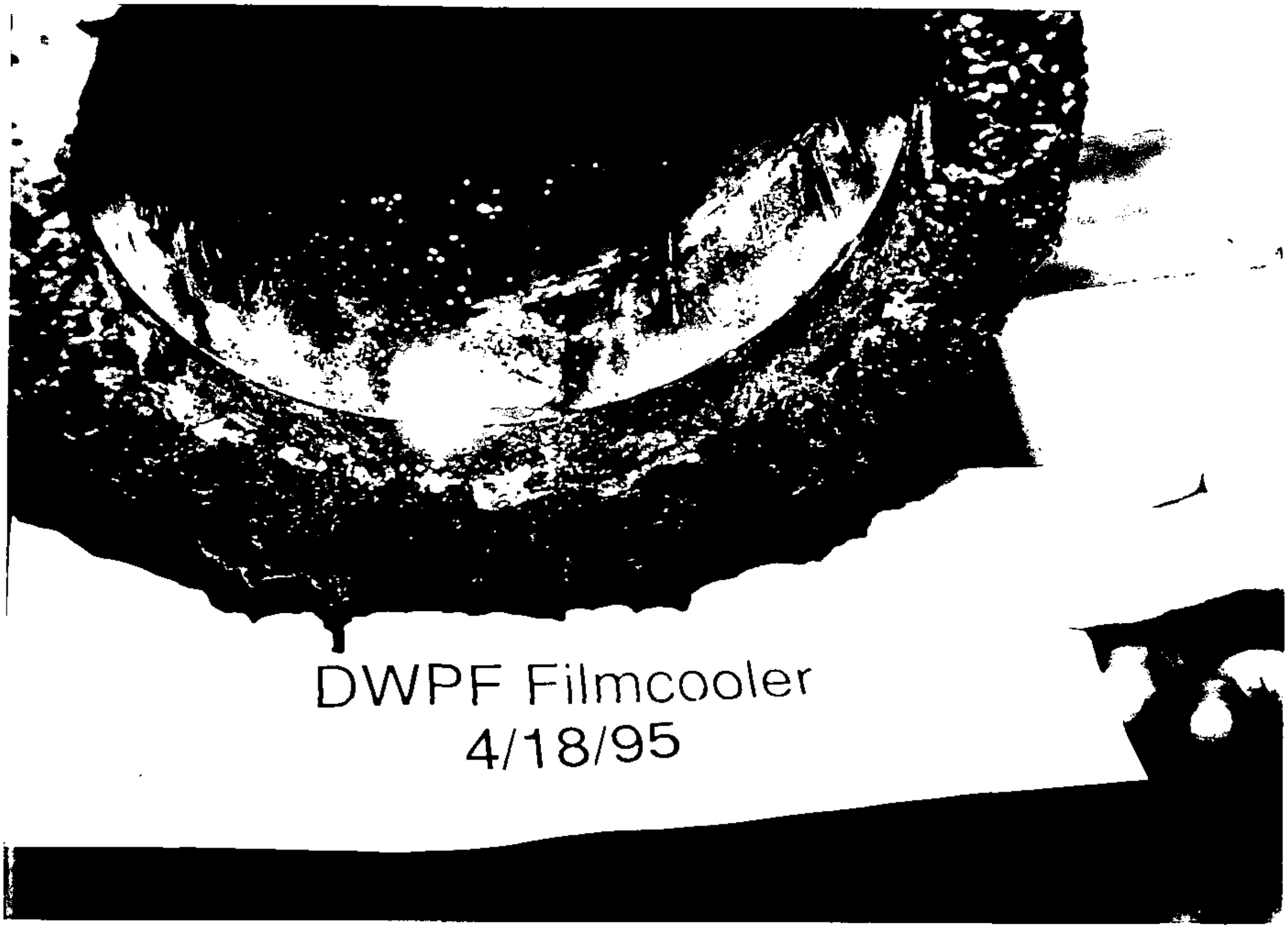


Figure 11. Scale on the lower edge of the primary film cooler (WSRC-FM-95-0049-49).

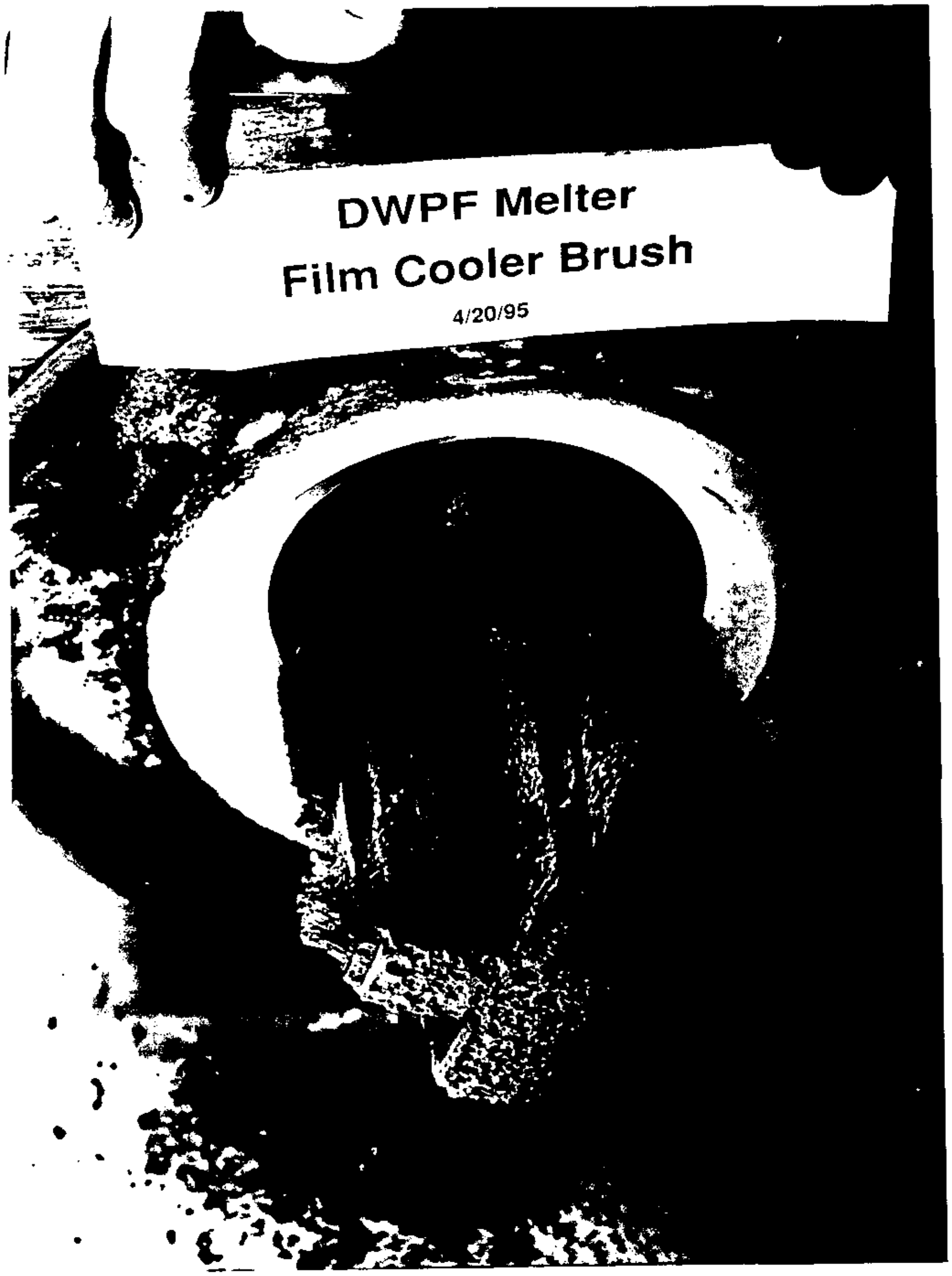
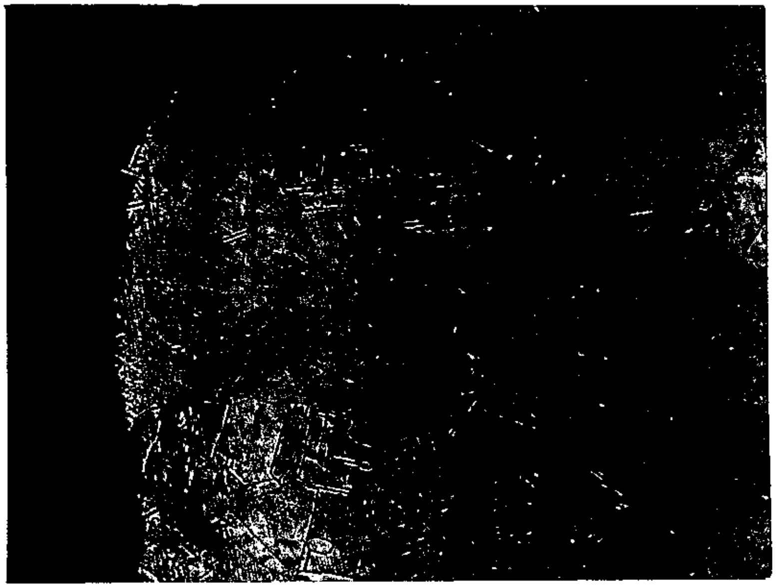


Figure 12. Severe pitting and bristle degradation on primary film cooler brush (WSRC-FM-95-0049-24).



(a)

(b)

Figure 13. Photomicrographs showing pitting attack of film cooler brush. a) Base material (Magnification 50X). b) Weld fusion zone (Magnification 50X).

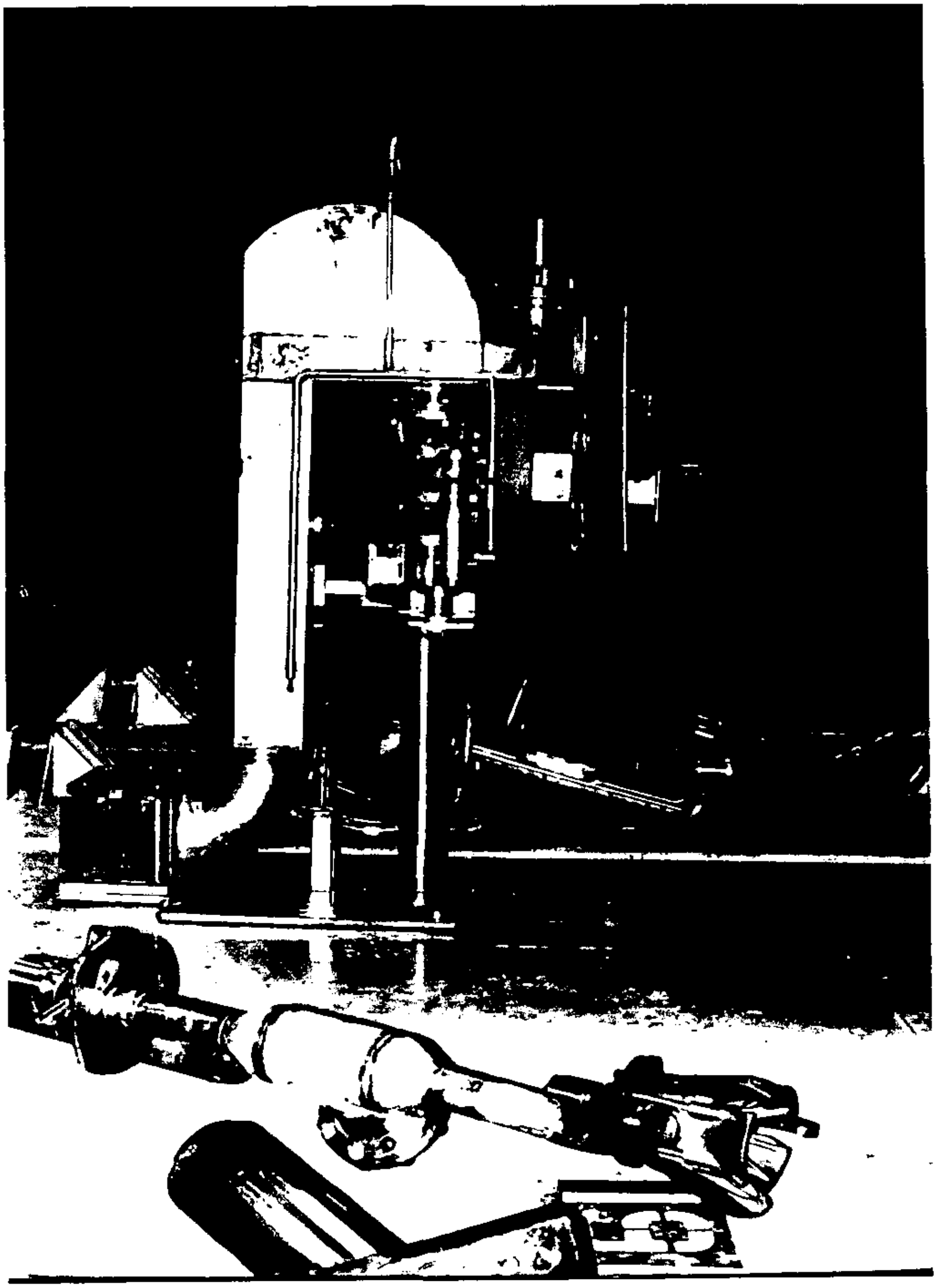


Figure 14. Primary off gas line (WSRC-FM-95-0049-15).

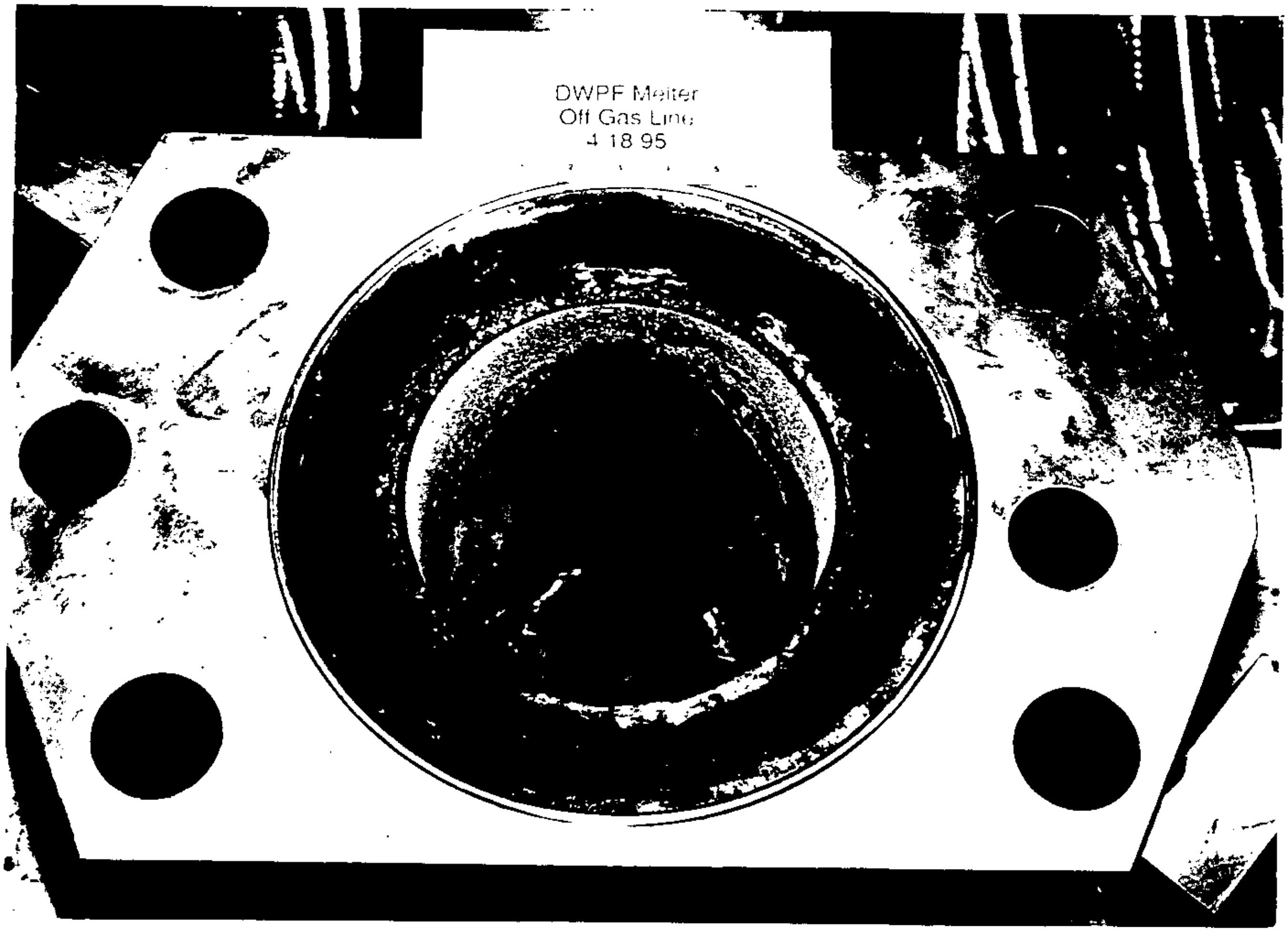


Figure 15. Pitting (see arrow) in primary off gas line below film cooler brush flange and above 90 degree elbow (WSRC-FM-95-0049-45).

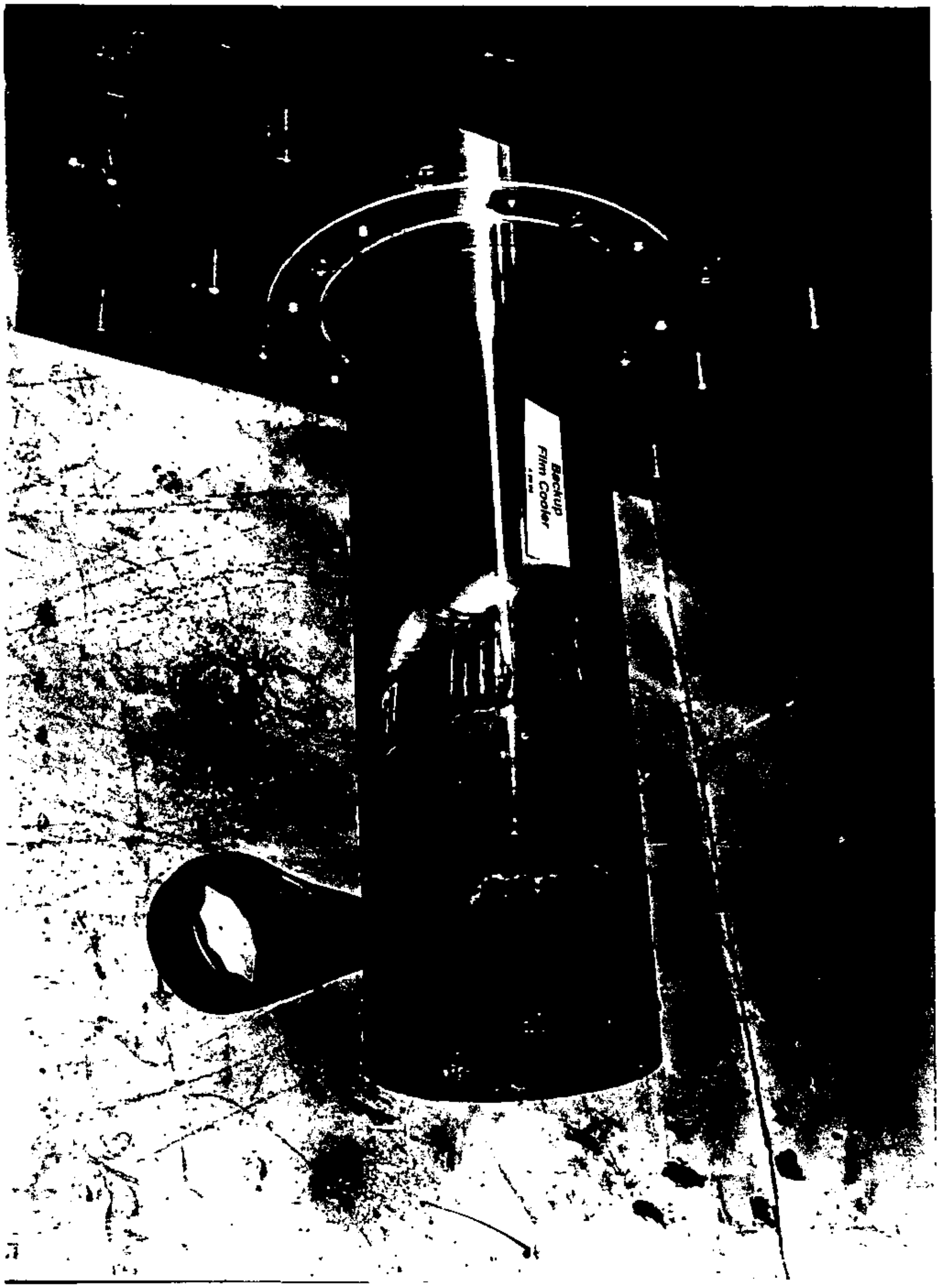


Figure 16. Backup film cooler immediately after removal (WSRC-FM-95-0049-75).

Figure 17. Deposits on the lower edge of the backup film cooler (WSRC-FM-95-0049-66).

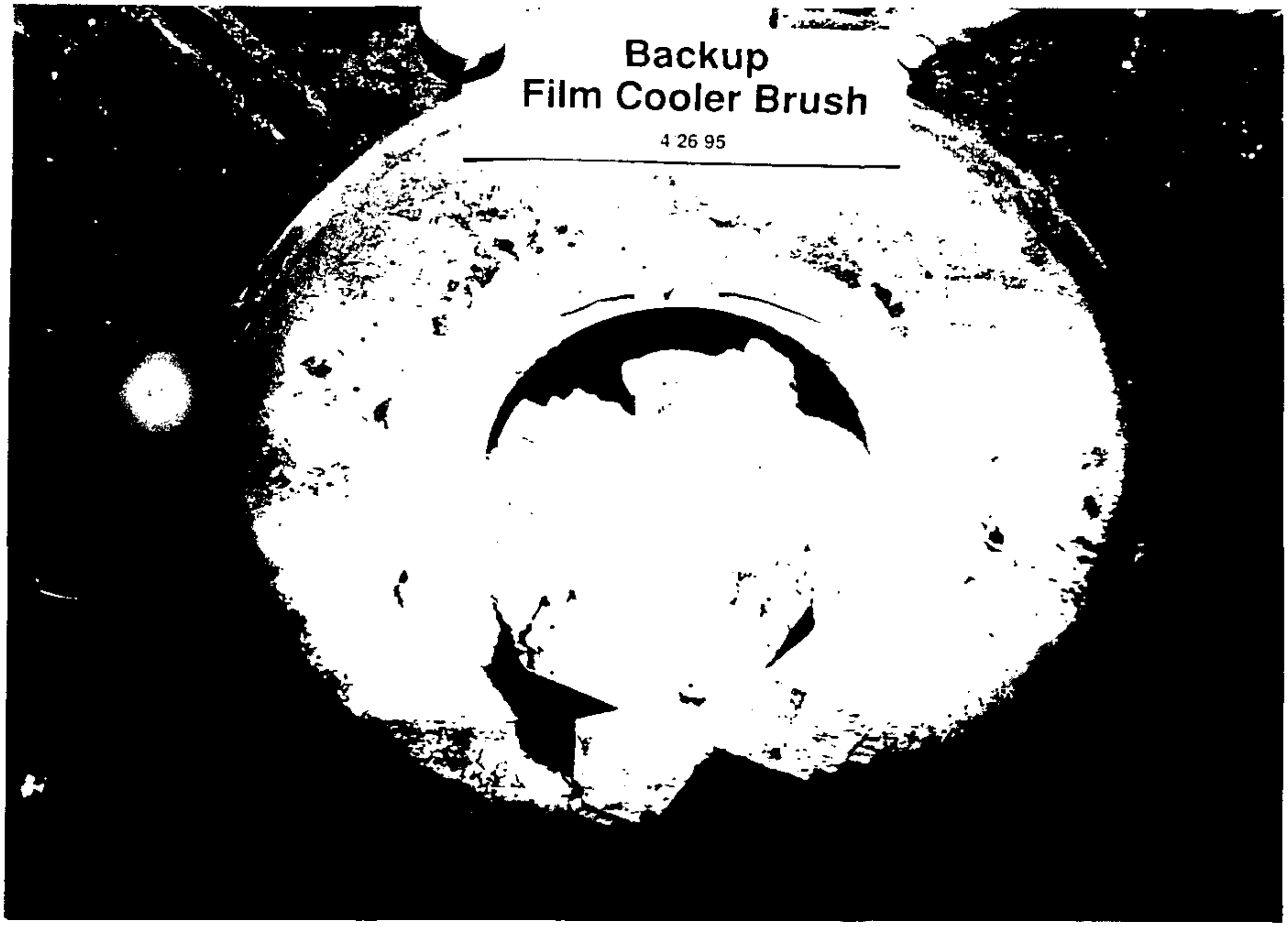


Figure 18. Backup film cooler brush (WSRC-FM-95-0049-60).

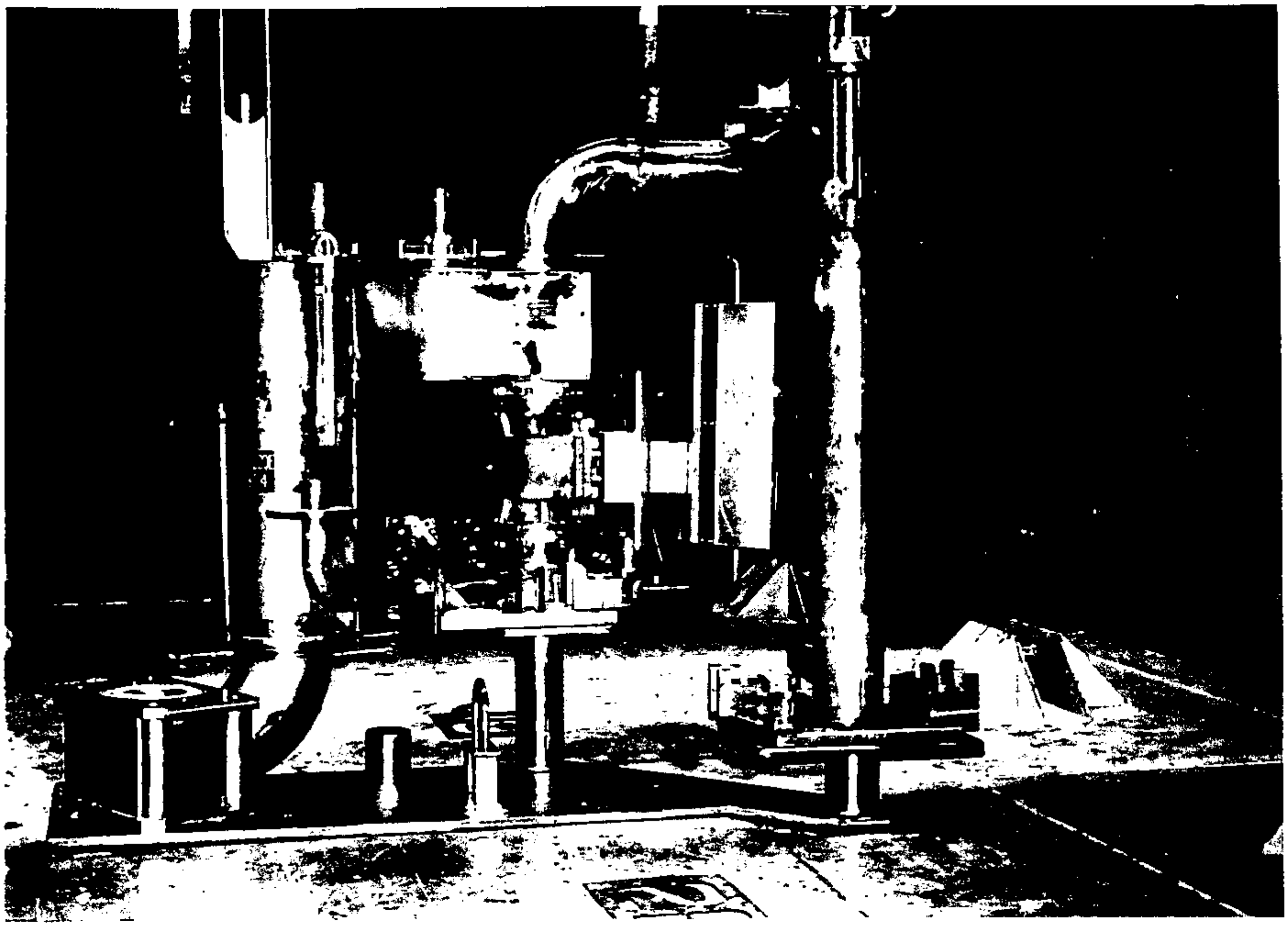


Figure 19. Backup off gas line (WSRC-FM-95-0049-58).

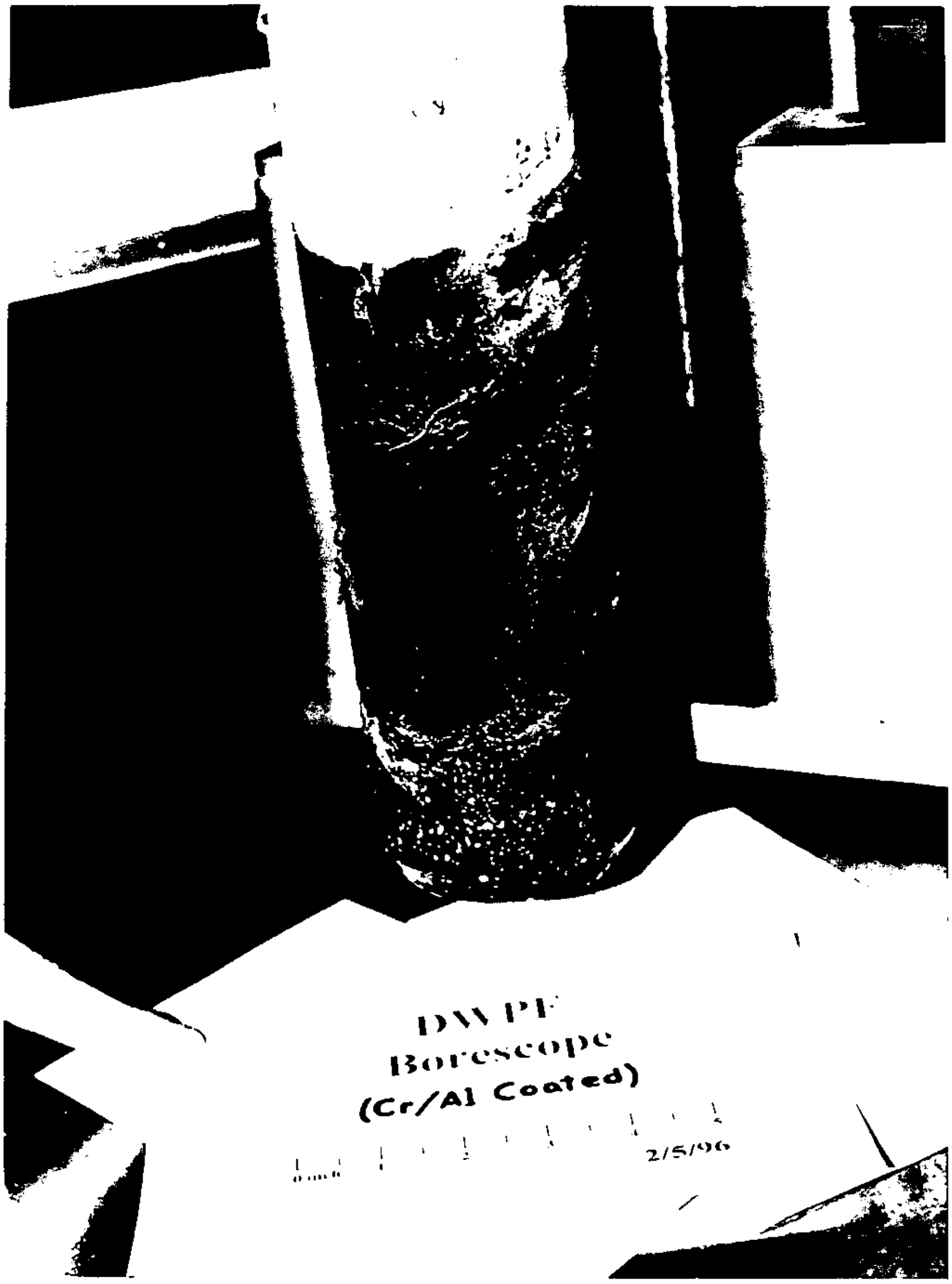


Figure 20a. Outer housing of Cr/Al coated borescope outer housing following approximately 2 months of service (WSRC-FM-96-294-24). Note no significant degradation on outer housing.

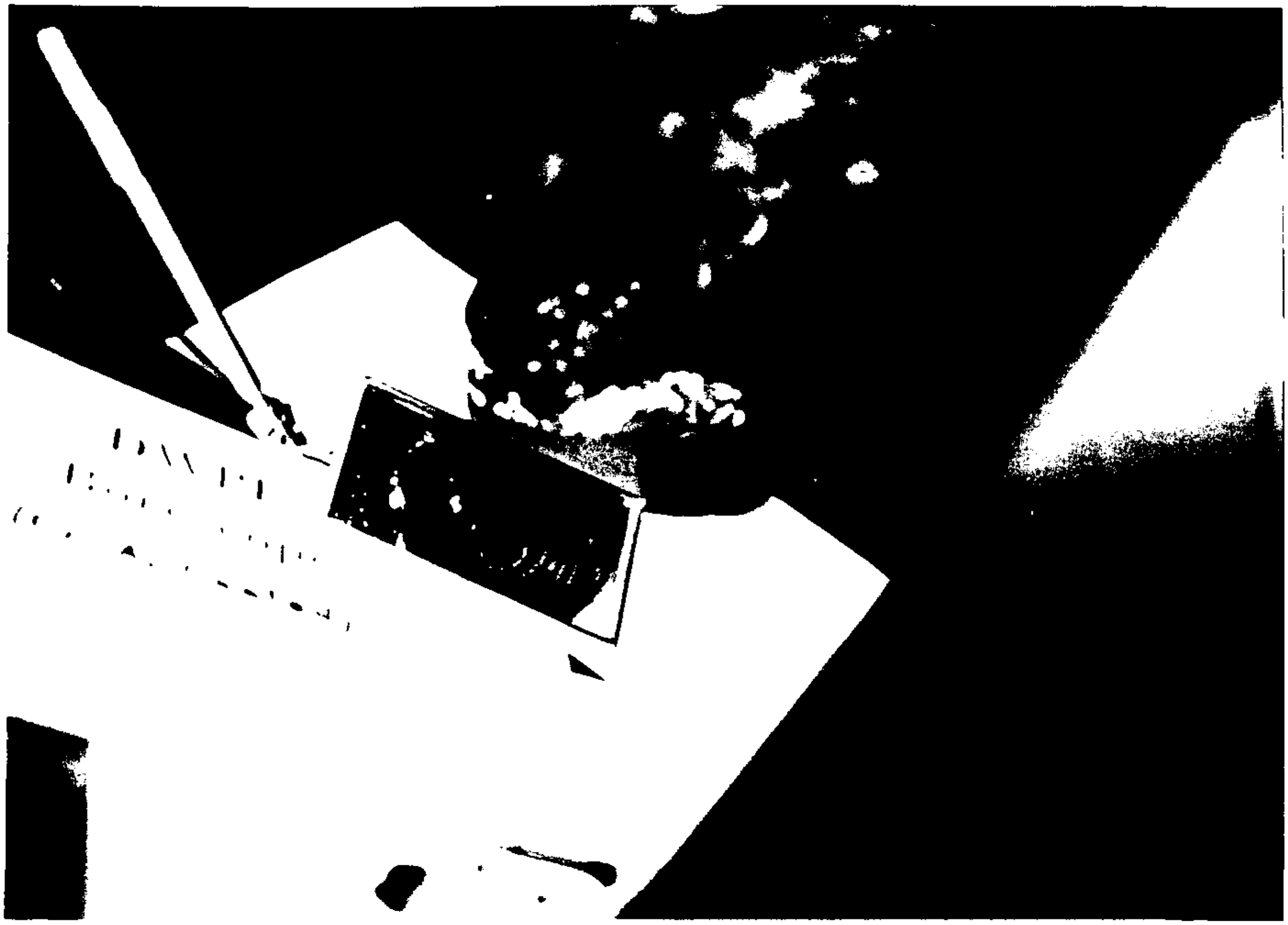


Figure 20b. Orifice of Cr/Al coated borescope outer housing following approximately 2 months of service (WSRC-FM-96-294-9). Note no significant degradation around orifice.

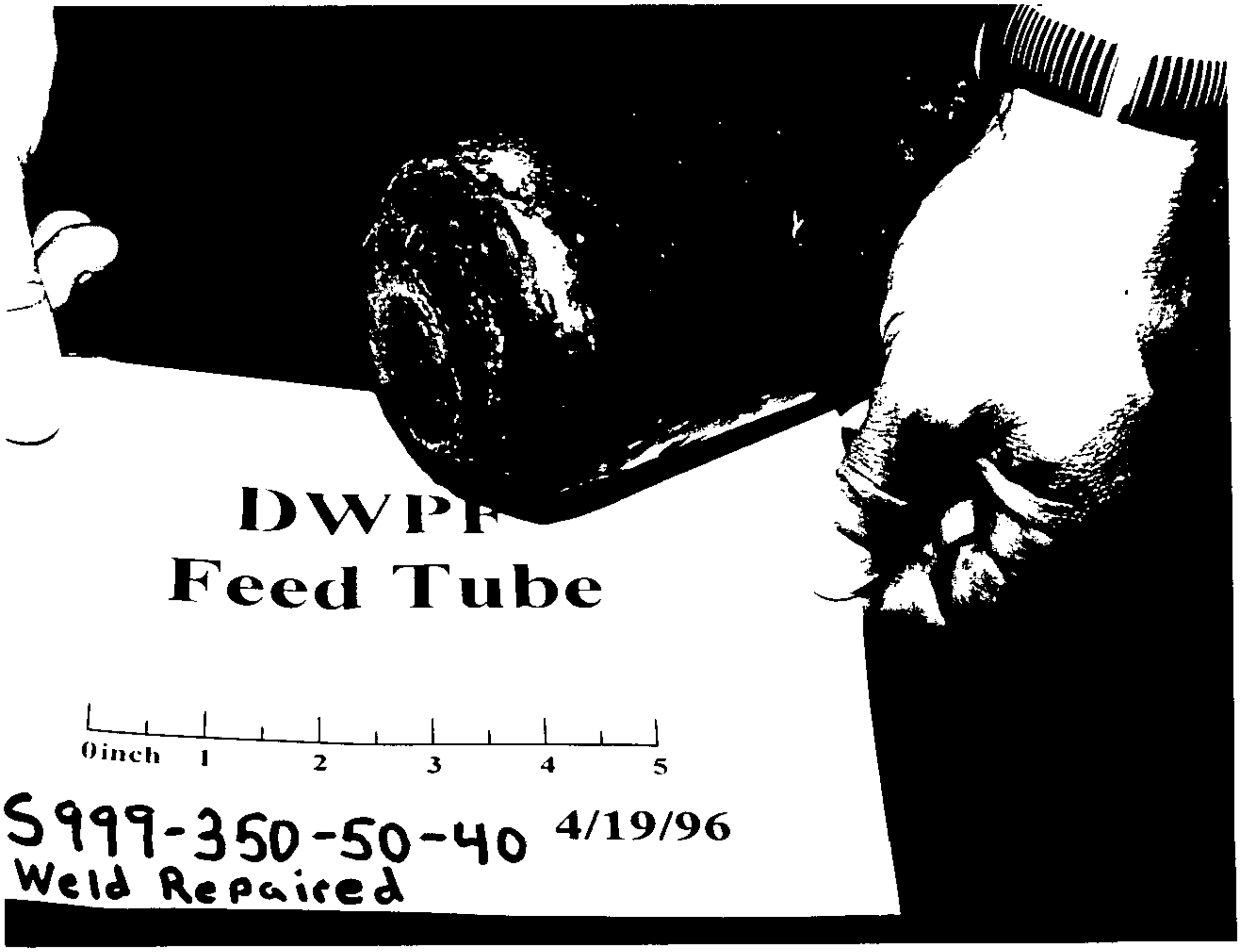


Figure 21. Weld repaired feed tube S999-350-50-40 (WSRC-FM-96-360-18). Note no significant degradation around beveled region of core end piece.

APPENDIX 6

REMOTE VISUAL INSPECTION OF

IDMS OFF GAS SYSTEM

SRTC
Savannah River Technology Center

APPENDIX 6

March 8, 1996

MTS-SRT-96-2014

To: J.T. Gee, 704-25S
Defense Waste Processing Engineering

From: K.J. Imrich, 773-A KJI
Materials Technology Section

N.C. Iyer, Manager
Materials Applications & Corrosion Technology Group
Materials Technology Section

Date: 7/2/96

REMOTE VISUAL INSPECTION OF IDMS OFF GAS SYSTEM (U)

Summary

Inspection of the IDMS off gas quencher, SAS inlet, HEME outlet, HEPA inlet and associated piping did not reveal any evidence of significant corrosive attack. In addition, visual examination of coupons from the off-gas system did not reveal any degradation of coupons representative of DWPF materials of construction. Therefore, inspection of similar DWPF components as part of the FA-04 program is not warranted.

Background

The Materials Technology Section was requested to evaluate the performance of the Integrated DWPF Melter System (IDMS) off gas components and corrosion coupons following seven years of service. Although the melter was idled (i.e. no cold cap) most of the time, the off gas system was always operational. Inspection of the IDMS off gas equipment was recommended by DWPF Engineering with concurrence from the DWPF Materials Committee. The intent was to minimize the number of inspections in DWPF during the FA-04 Erosion/Corrosion Program, allowing more time to concentrate on critical areas of the DWPF system where corrosion was most likely to occur. In addition, eliminating inspections would free up the crane for other more critical tasks. If problems were found during the visual examinations of IDMS off gas components, inspection of similar DWPF equipment would be recommended.

Remote visual inspection of the IDMS process equipment was performed by Administration & Infrastructure Quality / Quality Control Section (AIQ/QC) on August 8, 1995. Equipment and piping inspected included:

1) Steam Atomized Scrubber (SAS) - Inlet region.
2) High Efficiency Mist Eliminator (HEME) - Outlet to heater.
3) High Efficiency Particulate Air (HEPA) Filter - Inlet to filters.
4) Off gas Quencher - Inlet and outlet including nozzle.
5) Associated piping.

In addition to the remote visual inspection, coupons from all coupon racks were pulled and visually inspected. Figure 1 shows the location of the coupon racks in the off gas system. These coupons were placed into the IDMS off gas system in August of 1993 [1]. All coupons except those on the quencher inlet crack were placed back into the IDMS following the inspection. The quencher inlet coupons were brought back to the lab for further metallurgical examination.

Results and Discussion

Remote visual examination of the off gas equipment from the IDMS off gas system did not show any evidence of significant corrosion in the regions inspected around the HEPA, SAS, HEME, Quencher. Inspection results were documented in AIQ/QC reports AID-QCM-950009 and 95-IR-06-VT-0687 and by the DWPF Materials Committee [2,3,4].

Corrosion coupon racks were removed from the off gas system, visually examined for evidence of corrosion and then reinstalled (Figure 1). Only the coupons from the quencher inlet were taken to the lab for further metallurgical evaluation. No evidence of significant corrosion was observed on any of the coupons. A metallurgical examination of the original corrosion coupons, which were placed in the IDMS feed preparation, melter and off gas systems, was performed in 1993. Results from this metallurgical evaluation did not reveal any evidence of pitting, general, stress corrosion cracking or crevice attack of any of the DWPF materials of construction [5]. However, both the Hastalloy C-276 and Allcorr coupons removed from the quencher inlet showed evidence of end grain attack. These are the materials of construction for the DWPF primary and backup quenchers, respectively. Exposure of end grains was minimized in the design of the IDMS and DWPF quenchers therefore, the potential for corrosion of the DWPF quenchers is low. The nozzle is the only component in the quencher that could potentially be vulnerable to this type of attack. Corrosive gasses are swept away from the tip of the nozzle, and therefore, end grain attack is not anticipated. Inspection of the DWPF primary [6] and IDMS [2,3] quenchers did not reveal any end grain attack of the nozzles.

Conclusions

Inspection of the IDMS off gas quencher, SAS inlet, HEME outlet, HEPA inlet and associated piping did not reveal any evidence of significant corrosive attack. In addition, visual examination of coupons from the off gas system did not reveal any degradation of coupons representative of DWPF materials of construction. Therefore, inspection of similar DWPF components as part of the FA-04 program is not warranted.

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3. D.V. Crunk, Melter and Melter Off Gas System (U), Visual Examination Report No. 95-IR-06-VT-0687, Westinghouse Savannah River Site, Aiken SC 29808, August, 1995.

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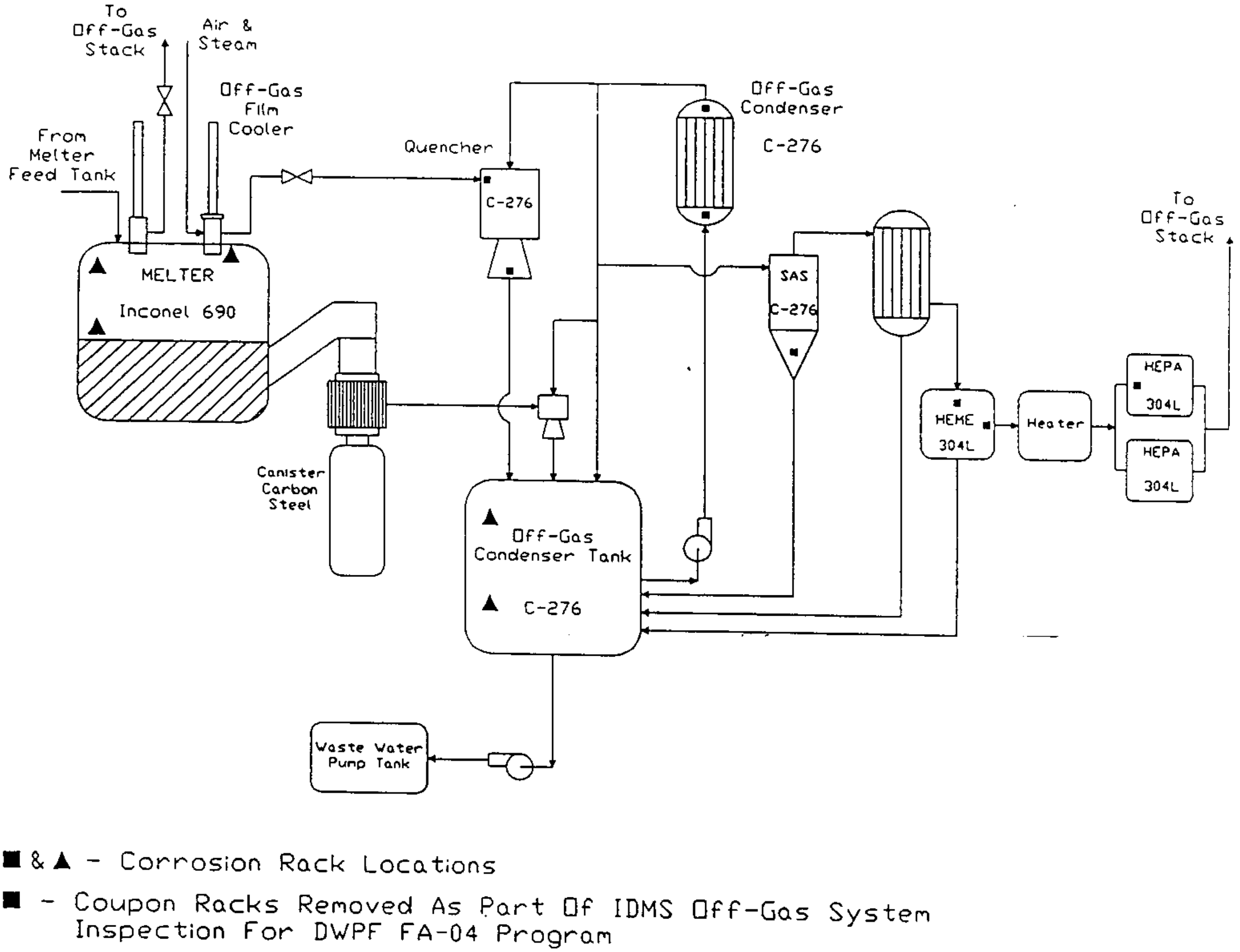

Figure 1. Schematic of the IDMS melter and of-gas system showing location of corrosion coupon racks and IDMS materials of construction.

APPENDIX 7

EVALUATION OF POTENTIAL FOR MATERIALS DEGRADATION OF DWPF SAFETY CLASS AND SAFETY SIGNIFICANT COMPONENTS

APPENDIX 7

WSRC-TR-95-0385, Rev. 0

Evaluation of Potential for Materials Degradation of DWPF Safety Class and Safety Significant Components (U)

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Savannah River Technology Center
Applied Science & Engineering Technology Department
Materials Technology Section

Publication Date: September 1995

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WSRC-TR-95-0385
Rev. 0

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APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Keywords: DWPF
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Evaluation of Potential for Materials Degradation of DWPF Safety Class and Safety Significant Components (U)

By: **W. L. Daugherty**

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Patent Status

SRTC SAVANNAH RIVER TECHNOLOGY CENTER, AIKEN, SC 29808
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EXECUTIVE SUMMARY

A number of safety class and safety significant components have been identified by the DWPF Structural Integrity Team for evaluation in accordance with the DWPF Structural Integrity Program. The components chosen for inclusion in the DWPF Structural Integrity Program were evaluated with regard to structural integrity attributes. This included evaluations in the areas of materials degradation, structural design, and inspection/test requirements. This report documents the detailed materials evaluations that have been performed in support of this effort.

Most of the components evaluated are likely to fulfill their design service lives with little materials degradation. In cases where degradation is considered likely, it is estimated to occur at a slow rate, without sudden catastrophic failure. Recommendations have been provided for additional testing or monitoring to track degradation that is likely to limit a component's service life and to provide supporting data to assess the potential for degradation of components for which such data was lacking. The overall favorable assessment of minimal degradation of most components results from following established industrial experience for standard component applications and from the extensive testing performed to support materials selection for those components exposed to the agressive process conditions in the vitrification building.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the assistance received from several individuals during the course of this work. G. T. Chandler pulled together the chemical composition data for a great many DWPF process streams. J. T. Gee and K. R. Jones provided numerous inputs defining component materials and operating conditions. The work of many others has been drawn upon and referenced herein.

1. BACKGROUND

The DWPF Structural Integrity Team has identified a number of components for evaluation based on their designation as safety class or safety significant [1]. Evaluation of these components is conducted in accordance with the DWPF Structural Integrity Program [2]. The components chosen for inclusion in the DWPF Structural Integrity Program [3] were then evaluated with regard to structural integrity attributes. This included evaluations in the areas of materials degradation, structural design, and inspection/test requirements. This report documents the detailed materials evaluations that have been performed in support of this effort.

2. DISCUSSION

Detailed materials evaluations of safety class and safety significant DWPF components have been documented in several memorandum reports [4-7]. These reports provide the basis for the materials degradation potential of most of the components considered to date in the DWPF Structural Integrity Program, and are provided as Appendices 1-4 to this report.. This report serves the purpose of collecting these degradation assessments under a single cover for reference and retrievability. Subsequent to issuing the appended reports, detailed reviews by the DWPF Structural Integrity Team identified a few cases in which corrections/clarifications to those reports were warranted. These cases are marked up in the appendices.

In general, the components specifically addressed in the reference 4-7 assessments are those considered most likely to experience degradation, those with the greatest visibility in terms of management attention, and/or components chosen as indicative of a number of components in similar service.

In general, no potential for rapid degradation of materials properties was identified. For those components where degradation is anticipated, it is generally limited to general corrosion at a slow, predictable rate. In relatively few cases were other forms of degradation expected. This reflects the care used initially in selecting the materials for most of the DWPF components. Materials for most of the components in the Vitrification Building Remote Process Cells were selected on the basis of extensive testing under what were considered at the time to be prototypic conditions. Due to subsequent changes in the process flowsheet, the forecast conditions no longer match the actual conditions. However, sufficient variation was built into the test conditions that they generally bound even the current forcast operating conditions. The specific corrosion test data used in these evaluations are referenced in the appendices. Data for the Remote Process Cell vessels and other waste-handling components are generally from SRTC and DuPont Engineering Test Center studies. Corrosion data for the other components are generally taken from the published literature, and are also referenced in the appendices.

A materials degradation evaluation was performed for the components listed in Table 1. Most of these components are expected to experience minimal degradation, within the bounds of corrosion allowances, and should perform acceptably for their design service lives. Upper bound corrosion rate estimates are also provided in Table 1.

A number of components beyond those specifically evaluated are fabricated from the same materials and see similar service conditions as those evaluated. The conclusions reached in the subject evaluations extend to these components as well. For example, reference 6 identifies that unprotected carbon steel pipe exposed to ambient air would be expected to corrode at a rate of about 1 - 2 mil/year. However, pipe that is painted or galvanized should experience essentially no corrosion unless the protective coating is breached. This same conclusion would generally apply to any other carbon steel component that is exposed to ambient air.

Another example illustrates potential difficulties that might arise in extending the reported results to similar components. The SRAT feed orifice plate, located in the jumper between the Precipitate Reactor Bottoms Tank (PRBT) and the Slurry Receipt Adjustment Tank (SRAT), is fabricated from Hastelloy C-276. The fluid flowing through this jumper is the same as the fluid leaving the PRBT and entering the SRAT. Both the PRBT and SRAT are constructed of Hastelloy C-276 and are estimated to experience less than 1 mil/year general corrosion [4]. Accordingly, the SRAT feed orifice plate is also expected to experience corrosion of less than 1 mil/year. However, the fluid in the SRAT feed orifice plate contains about 5% solids, which are of no particular consequence to either tank, but present the possibility of erosion given the fluid velocity through the orifice plate. Because of this possibility, the SRAT feed orifice plate has been identified for examination during DWPF Startup Test FA-04 [8], which is being performed in September-October 1995.

For components likely to experience degradation beyond design allowances, recommendations for inspection or other forms of monitoring have been identified, and are summarized in Table 2. These recommendations have been passed on to the DWPF Structural Integrity Team for consideration. Formal recommendations to implement such actions will be made by the DWPF Structural Integrity Team.

In several cases, piping presents a special case of degradation exceeding the corrosion allowance - cases in which there is zero corrosion allowance. While no significant degradation is expected, it is impossible to conclude that zero corrosion will occur. In fact, the stainless steels derive their good corrosion resistance from the formation of a thin oxide film on the surface. While this presents no difficulty in an engineering sense (the expected corrosion is practically zero), an administrative comparison of the very small expected wall loss and that allowed shows that the zero corrosion allowance will be exceeded. Such administrative noncompliance can likely be remedied by comparing the actual (maximum) applied loads with those given in the piping specifications. Each piping code specifies a corrosion allowance and design pressure / temperature values. To the extent that the maximum pipe loads are less than the design conditions, the corrosion allowance can be increased without sacrificing safety margins. Accordingly, recommendations are made in such cases for Structural Mechanics to verify based on actual loads that some small "as-built" corrosion allowance exists for the component.

As noted above, engineering common sense shows that the actual corrosion in such cases is so small as to not create any technical concern. However, the additional review of available margins will address the non-engineering assessement that insists on demonstrated compliance with every requirement and specification.

Limited in-service inspection is also recommended for some components with no identified corrosion allowance. These should be viewed as one-time confirmatory inspections, unless they produce unexpected results. If this first in-service inspection shows no change from baseline measurements attributable to corrosion or other degradation mechanism, then no significant degradation should occur and further inspections may be discontinued.

3. CONCLUSIONS

Most of the components evaluated are likely to fulfill their design service lives with little materials degradation. In cases where degradation is considered likely, it is estimated to occur at a slow rate, without sudden catastrophic failure. Recommendations have been provided for additional testing or monitoring to track degradation that is likely to limit a component's service life and to provide supporting data to assess the potential for degradation of components for which such data was lacking. The overall favorable assessment of minimal degradation of most components results from following established industrial experience for standard component applications and from the extensive testing performed to support materials selection for those components exposed to the agressive process conditions in the vitrification building.

4. REFERENCES

[1] WSRC-TR-95-0189, DRAFT, "Safety Class and Safety Significant Final Functional Classification Report for the Defense Waste Processing Facility", J. D. Townsend, May 1995.

[2] SW4-V5, Conduct of Technical Standard Practices Manual, Procedure CT 3.03, "DWPF Structural Integrity Program".

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[4] SRT-MTS-945193, "Materials Degradation Assessment for DWPF Tanks", W. L. Daugherty and G. T. Chandler, April 4, 1995.

[5] SRT-MTS-955165, "Materials Degradation Assessment for DWPF Waste Transfer Pipe and Tanks", W. L. Daugherty and G. T. Chandler, July 21, 1995.

[6] SRT-MTS-955152, "Materials Degradation of DWPF Chemical Tanks and Piping", W. L. Daugherty, August 8, 1995

[7] SRT-MTS-955214, "Degradation of DWPF Concrete and Steel Structures", W. L. Daugherty, September 8, 1995.

[8] DWPF-FA-04, Revision 1, "Process Vessels Erosion/Corrosion Study, January 18, 1993.

Table 1. Summary of Components Evaluated.

Component	Material	Corrosion Rate
Precipitate Reactor (PR)	C-276	5 mpy steam coils; 1 mpy remainder
Organic Evaporator (OE)	C-276	5 mpy steam coils; 1 mpy remainder
OE Condensate Tank (OECT)	304L	2 mpy, potential for local attack
OE Condenser/Decanter (OECD)	C-276	< 1 mpy
PR Condenser/Decanter (PRCD)	C-276	< 1 mpy
PR Feed Tank (PRFT)	C-276	not quantified, but < 1 mpy is expected
PR Bottoms Tank (PRBT)	C-276	1 mpy
Slurry Mix Evaporator (SME)	C-276	1 mpy, potential for erosion
SME Condensate Tank (SMECT)	316L	1 - 5 mpy
Sludge Receipt & Adjustment Tank (SRAT)	C-276	1 mpy
Recycle Collection Tank (RCT)	C-276	1 mpy
Melter Feed Tank (MFT)	C-276	1 mpy, potential for erosion
Off-Gas Condensate Tank (OGCT)	C-276	1 mpy
Steam Atomized Scrubber (SAS)	C-276	Vapor region - rate TBD; potential for local attack. Liquid region - 1 mpy
Off-Gas Condenser	C-276	1 mpy
High Efficiency Mist Eliminator (HEME)	C-276	1 mpy
HEPA Filter Assembly	304L	1 mpy
Off-Gas Quencher (OGQ)	Allcorr (primary) & C-276 (backup)	Liquid region - 1 mpy, primary; 4 mpy with potential for local attack, backup Vapor region - rate TBD; potential for local attack
Interarea Transfer Lines - inner pipe	304L	0.5 mil/yr
Interarea Transfer Lines - outer pipe	c. steel	1 mil/yr, with local attack in vapor space, if inner pipe leaks
Late Wash Facility (LWF) Precipitate Tank (LWPT)	304L	0.5 mil/yr
LWF Hold Tank (LWHT)	304L	0.5 mil/yr
Low Point Pump Pit (LPPP) Sludge Tank (SPT)	304L	0.5 mil/yr
LPPP Precipitate Tank (PPT)	304L	0.5 mil/yr
Organic Waste Storage Tank (OWST) Inner Tank	304L	< 2 mil/yr
OWST Outer Tank	c. steel	ranging from approx. 0 to < 20 mil/yr, depending on leakage, etc.
OECT / OWST Transfer Pipe	304L	< 2 mil/yr
Formic Acid Storage Tanks #1 and 2	316L	< 1 mil/yr
Organic Acid Drain Catch Tank	316L	< 1 mil/yr
Formic Acid Dilution Tank	304L	< 2 mil/yr with potential for local attack
Dilute Formic Acid Feed Tank	304L	< 2 mil/yr with potential for local attack
Formic Acid Feed Tank and piping	316L	< 1 mil/yr
Organic Acid Neutralization Waste Tanks #1 and #2	316L	< 1 mil/yr
Nitric Acid Feed Tank and piping	304L	< 2 mil/yr

Table 1. Summary of Components Evaluated (continued).

Nitric Acid Waste Hold Tank	304L	< 2 mil/yr
Acid Drain Catch Tank	304L	< 2 mil/yr
Nitric Acid Dilution Tank	304L	< 2 mil/yr
Nitric Acid Dilution Tank piping	304L	< 2 mil/yr
Canned motor pumps for various tanks	304L	approx. 0 mil/yr
Diesel Fuel Oil Storage Tanks #1 and #2 and underground pipe	c. steel	approx. 0 mil/yr, unless water is present
Diesel Fuel Oil Day Tanks #1 and #2	c. steel	approx. 0 mil/yr, unless water is present
Diesel Fuel Oil System piping	c. steel	approx. 0 mil/yr, unless water is present
Diesel Gen. System piping (air & lube oil)	c. steel	approx. 0 mil/yr, unless water is present
Diesel Generator System piping (water)	c. steel	approx. 0 mil/yr
Purge System Piping and Jumpers:	304L, C-276, galv. c. steel, & copper	approx. 0 mil/yr
LWF Primary (P) & Backup (BU)		approx. 0 mil/yr
CPC Safety Grade (SG), P & BU		approx. 0 mil/yr
SPC SG, P & BU		approx. 0 mil/yr
LPPP SG & P; OWST SG & P		approx. 0 mil/yr
PPT/SPT Chem. Feed (LPPP SG)		approx. 0 mil/yr
Purge System Tanks: CPC SG, LPPP SG, OWST SG, SPC SG, LWF P & BU, 422-S Supply Tanks	9% Ni steel inner tank, carbon steel outer tank,	approx. 0 mil/yr
SPC P and CPC P Tank	c. steel	approx. 0 mil/yr
Purge System Vaporizers	Al	approx. 0 mil/yr
Vitrification Building: Bldg. Structure, SPC/CPC Removable Wall, Remote Process Cell Covers, Melt Cell Crane Rails & Superstructure	coated c. steel	approx. 0 mil/yr if coating intact, < 2 mil/yr otherwise
Glass Waste Storage Building (GWSB) Canister Supports	galv. c steel	approx. 0 mil/yr if coating intact, < 2 mil/yr otherwise
LWF Crane Rails and Superstructure	c. steel	approx. 0 mil/yr if coating intact, < 2 mil/yr otherwise
LPPP Process Cell Crane Rails and Superstructure	c. steel	approx. 0 mil/yr if coating intact, < 2 mil/yr otherwise
Zone 1 Exhaust Tunnel	coated c. steel	approx. 0 mil/yr if coating intact, < 2 mil/yr otherwise
Fan House Crane Rails and Superstructure	c. steel	approx. 0 mil/yr if coating intact, < 2 mil/yr otherwise
422-S Superstructures	coated c. steel	approx. 0 mil/yr if coating intact, < 2 mil/yr otherwise

Table 1. Summary of Components Evaluated (continued).

Vitrification Building: Bldg. Structure, Canyon Walls, Remote Process Cell Walls, Crane Maint. Shield Door Struct. Support Main Process Cell Crane Struct. Support Nitric Acid Dilution Tank Dikes Formic Acid Feed Tank Dikes Org. Acid Floor Drain Catch Tank Dikes Nitric Acid Feed Tank Dikes	concrete	N/A - see Appendix 4 for discussion of concrete degradation mechanisms
GWSB Vault Supports	concrete	
LWF Cells & Cell Covers	concrete	
LPPP Cells, Cell Covers & Crane Operator Station	concrete	
Sand Filter & Zone 1 Exhaust Tunnel	concrete	
Fan House Building Structure	concrete	
FESV Vaults	concrete	
422-S Acid Tank Dikes	concrete	
980-S Organic and Nitric Dikes	concrete	

Table 2. Summary of Recommendations Made to the DWPF Structural Integrity Team

Component	Recommendation
OECT	Inspect to evaluate susceptibility to local attack and quantify rates
SME, MFT, SMECT, OGQ vapor space	Inspect before hot runs to quantify erosion, corrosion rates, and/or verify local attack
SAS	Inspect TNX SAS vapor space to assess susceptibility to corrosion
Backup OGQ	Inspect IDMS OGQ liquid space to quantify local attack
OWST Outer Tank	Periodic visual inspection to verify paint is intact
Formic Acid Feed Tank Piping and Nitric Acid Dilution Tank Piping	Structural Mechanics should identify a corrosion allowance based on actual applied loads
Diesel Fuel Oil Storage Tanks #1 & 2 and Underground Pipe	1. Continue existing fuel oil sampling program 2. Track cumulative time cathodic protection system is inactive
Diesel Fuel Oil Day Tanks #1 & 2	1. Continue existing fuel oil sampling program 2. Periodic visual inspection to verify paint is intact
Diesel Fuel Oil System Piping	Periodic visual inspection to verify paint is intact
Diesel Generator Piping (water, air, lube oil)	Periodic visual inspection to verify paint is intact
Purge System Piping (carbon steel)	Periodic visual inspection to verify paint is intact
Purge System Tanks (outer shell)	Periodic visual inspection to verify paint is intact
GWSB Canister Supports	Confirm that the lifetime radiation exposure is $< 4 \times 10^{10}$ rads
Steel Structures (general)	1. Confirm that steel structures are not in contact with dissimilar metals 2. Periodic visual inspection to verify coatings are intact
Concrete Structures (general)	1. Survey & document cracks that currently exist 2. Ensure procedures are in place for the prompt cleanup of chemical spills
FESV	Evaluate whether any degradation has occurred from water intrusion
Vitrification Building	Reevaluate likelihood of groundwater damage if the water table has risen above the elevation of the building base
LWF Cells, Sand Filter, FESV, LPPP Cells & Cell Covers, GWSB Vault Supports,	Confirm that the lifetime radiation exposure is $< 10^{10}$ rads
Coated Concrete Structures	Periodic visual inspection to verify coatings are intact
GWSB Vault Supports	Reevaluate potential for high temperature degradation after GWSB thermal analysis is complete

Appendix 1.

Copy of SRT-MTS-945193, "Materials Degradation Assessment for DWPF Tanks"

Westinghouse Savanah River Company
MATERIALS TECHNOLOGY SECTION

Materials Consultation

Subject Describers:
SRT-MTS-945193
DWPF
Tank
Corrosion
Retention: 20 years

April 4, 1995

cc: R. Ostrowski, 730-B
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Group Copy

TO: S. F. Piccolo, 704-S
Attention: J. T. Gee, 704-25S

FROM: W. L. Daugherty, 730-A and G. T. Chandler, 773-A
Materials Technology Section

MATERIALS DEGRADATION ASSESSMENT FOR DWPF TANKS (U)

Summary

The susceptibility of DWPF tanks and tank internals to in-service degradation has been reviewed as part of the DWPF Structural Integrity Program. No reduction in mechanical properties is expected from service conditions; however, a loss of net section is predicted due to corrosion (general, crevice, pitting, and SCC) and erosion. Significant general corrosion rates (up to 5 mil/year) are predicted for several tanks and internal components. The remaining tanks and internals evaluated should have low corrosion rates (< 2 mil/year). All tanks that contain frit have a potential for erosion. Table 1 summarizes the available degradation data for each tank in the scope of this assessment. Data are taken from (1) laboratory test data in simulated DWPF chemistries, (2) test coupons from pilot plant systems, and (3) inspection data from DWPF and pilot scale systems.

The nominal service life estimates range from less than 12 years to 60 years, based on the time for general corrosion to consume the corrosion allowance of 1/16 inch. Local corrosion and/or erosion may reduce the service lives of several tanks below these nominal values. Tanks thinned in excess of the corrosion allowance may require structural analysis to support continued operation. Failure to meet structural requirements, or leakage due to local corrosion/erosion, would signal the end of the tank's service life unless repair is feasible. In-service inspections (ISI) and baseline inspections conducted under startup test program FA-04 [6, 26], and laboratory testing are recommended to provide erosion and local corrosion rate estimates. The need for subsequent periodic ISI will be assessed based on the FA-04 results. Current inspection plans, summarized in Table 2, should be implemented as described. Details of additional recommendations will be developed and reviewed with the DWPF Structural Integrity Team.

Background

As part of an initial phase of the DWPF Structural Integrity Program [1], a number of the process tanks (and their cooling coils and agitators) were singled out for consideration of potential degradation. This initial review is restricted to key tanks identified by DWPF personnel [2]. Efforts to characterize potential materials degradation of other DWPF components are continuing.

Table 1. Summary of DWPF tank degradation data

Tank	General Corrosion Rate	Susceptibility to Other Forms of Degradation [1]	Nominal Service Life Estimate	Additional Data Recommended
PR	5 mpy steam coils 1 mpy remainder	No	12 yr steam coils 60 yr remainder	none
OE	5 mpy steam coils 1 mpy remainder	No	12 yr steam coils 60 yr remainder	none
OECT	2 mpy	P, C, SCC	TBD [2]	ISI to evaluate susceptibility and quantify local attack rates
OECD	< 1 mpy	No	60 yr	none
PRCD	< 1 mpy	No	60 yr	none
PRFT	not quantified, but < 1 mpy is expected	No relevant data found, but none expected	60 yr	none
PRBT	1 mpy	No	60 yr	none
SME	1 mpy	Erosion	TBD [2]	inspection before hot runs to quantify erosion
SMECT	1 - 5 mpy	Probably none	12 - 60 yr	inspection before hot runs to verify general corrosion rate and absence of local attack
SRAT	1 mpy	No	60 yr	none
RCT	1 mpy	No	60 yr	none
MFT	1 mpy	Erosion	TBD [2]	inspection before hot runs to quantify erosion
OGCT	1 mpy	No	60 yr	none
SAS (vapor)	No data available	P	TBD [2]	inspection of TNX SAS to assess susceptibility to corrosion
SAS (liq.)	1 mpy	No	60 yr	none
OGC	1 mpy	No	60 yr	none
HEME	1 mpy	No	60 yr	none
HEPA	1 mpy	No	60 yr	none
OGQ (vapor)	TBD [2]	EG, P, primary & backup	TBD [2]	inspection before hot runs to assess susceptibility to corrosion
OGQ (liq.)	1 mpy, primary 4 mpy, backup	No, primary P, SCC, backup	60 yr primary ≤ 15 yr backup	inspection of IDMS OGQ to quantify local attack on backup OGQ

[1] P - pitting, C - crevice, SCC - stress corrosion, EG - end grain. No significant degradation was identified from corrosion fatigue, galvanic corrosion, hydrogen embrittlement, or radiation effects.

[2] TBD - To be determined. Lack of information on local corrosion, erosion, or general corrosion rates prevents establishing a nominal service life estimate.

Table 2. Current plans for future inspection of DWPF process vessels

Inspection Opportunity	Planned Tank / Coil Inspection	Reference
After cold run feed tests & before adding mercury	Visual inspection of critical or representative pieces of equipment (tanks, coils, agitators, etc.) - especially look for erosion on back side of lower agitator blades and tank floor behind coil support guides Thickness measurements in critical wear areas Analysis of process streams for chemical composition	3, 4, 6
After mercury feed runs	Visual examination and tank thickness measurement (erosion and corrosion evaluation) of SRAT, SME and MFT, including agitators, steam and cooling coils, sample pumps and transfer pumps Visual inspection of all accessible process vessel exterior surfaces Video probe inspection of the interior of selected vessels, including welds Remove corrosion sample racks from process tanks (SRAT, SME, MFT and PR) for evaluation Analysis of process streams for chemical composition	3, 4, 6

The materials of construction for the DWPF process vessels were selected following a laboratory test program that evaluated the susceptibility of a number of candidate alloys to expected process conditions [3, 4, 5]. After the initial selection of Alloy 20, further confirmatory tests were performed under more prototypic conditions. These tests included a small scale melter test (at PNL) which incorporated the combined effects of formic acid, halides, mercury and abrasion. Following the observation of pitting and crevice corrosion of Alloy 20, the reference material was changed to Hastelloy C-276 which resisted such local attack and had a low general corrosion rate. There are two process areas addressed in this report that do not use C-276: tanks which do not see the sludge / formic acid environment are made of stainless steel (304L or 316L), and the primary Off-Gas Quencher is constructed of Allcorr [5].

The materials verification program is still ongoing as plans exist to inspect some of the tanks, internal components and piping after cold chemical runs and mercury runs to verify expected performance [3, 4, 6]. In addition, TNX operating experience and inspection results continue to provide data relevant to some DWPF operations. This TNX experience is based on the IDMS (a 1/10 scale version of the DWPF system) and the full scale SRAT/SME tank. Inspections and coupon test data from these components provide a good indication of key areas of DWPF to inspect. Current plans for inspection of DWPF components are summarized in Table 2.

The intent of the material selection testing was to identify materials of construction capable of achieving the design life for each component. Planned future testing will validate the material selections by providing data under fully prototypic conditions. The followup testing also provides the opportunity to examine any components whose service conditions might not have been well approximated in earlier testing and for which no good estimate of degradation rate currently exists.

The design life of the major process equipment (other than the melter) is 5 years, while that of the permanent piping is 20 years [3]. Obviously, if the integrity of the process equipment can be demonstrated for longer than the design life, savings in operating time and replacement costs can be realized. The continuing tests and inspections should help establish realistic service life estimates.

Discussion

This report identifies potential degradation mechanisms and rates for the DWPF process tanks, agitators and coils. The degradation mechanisms that are considered in this report have been described in reference 7 and are summarized as follows:

General Corrosion - uniform attack that results in gradual thinning of the material.

Transgranular Stress Corrosion Cracking - cracking that occurs due to the combined action of material, environment, and stress.

Pitting Corrosion - localized attack typically leading to relatively small throughwall holes.

Crevice Corrosion - localized attack at crevice locations due to isolation from the bulk chemistry.

Intergranular Stress Corrosion Cracking - attack and cracking along grain boundaries due to the combined action of a sensitized microstructure, environment and stress.

Corrosion Fatigue - accelerated attack due to the combined effects of a corrosive environment and cyclic loading.

Erosion - wear of the metal surface due to an abrasive fluid.

Erosion Corrosion - accelerated attack due to the combined effects of a corrosive environment and an abrasive fluid that removes a protective oxide layer.

Galvanic Corrosion - corrosion of the more active of 2 metals in contact with each other in the presence of an electrolyte.

Radiation Induced Erosion - Removal of material due to sputtering and/or blistering from alpha radiation.

Hydrogen Embrittlement - loss of ductility and the potential for cracking due to migration of hydrogen into the metal lattice.

Radiation Embrittlement - loss of ductility and toughness due to radiation interactions that disrupt the metal lattice structure.

End Grain Corrosion - preferential attack of inclusions, grain boundaries and other defects which are more numerous on surfaces transverse to the rolling direction.

The above list of degradation mechanisms does not include structural failure modes such as stress overload, fatigue, or creep. Review of available test data on the alloys and environments of interest identifies the possibility of degradation due to general corrosion, pitting corrosion, crevice corrosion, galvanic corrosion, transgranular cracking, and end grain attack. Within the DWPF process tanks, galvanic couples exist only in the case of Stellite overlay on the agitator blades. This case is addressed in the discussion of SRAT / SME / MFT corrosion. In addition, there are dissimilar metals in contact at various locations in the lines between the tanks. While outside the stated scope of this report, it is noted that these locations would be susceptible to galvanic corrosion.

Erosion corrosion is a particular concern due to the presence of glass frit, which is a relatively hard abrasive material. Inspection data from some TNX and DWPF components (discussed in more detail below) indicates that significant erosion can occur.

Free hydrogen can come from two sources: from the process fluid, or from a corrosion reaction. In DWPF, free hydrogen can be generated in the SRAT, SME, and MFT from the formic acid. While a purge is present to maintain hydrogen levels below the point of flammability concerns, a low level of hydrogen might be present within the slurry on a continuous basis. The possibility of hydrogen embrittlement of these three tanks and their internals is discussed further below. The remaining tanks have sufficiently low corrosion rates that little hydrogen should be generated, and hydrogen embrittlement from this source is not expected.

Corrosion fatigue requires application of a cyclic load in a corrosive environment. Such loading might occur in an unbalanced agitator shaft (high-cycle fatigue), or following thermal cycles of the heating and cooling coils (low-cycle fatigue). Corrosion fatigue is not considered likely unless significant cyclic loads are present.

The test data reviewed did not include radiation effects (radiation induced erosion and radiation embrittlement), but they are not considered likely based on expected radiation levels. The radiation source in DWPF is the waste currently stored in the waste tanks. The rate of radiation-induced erosion due to alpha sources is insignificant compared to nominal corrosion rates in waste tank structures [7]. The radiation damage to the high heat, high level waste tank walls over a 50 year life is estimated to be about 10^{-7} dpa [8], whereas damage on the order of 10^{-2} dpa or greater is typically necessary for observable loss in ductility in austenitic stainless steel at low irradiation temperatures (< 150 °C) [9]. It is judged that the different geometry of the DWPF process vessels and the degree of concentration that occurs in them is not sufficient to increase the tank wall (or coil) fluence by 5 orders of magnitude. Therefore, radiation effects are not expected.

Table 3 provides a list of the equipment considered. These tanks include those in the salt process cell and the chemical process cell. The tanks and internals are constructed of Hastelloy C-276, stainless steel (type 304L or 316L), or Allcorr. For simplicity, the discussion is structured according to material-environment combinations rather than addressing each tank separately.

Table 3. DWPF components evaluated for degradation

Tank	Coils	Agitator	Material
Precipitate Reactor (PR)	85 psi steam, PCW *	yes	C-276
Organic Evaporator (OE)	85 psi steam, PCW	yes	C-276
OE Condensate Tank (OECT)	no	yes	304L
OE Condenser/Decanter (OECD)	PCW	no	C-276
PR Condenser/Decanter (PRCD)	PCW	no	C-276
PR Feed Tank (PRFT)	PCW	yes	C-276
PR Bottoms Tank (PRBT)	PCW	yes	C-276
Slurry Mix Evaporator (SME)	85 psi steam, PCW	yes	C-276
SME Condensate Tank (SMECT)	PCW	no	316L
Sludge Receipt & Adjustment Tank (SRAT)	85 psi steam, PCW	yes	C-276
Recycle Collection Tank (RCT)	PCW	yes	C-276
Melter Feed Tank (MFT)	PCW	yes	C-276
Off-Gas Condensate Tank (OGCT)	PCW	yes	C-276
Steam Atomized Scrubber (SAS)	no	no	C-276
Off-Gas Condenser	PCW	no	C-276
High Efficiency Mist Eliminator (HEME)	no	no	C-276
HEPA Filter Assembly	no	no	304L
Off-Gas Quencher (OGQ)	no	no	Allcorr & C-276 **

* PCW - Process Cooling Water

** The primary OGQ is fabricated of Allcorr. The backup OGQ is fabricated of C-276. [10]

The nominal corrosion allowance in the design of the tanks is 1/16 inch. (Some local regions, such as the tank bottoms, have a larger corrosion allowance.) This same allowance (1/16 inch) is assumed for the steam and cooling coils. This allowance would apply for uniform thickness loss due to general corrosion or erosion. Additional wall loss could be justified for local wall thinning beyond the corrosion allowance, such as results from pitting or crevice corrosion, but structural analysis may be required. The primary consequence of local attack to be avoided is throughwall penetration.

The likely impact of component failure can be estimated for some degradation modes. For example, forms of local attack such as pitting or crevice corrosion could lead to local tank wall penetration, with minor leakage resulting. Penetration of steam or cooling coils would lead to in-leakage during normal operation, due to the differential pressure. Only in the extreme case of widespread attack would more severe failures be anticipated. Erosion could affect local regions preferentially, as determined by slurry flow patterns, or it could produce uniform wall thinning. Uniform wall thinning will also result from general corrosion.

Uniform wall thinning rates (due to general corrosion or erosion) can be used to estimate the period of time required for the corrosion allowance to be consumed. This approach would maintain the required beginning-of-life structural safety margins throughout the tank life. However, relaxed structural margins can typically be invoked for equipment in service provided supporting analysis is performed (see ASME Boiler & Pressure Vessel Code, Section XI, for example). Preventing leakage of any type is more difficult due to the variability of erosion and local corrosion rates within crevices or pit locations. Inspection locations should be selected to maximize the likelihood of finding such degradation.

The chemical composition in each tank was estimated from the most recent material balance for the DWPF startup with Batch 1 sludge and is summarized in Table 4 [11]. This table is presented in two parts, addressing separately the liquid and gaseous process streams. Only the ionic components that are considered corrosion concerns for the materials of construction of the selected vessels are shown. Due to the nature of the process, the concentrations of chemicals change with time in some of the tanks (e.g. before vs after acid addition, or concentration due to evaporation losses). However, maximum concentrations can be used to bound the agressiveness of the environment in these tanks. For the PR, OE, SRAT and SME, the most aggressive conditions were assumed to be at the exit liquid streams after evaporation and concentration.

Table 4.a. Summary of tank liquid environments.

	Max. Temp.		Tank Service Chemistry (wt %)								
Tank	(°C)	pH	NO3-	NO2-	SO4(-2)	COOH-	PO4(-3)	F-	Cl-	Cu(+2)	Hg(+2)
PR	100	2	0.0005	0	0.017	2.195	0.0001	0.0001	0.0005	0.096	0.035 (Hg)
OE	100	4	0	0	0	0.0018	0	0	0	0	0.0003
OECT	50	5	0	0	0	0	0	0	0	0	0.0015
OECD	50	4	0	0	0	0.001	0	0	0	0	0.0005
PRCD	50	2	0	0	0	0.293	0	0	0	0	0
PRFT	40	12	0.001	0.4	0.05	0	0.0001	0	0.001	0	0.056 (Hg)
PRBT	45	2	0.0005	0	0.017	2.181	0.0001	0.0001	0.0005	0.095	0.005 (Hg)
SME *	100	7	2.129	0	0.11	1.733	0.001	0.003	0.004	0.112	0.043 (Hg)
SMECT	50	1	0.36	0	0	0	0	0	0	0	0.028 (Hg)
SRAT	100	3	2.746	0	0.142	2.292	0.001	0.004	0.005	0.144	0.069 (Hg)
RCT	50	7	0.321	0.002	0.003	0	0.0002	0.0002	0.0005	0	0.008 (most Hg)
MFT *	50	7	2.099	0	0.048	1.972	0.001	0.003	0.003	0.107	0.04 (Hg)
OGCT	50	2	0.023	0.0005	0.006	0	0	0.0005	0.0005	0	0.016 (most Hg)
SAS	50	2	0.023	0.0005	0.006	0	0.0005	0.0005	0.0005	0	0.015 (most Hg)
Off-Gas Condenser	10	2	0.045	0	0	0	0	0	0	0	0.204 (Hg)
OGQ	50	2	0.023	0.0005	0.006	0	0.0005	0.0005	0.0005	0	0.016

* The SME and MFT also contain glass frit and are subject to erosion as well as corrosion.

Table 4.b. Summary of tank gaseous environments.

Tank	Max. Temp. (°C)	Tank Service Chemistry (wt %)											
		Compounds of....								Gases			
		NO3	NO2	SO4	COOH	PO4	F	Cl	Hg	NO	NO2	SO2	SO3
OGQ	380	0	0	0.005	0	0.001	0.001	0.001	0.003	0.013	0.19	0	0
HEME	100	0.001	0	0	0	0	0.0001	0	0.001	0.091	0.171	0	0
SAS	50	0.004	0	0.0001	0	0.0001	0.001	0.001	0.01	0.085	0.16	0	0
HEPA	20	0.001	0	0	0	0	0.0001	0	0.001	0.091	0.17	0	0

For tanks which contain 85 psi steam coils, the steam saturation temperature of 164 °C is assumed for the coils. Therefore, the steam coils will be much hotter than the tank and other internals, and are considered separately.

Where the contents of a tank were split between soluble and insoluble species, the concentration of soluble species is cited. In general, the insoluble species other than mercury are assumed to remain in the bulk solution due to agitation. Calcium phosphate ($Ca_3(PO_4)_2$) is assumed always insoluble and is not included in the phosphate concentration. One exception is in the case of mercury. Where the mercury is present in elemental (insoluble) form, that is noted. Most of the tanks (PR, PRFT, PRBT, OECT, SME, MFT, SRAT, SMECT, RCT and OGCT) have sumps to collect elemental mercury, which is periodically pumped to the MWWT. However, reference 12 identifies that C-276 experiences little corrosion (< 2 mpy) from elemental mercury. Testing in simulated offgas condensate solutions shows crevice corrosion attributable to mercury only in the +2 oxidation state (i.e., $HgCl_2$). Such attack is accelerated in the presence of 0.1% nitrate [13].

Corrosion Evaluation - General:
Several sources of corrosion data for the tank materials have been identified. The primary reference used in this review reports data compiled by the DuPont Engineering Test Center (ETC) [14]. In many cases, the test environment provides a reasonable match to that listed in Table 4, since the test data were developed in support of materials selection for DWPF components. However, due to changes in the anticipated DWPF process chemistry over time, the test conditions do not provide an exact match in most cases. Therefore, the best match(es) available is presented for each component. In many cases, the selected test environment is more severe in terms of containing greater concentrations of some chemical species. Components for which a bounding match (i.e., the test solution matched or exceeded the concentration of important species) was not identified are discussed further below.

Tables 5 - 10 summarize the test conditions and results that best apply to each tank. In some cases, more than one test approximates or bounds the tank conditions, and multiple results are cited. Test coupons are identified by ETC by designations such as F (flat), C (crevice corrosion), UB (U-bend), and HW (hot wall). Additional data is drawn from reference 10, which reports results from examination of the IDMS corrosion coupons. These coupons were inside several of the IDMS tanks during several runs which simulate about 4 months of DWPF operation. In this time, 3 of the 20 batches of sludge that were processed were of a chemistry consistent with that listed in Table 4. Therefore, the corrosion results from these coupons are applicable to anticipated DWPF conditions.

Corrosion rates of test coupons are given in terms of an average corrosion rate, where appropriate. In other words, for corrosion attack of the general surface, the attack is assumed to occur at the same rate over the entire surface. In cases of local attack, a corrosion rate is more difficult to assess and may vary with time. Therefore, corrosion rates are not cited for local attack, but rather the number of corrosion sites observed is reported.

Corrosion Evaluation - PR, OE, PRBT, PRFT:
The test solutions listed in Table 5 provide an approximation to the identified tank conditions, exceeding the tank conditions for nitrate, formate, chloride and mercury. On the basis of this data, general corrosion rates of 5 mpy for the PR and OE steam coils and 1 mpy for the other PR, OE, and PRBT components are predicted. Local attack is not expected to be significant.

No reasonable match was found between the PRFT tank conditions and test solutions. An estimate of the corrosion rate for this tank can be obtained from future inspections [6]. In general, C-276 is not expected to experience significant corrosion in high pH solutions. A nominal general corrosion rate of 1 mpy is assumed for the PRFT. No local attack is expected.

Table 5. Data Summary for PR, OE, and PRBT

		PR, OE, PRBT cooling coils & agitator	ETC test solution 4A-6 on C-276	PR & OE steam coils	ETC test solution 4A-8 on C-276
E	Temp. (C)	100	90	164	185
n	pH	2	1.8	2	1.8
v	NO3- (wt%)	0.0005	0.5	0.0005	0.5
i	NO2- (wt%)	0	0	0	0
r	SO4(-2) (wt%)	0.017	0.07	0.017	0.1
o	COOH- (wt%)	2.195	10	2.195	10
n	PO4(-3) (wt%)	0.0001	0	0.0001	0
m	F- (wt%)	0.0001	0.01	0.0001	0.01
e	Cl- (wt%)	0.0005	0.045	0.0005	0.045
n	Hg/Hg(+2) (wt%)	0.035	0.125	0.035	0.125
t	other (wt%)	0.096 Cu	0.2 Cu	0.096 Cu	0.2 Cu
	Test Results		0.8 mpy, C 0.9 mpy, F, weld		5.2 mpy, HW, weld

Corrosion Evaluation - OECD, PRCD:
Table 6 identifies two test solutions relevant to the OECD and PRCD chemistry. Test solution A-2 bounds the chemistry except for the absence of mercury and shows no attack. Test solution 4A-5 is much more aggresive in a number of species, but bounds the identified tank chemistry. This very conservative solution shows a corrosion rate of 1.1 mpy. A nominal corrosion rate of less than 1 mpy will be assumed for the OECD and PRCD.

Table 6. Data Summary for OECD and PRCD

		OECD, PRCD tank & cooling coils	ETC test solution A-2 on C-276	ETC test solution 4A-5 on C-276
E	Temp. (C)	50	98	90
n	pH	2	2	1.8
v	NO3- (wt%)	0	0	0
i	NO2- (wt%)	0	0	0
r	SO4(-2) (wt%)	0	0	0.07
o	COOH- (wt%)	0.293	3.5	10
n	PO4(-3) (wt%)	0	0	0
m	F- (wt%)	0	0	0.01
e	Cl- (wt%)	0	0	0.045
n	Hg(+2) (wt%)	0.0005	0	0.125
t	other (wt%)			0.2 Cu
	Test Results		0 mpy, F	1.1 mpy, C 0.8 mpy, F weld

Corrosion Evaluation - OECT:
In addition to the Table 7 data, the literature identifies corrosion rates of < 2 mpy for 304 stainless steel in 10% mercuric chloride at 38 °C, and < 20 mpy at 93 °C [12]. A general corrosion rate of 2 mpy is therefore assumed for the OECT tank and agitator. Local attack (pitting, crevice corrosion, and cracking) is possible, but the test results might reflect the increased severity of the test solution over that expected in service. A program of in-service inspection [6] is recommended to identify the likelihood and rate of local attack in service.

Table 7. Data Summary for OECT

		OECT tank & agitator	ETC test solution 2B-1 on 304L	ETC test solution 3C-1 on 304L
E	Temp. (C)	50	95	100
n	pH	5	4 (cond.), 6 (Liq.)	0
v	NO3- (wt%)	0	0	0
i	NO2- (wt%)	0	0	0
r	SO4(-2) (wt%)	0	0.14	0.018
o	COOH- (wt%)	0	0	0
n	PO4(-3) (wt%)	0	0	0
m	F- (wt%)	0	0.23	0.006
e	Cl- (wt%)	0	2.01	0.021
n	Hg(+2) (wt%)	0.0015	1.0	0.025
t	other (wt%)		0.03 I	0.001 I, 0.028 C6H5OH
	Test Results		0.1 mpy, C & UB, weld (condensate) 1.2 mpy, C & UB, weld (liquid) with 29 pits, 1 CC site and cracking	0.1 mpy, F

Corrosion Evaluation - SME, SRAT, MFT, RCT:
The SRTC test solution cited in Table 8 was set up to represent liquid, vapor, liquid/vapor, and condensate regions. In addition, no pitting was observed in cyclic polarization tests. C-276 coupons in the IDMS SRAT/SME (vapor space, liquid/vapor zone) and MFT (vapor space, liquid/vapor zone) showed no signs of general, crevice or pitting corrosion. Grinding marks from fabrication were still visible, although the surfaces were stained. On the basis of this data, a bounding general corrosion rate of 1 mpy is assumed for the SME, SRAT, MFT, RCT, and their internals. Local attack is not expected to be significant, but the impact of mercury is not addressed in the available data. Test program FA-04 should indicate whether these tanks are susceptible to mercury attack.

Some of these tanks will contain glass frit, raising concerns of erosion (see below). Anticipating this possibility, some of the agitator blades contain stellite overlay in areas expected to wear the fastest. With the introduction of a different metal, the possibility of galvanic corrosion arises. Data from reference 12 (in solutions 1B-2, 2A-1, and 3B-2) are inconclusive as to whether these two materials produce an active galvanic couple. Therefore, electrochemical corrosion tests were performed to measure the strength of the galvanic couple between these two alloys [16]. These tests show a low difference in galvanic potential (0.04 volt) and displayed an initial active stage (high current) followed by passivation (low current) and low corrosion rates. The estimated corrosion rates are ≤ 1.6 mil/year at 95 C.

Hydrogen evolution from formic acid can occur in the SME, SRAT, and MFT. Depending on the material condition of the tank and its internals, and their environment (temperature, hydrogen concentration, and the presence of galvanic couples), hydrogen embrittlement might occur. Embrittlement has been observed in cold worked C-276, and cold worked plus aged C-276 [17, 18]. Reference 18 found that cold-worked C-276 underwent hydrogen embrittlement only when samples were galvanically coupled to steel, even though a hydrogen-rich environment was present. In other words, without the galvanic couple, insufficient hydrogen was picked up by the C-276 sample within the duration of the test (~ 100 days) to cause embrittlement. The literature does not indicate whether embrittlement would occur over much longer exposure times, but reference 19 suggests the passive surface film might partially control the hydrogen absorption rate.

The following fabrication details were identified in discussions with DWPF personnel (J.T. Gee):

- The tank walls were formed from annealed plate, with minimal cold working involved.
- The tank top and bottom heads were solution annealed after fabrication.
- The coils were cold bent (to as tight as a 4 foot radius), and were not solution annealed.

The coils, therefore, might be susceptible to hydrogen embrittlement, but no mechanism is present to concentrate hydrogen on the coil surface. Therefore, hydrogen embrittlement of the coils is judged unlikely.

Table 8. Data Summary for SME, SRAT, MFT, and RCT

		SME, SRAT, MFT, RCT tank, cooling coils & agitator	SRTC test solution [ref. 15] on C-276	SME, SRAT steam coils	SRTC test solution [ref. 15] on C-276
E	Temp. (C)	100	100	164	150
n	pH	3	4	3	4
v	NO3- (wt%)	2.746	4.65	2.746	4.65
i	NO2- (wt%)	0.002	0.001	0.002	0.001
r	SO4(-2) (wt%)	0.142	0.0167	0.142	0.0167
o	COOH- (wt%)	2.292	0.0001	2.292	0.0001
n	PO4(-3) (wt%)	0.001	0.0001	0.001	0.0001
m	F- (wt%)	0.004	0.0133	0.004	0.0133
e	Cl- (wt%)	0.005	0.1014	0.005	0.1014
n	Hg/Hg(+2) (wt%)	0.069	0	0.069	0
t	Cu(+2) (wt %)	0.144	0	0.144	0
	other (wt%)		15 wt% solids		15 wt% solids
	Test Results		< 1 mpy, F		< 1 mpy, HW

Corrosion Evaluation - OGCT, SAS, Off-Gas Condenser:
ETC test data is summarized in Table 9. In addition, C-276 coupons in the IDMS OGCT (vapor space and liquid zone), Off-Gas Condenser (vapor inlet), and SAS (drain) showed no signs of general, crevice or pitting corrosion. Grinding marks from fabrication were still visible on the OGCT samples, although the surfaces were stained. On the basis of this data, a bounding general corrosion rate of 1 mpy is assumed for the OGCT, SAS, Off-Gas Condenser, and their internals. Local attack is not expected to be significant.

Table 9. Data Summary for OGCT, SAS, and Off-Gas Condenser

		OGCT, SAS (liquid), & Off-Gas Condenser tank, cooling coils & agitator	ETC test solution 4A-6 on C-276	ETC test solution 1C-1 on C-276
E	Temp. (C)	50	90	101
n	pH	2	1.8	3.2
v	NO3- (wt%)	0.045	0.5	0.1
i	NO2- (wt%)	0.0005	0	0
r	SO4(-2) (wt%)	0.006	0.07	0.08
o	COOH- (wt%)	0	10	0
n	PO4(-3) (wt%)	0.0005	0	0
m	F- (wt%)	0.0005	0.01	0.3
e	Cl- (wt%)	0.0005	0.045	2.62
n	Hg/Hg(+2) (wt%)	0.204	0.125	7.38
t	other (wt%)		0.2 Cu	
	Test Results		0.8 mpy, C 0.9 mpy, F, weld	0.2 mpy, C 0.2 mpy, F, weld

Corrosion Evaluation - SMECT, OGQ:
In addition to the data cited in Table 10 for the SMECT, 316L coupons in the IDMS SMECT (vapor inlet) were inspected [10]. They showed no signs of general, crevice or pitting corrosion. Grinding marks from fabrication were still visible, although the surfaces were stained. Several data sources indicate general corrosion rates ranging from < 1 to 10 mpy. Reference 20 shows that a high ratio of NO_3- to Cl- tends to inhibit corrosion at high pH. Although the SMECT operates at a low pH, the NO_3-/Cl- ratio for each of the test solutions suggests that the lower corrosion rates are more applicable. Accordingly, a range in general corrosion rate of 1 - 5 mpy is recommended for preliminary estimates of degradation of the SMECT and its internals. Inspection of the SMECT prior to hot runs is recommended to resolve the significant difference in observed test behavior.

The possibility of local attack is suggested by the ETC data. However, the results on the SRTC solution (a less agressive solution that bounds the actual acticipated tank conditions) indicate no susceptibility to pitting. Therefore, local attack is not considered likely, but inspection of the SMECT is desirable to confirm this conclusion.

Table 10. Data Summary for SMECT and OGQ drain

		SMECT tank & cooling coils	ETC test solution 3B-2 on 316L	SRTC sol'n PN21 PHA, diluted & acidified (ref. 21), on 316L	OGQ tank (liquid)	ETC test solution 3B-2 on Allcorr	ETC test solution 3B-2 on C-276
E	Temp. (C)	50	90	50 & 70	50	90 & 95	90, 95 & 100
n	pH	1	2.2	1	2	1.2 & 2.2	1.6 & 2.2
v	NO3- (wt%)	0.36	0.1	0.14	0.023	0.1	0.1
i	NO2- (wt%)	0	0	~0	0.0005	0	0
r	SO4(-2) (wt%)	0	0.08	0.004	0.006	0.08	0.08
o	COOH- (wt%)	0	0	0.24	0	0	0
n	PO4(-3) (wt%)	0	0	~0	0.0005	0	0
m	F- (wt%)	0	0.03	~0	0.0005	0.03	0.03
e	Cl- (wt%)	0	0.25	0.008	0.0005	0.25	0.25
n	Hg/Hg(+2) (wt%)	0.028	0.1	1 drop Hg	0.016	0.1	0.1
t	other (wt%)		0.003 I			0.003 I	0.003 I
	Test Results		7-10 mpy, SC, 10 pits & 24 CC sites in 14 days	50C: 0.04 mpy 70C: 0.05 mpy Not susceptible to pitting based on CPP scan.		0.1- 0.3 mpy, C & F 0-0.3 mpy, C & F, weld 0.1-1.2 mpy, F, weld @ 60 C 0 mpy, UB, weld	0.3-2 mpy, C & F ≥850 mpy, special C w/ stress or heat treat 0.3-3.6 mpy, C & F, weld, some with weld or intergranular attack (IGA) 0.8 mpy, UB, weld, with weld & IGA

In addition to the Table 10 data for the OGQ, some localized pitting was seen in C-276 coupons subject to acid dew point conditions (i.e., condensation) in the PNL small scale melter test. General corrosion rates of 1 mpy for the OGQ (Allcorr) and 4 mpy for the backup OGQ (C-276) appear reasonable based on the above data. In addition, the backup OGQ may be susceptible to limited pitting and local attack around welds [4]. Inspection of the TNX OGQ is recommended to quantify local attack rates on the backup OGQ. Details of the special stress and heat treat C-276 coupons were not provided, but such conditions are probably beyond normal operation. Note that the U-bend specimen showed little corrosion even though it is in a stressed condition.

Corrosion Evaluation - Off-Gas Quencher, HEPA, HEME gaseous streams:
The Off-Gas Quencher, HEPA and HEME gaseous streams were tested through corrosion coupons in the IDMS. As discussed above, 3 of the batches processed while the coupons were in place are representative of the chemistry listed in Table 4. Table 11 summarizes the data from these coupons. No coupons were placed in the IDMS SAS gas stream. However, based on coupon

data from the PNL small scale melter, the SAS might be subject to pitting attack in areas of acid condensation, similar to the backup OGQ [4]. Additional laboratory data or inspection results are needed to evaluate degradation rates from the SAS gas stream.

Table 11. Gas Stream Data Summary from IDMS Components

Component	Coupon Material	Results
OGQ (Inlet)	C-276	Minor end grain attack, minor pitting, definite but satisfactory general non-uniform attack
OGQ (Inlet)	Allcorr	Moderate end grain attack, moderate pitting, minor general non-uniform attack
HEPA (Inlet)	304L	No general, pitting, or crevice corrosion, no significant weight change
HEME (Inlet)	C-276	No general, pitting, or crevice corrosion, no significant weight change
HEME (Outlet)	C-276	No general, pitting, or crevice corrosion, no significant weight change

On the basis of the Table 11 data, additional data should be developed to assess the corrosion rate for the OGQ (fabricated of either C-276 or Allcorr). Additional data is also required to evaluate the SAS. It is recommended that such data be obtained from examination of these DWPF and/or TNX components prior to hot runs. Inspection of the IDMS OGQ (fabricated from C-276) could also provide important data. Followup inspections of the TNX SAS are recommended to evaluate its susceptibility to general or local attack. Based on the observed lack of attack on the HEPA and HEME coupons, a nominal general corrosion rate of 1 mpy is considered reasonable, with no local corrosion expected.

Erosion Evaluation:
In addition to the potential for corrosion degradation, the SME and MFT contain frit which can act as an abrasive leading to erosion of the tanks and tank internals. Areas of concern for erosion include any region of the tank or internals which is exposed to moving frit. Areas particularly susceptible to erosion are those which experience turbulence in the slurry, such as regions of the agitator blades and near internals that present flow obstructions. The effect of frit on component wall thinning was evaluated as part of the materials selection program [22]. Several conclusions were reached at that time:

- The frit tends to be alkaline, and the process acid additions tend to reduce the abrasiveness of the frit.
- Agitation also tends to decrease the frit abrasiveness.
- Rotating disk abrasion tests using SME-type slurry produced significant wear rates in C-276.
- Abrasion tests similar to ASTM G75 simulating SRAT/SME conditions showed different, but still significant, wear rates in C-276.

The nature of the abrasion tests that were performed, and the results reported, suggest that they are best used for relative ranking purposes rather than absolute predictions of in-service performance.

Better indications of expected erosion behavior are available from DWPF and TNX component inspections [23, 24, 25]. Inspections have been performed on several vessels at DWPF and TNX to characterize the degree of erosion. These vessels include the SME and MFT at DWPF, and the full scale SRAT and IDMS SRAT/SME at TNX.

The inspections of these vessels concentrated on the agitators, although the TNX SRAT coils and the inside of the two TNX vessels were also viewed. Thicknesses were recorded for the agitator blades from all four tanks, and for the two TNX tanks and their coils. However, the pre-service dimensions are generally not known, so reliable erosion rates cannot be inferred. It was noted that all surfaces had some degree of polish resulting from service wear, although most areas had no significant metal loss.

No significant wear to either of the TNX tanks was noted in recent inspections by either visual or UT techniques [23, 24, 25]. On the other hand, past inspections identified wear on the floor near the bumper guides of the TNX full-scale SRAT/SME [4]. Areas of erosion were noted on the coil support structure and around welds on the lower coils. Distinct wear patterns were observed on the upper agitator blades, but the total metal loss from these regions appeared to be minimal. The greatest erosion was generally observed on the lower agitator blades. Several variations in design, involving the blade attachment tab configuration, and the use of Stellite overlay in different areas, are represented in the several agitators, with some agitators incorporating two or more variations. Regions of wear on the lower blades are primarily on the back of the blade, near the corners of the attachment tabs, and in regions above and below the attachment tabs. Extreme cases include throughwall penetration. Stellite overlay around the blade edge appeared effective in reducing erosion of the edge, but overlay across the tab corners simply caused a shift in erosion patterns in those areas. Variations observed among the several designs suggests that design changes can greatly reduce agitator blade erosion, but further tests or production experience would be needed to confirm a final design.

The wear on the agitator blades generally occurred in locations that appear unlikely to impact structural integrity. Greater (and possibly life-limiting) concerns resulting from the observed erosion patterns might include agitator contact with guides at the tank bottom due to loss of balance, inadequate mixing due to holes in the agitator blades, or loss of slurry chemistry control due to wear particles.

While the available erosion data are not sufficiently detailed to provide wear rate estimates, they do show a strong potential for erosion of local regions of agitator blades and the other tank internals. Continued monitoring of DWPF components which are exposed to frit is recommended to develop quantitative estimates of erosion rates. Specifically, erosion rates in service should be determined based on the FA-04 test program.

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Technical Review: (MTS SI coordinator)

Technical Review:

Appendix 2.

Copy of SRT-MTS-955165, "Materials Degradation Assessment for DWPF Waste Transfer Pipe andTanks"

Westinghouse Savannah River Company
MATERIALS TECHNOLOGY SECTION
Materials Consultation

Subject Describers:
SRT-MTS-955165
DWPF
Pipe
Corrosion
Retention: 20 years

July 21, 1995

cc: R. Ostrowski, 730-B
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TO: S. F. Piccolo, 704-S
Attention: J. T. Gee, 704-25S

FROM: W. L. Daugherty, 730-A and G. T. Chandler, 773-A
Materials Technology Section

MATERIALS DEGRADATION ASSESSMENT FOR DWPF WASTE TRANSFER PIPE AND TANKS (U)

Summary

The interarea transfer lines consist of an inner stainless steel pipe for primary containment of the waste streams being transferred. This pipe is not particularly susceptible to corrosion attack, with a bounding corrosion rate of 0.5 mil/year. A similar bounding corrosion rate is applicable to the late wash facility and low point pump pit tanks. An outer carbon steel pipe provides secondary containment and is judged to be slightly susceptible to chemical attack, should it be exposed to the waste streams. A general corrosion rate of about 1 mil/year is judged appropriate for the carbon steel pipe. In addition, higher corrosion rates, including local attack, may occur within the vapor space above any waste material. However, a leak detection system is in place to identify if any waste leaks into the carbon steel outer pipe, providing time to take appropriate mitigative measures before significant degradation occurs.

Background

Radioactive waste goes through the Late Wash Facility (LWF), on its way to DWPF, through a series of underground transfer lines and tanks. Within the LWF, designed to reduce the nitrite levels of the slurry, a precipitate tank (LWPT) and a hold tank (LWHT) hold the precipitate slurry waste for transfer. A buried transfer line carries this waste (by gravity feed) to the low point pump pit (LPPP), where a sludge tank (SPT) and precipitate tank (PPT) are located. Another buried transfer line carries waste from the LPPP to the vitrification building. In addition, a recycle waste stream is carried back to H area by buried transfer line. The composition of these waste streams is shown in Table 1. The chemical composition of the waste streams was estimated from a material balance for the DWPF startup with Batch 1 sludge [1].

The inter-area transfer lines are of double wall construction, with the inner pipe (the primary containment) made of type 304L stainless steel. The LWF and LPPP tanks are also made of type 304L stainless steel. The outer pipe (secondary containment) is ASTM A53 Grade B carbon steel. The first and last 30 feet of the outer pipe is 6 inch type 304 stainless steel pipe. The 3 inch diameter Schedule 10S primary pipes are supported within the 10 inch diameter Schedule 20 (or 40) carbon steel pipe at regular intervals within the pipe. The carbon steel support plates have two holes for the inner pipes to pass through, and a small opening at the bottom for leakage to pass through and drain toward the low point in the line.

Table 1. Composition of Waste Streams for Inter-Area Transfer Pipes and Tanks

Chemical Species	Composition (ppm)		
	Sludge	Precipitate Slurry (after LWF)	Recycle Collection Tank plus Inhibitors
NO3-	400	10	3000
NO2-	13000	400	6200 **
SO4(-2)	800	250 *	30
COOH-	0	0	0
PO4(-3)	3000 *	5	5
F-	50	5	5
Cl-	50	10	5
Cu+2	50 *	0	5
Hg+2	600 *	600 *	5
Hg	0	0	60
OH-	1500	250	10,000
pH	> 11	> 11	13
Max Temp. (C)	60	30	50

* Mostly insoluble.

** The NO_2^- concentration is the calculated inhibitor level to preclude pitting of the carbon steel waste tanks, based on electrochemical and coupon imersion tests in simulated DWPF recycle streams [2]. This concentration was obtained after the material balance sheets were developed.

Discussion

This report identifies potential degradation mechanisms and rates for the DWPF underground piping and related tanks. Reference 3 describes a number of degradation mechanisms that were considered for the DWPF process tanks. Of these degradation mechanisms, the following could potentially affect the transfer lines and tanks. This report does not consider structural failure modes such as stress overload, fatigue, or creep.

General Corrosion - uniform attack that results in gradual thinning of the material.

Stress Corrosion Cracking (SCC) - cracking that occurs due to the combined action of a susceptible material, environment, and stress. Such cracking can be intergranular or transgranular. Austenitic stainless steels are susceptible to SCC in the presence of chlorides, while carbon steels can undergo SCC in the presence of NaOH at high pH, or nitrates at low pH [4].

Pitting Corrosion - localized attack typically leading to relatively small throughwall holes.

Crevice Corrosion - localized attack at crevice locations due to isolation from the bulk chemistry.

Galvanic Corrosion - corrosion of the more active of 2 metals in contact with each other in the presence of an electrolyte.

Radiation Embrittlement - loss of ductility and toughness due to radiation interactions that disrupt the metal lattice structure.

In addition, carbon steel is also susceptible to low temperature embrittlement - a loss of ductility and toughness due to a reduction in temperature below the nil-ductility temperature.

In addition, the following degradation mechanisms have been considered, but are not credible for the transfer pipe and tanks:

Corrosion Fatigue - This accelerated attack by a corrosive environment and cyclic loading is not considered likely since there is no identified source of cyclic loading.

Erosion - No wear of the pipe surfaces is expected due to the low velocity of the waste in the shallow slope gravity drain transfer lines.

Erosion Corrosion - This mechanism is similarly not expected without high flow rates [21].

Radiation Induced Erosion - Removal of material can be accomplished by sputtering or blistering by alpha radiation. Since none of the radionuclides in the waste (Ce-144, Pr-144, Zr-95, Y-91, Nb-95, Ru-106, Rh-106, or Cs-137 [5]) undergo alpha decay [6], this mechanism is not possible. (All of these radionuclides lead to stable daughter products except Pr-144. Its decay product, Nd-144, undergoes alpha decay, but has a 10^{15} year half-life.)

Hydrogen Embrittlement - The loss of ductility due to the absorption of hydrogen was considered possible for some of the DWPF process tanks since the breakdown of formic acid would provide a source of atomic hydrogen. In the transfer lines and tanks, no significant hydrogen source is present, and this degradation mechanism is not plausible.

End Grain Corrosion - The preferential attack of inclusions, grain boundaries and other defects that are more numerous on surfaces transverse to the rolling direction is not possible in the transfer pipes and tanks, since no end grain is exposed to the waste streams in these components.

Microbiologically Influenced Corrosion - Localized attack due to the chemical environment created by microbiological activity.

The stainless steel pipe and tanks are primarily exposed to the waste streams. The carbon steel pipe should normally be dry both inside and outside, but could potentially be exposed to moisture and other corrosive species on both the inside (from leakage of the inner stainless steel pipe) and the outside (from groundwater). For these particular environmental conditions, general, pitting and crevice corrosion are all possible. In addition, the combination of carbon steel outer pipe (and annular supports) and stainless steel inner pipe creates a galvanic couple that will preferentially attack the carbon steel if an electrolyte (fluid) is present - this could happen in the event of in-leakage of groundwater or leakage of waste from the inner pipes. The radioactivity of the waste in the inner pipe produces a possibility of radiation embrittlement of either the inner or outer pipe.

A previous evaluation of radiation damage to the waste storage tanks can be used to assess the likelihood of radiation damage to the transfer piping and tanks. The radiation damage to the high level waste tank walls due to fresh (high-activity) waste was estimated to be less than 4×10^{-7} dpa over a 100 year life [5]. In contrast, damage on the order of 1×10^{-5} dpa or greater is necessary for observable loss in ductility in carbon steel at low irradiation temperatures [5]. The threshold for observable loss of ductility in austenitic stainless steels is even higher, around 10^{-2} dpa [3].

Over a lifetime on the order of 25 years, the exposure of the waste tank walls would be 2 orders of magnitude less than required for radiation damage to occur in carbon steel, with even greater margin for stainless steel. Using the damage estimate for fresh waste in the waste tanks is conservative in the following respects:

- The waste that will be transferred through the inter-area transfer lines has been stored for a number of years and will have partially decayed. In the bounding case cited above (4×10^{-7} dpa), 58% of the damage comes from Zr-95 and Nb-95, which have half-lives of 64 and 35 days, respectively.
- Some degree of shielding from the stainless steel inner pipe and the distance between the inner and outer pipes will both act to reduce the exposure of the carbon steel pipe to radiation damage.
- The relatively small diameter of the inner pipe will limit the source strength to which either pipe is exposed.

Reference 1 was reviewed to determine the concentration of radioactive species in the sludge before and after extended sludge processing (ESP) and the concentration in the salt solution (supernate) before and after in-tank precipitation (ITP) and Late Wash. These concentrations are summarized in Table 2. The highest concentration ratios are seen in the salt solution, with a factor of 20 increase in the cesium concentration and a factor of >50 in the uranium concentration. The uranium concentration increase to 50 ppm is still well below the uranium concentration in the sludge, and the uranium radiation damage levels in reference 5 were 8 orders of magnitude lower than the total damage levels. Therefore, uranium does not constitute a concern in terms of radiation levels. The cesium concentration in the supernate after Late Wash represents a 20-fold increase over the original level, while Cs-137 activity contributes only 1% of the total radiation damage calculated in reference 5. Therefore, the transfer piping will not be exposed to sufficient radiation to produce observable loss of ductility.

Table 2. Concentrations of radioactive species * [1]

	Concentration (ppm) in Sludge			Concentration (ppm) in Supernate	
Element	from Tank 42	from Tank 51	Feed to DWPF	prior to ITP	Feed to DWPF
Cs	5	1	1	20	400
Rh	10	5	3	<1	<1
Ru	40	20	15	<1	2
Pu	25	30	15	<1	<1
Tc	5	15	5	5	1
Sr	50	50	25	<1	2
Th	750	100	250	<1	30
U	6000	8000	4000	<1	50

* Short half-life species such as Zr-95 and Nb-95 are not included in this table since they will have decayed significantly since initial placement in the waste tanks.

The inter-area transfer line is buried at a depth of 5 to 10 feet [7]. At such a depth, the pipe is not subject to temperature extremes, but may experience low enough temperatures to reduce the toughness (and ductility) of the carbon steel pipe. Reference (8) summarizes fracture toughness data for archival carbon steel piping for various material specifications. The lowest fracture toughness (K_{IC}) recorded for ASTM A53 carbon steel was 138 ksi$\sqrt{in}$, at a temperature of 40 °F. Since the ground typically does not freeze to a depth of more than a few inches in the area, and the slurry being transferred will provide some heat to the piping, a minimum temperature of 40 F for the transfer line is considered reasonable.

The fracture toughness can be used to estimate the maximum flaw size that will not lead to sudden, catastrophic failure of the carbon steel pipe. For the minimum measured fracture toughness (138 $\text{ksi}\sqrt{\text{in}}$), and assuming a stress in the pipe equal to the yield strength (35 ksi), the critical flaw length (2a) is given by:

$$2a = 2\,(K_{IC} / F(\lambda)\,\sigma_y)^2 / \pi$$

$$\text{with } F(\lambda) = 0.9 + 0.25\,\lambda$$

$$\text{and } \lambda = a / \sqrt{(Rt)}$$

This estimated flaw size assumes a throughwall circumferential flaw under internal pressure loading and a pipe wall thickness of 0.25 inch (thicker pipe is also allowed by the specified P code). Solving the above equations by iteration gives a total critical flaw length (2a) of 4.8 inch. Different loading conditions (axial load, bending load) were also considered, but the result for internal pressure load was the more conservative. Given the very low probability of such a flaw existing in the carbon steel pipe, sudden catastrophic failure due to low temperature embrittlement is not expected.

Corrosion Data:
The remaining degradation mechanisms that are listed above as potentially affecting the transfer piping are discussed in this section. Since both carbon steels and stainless steels are potentially degraded by these mechanisms (general, pitting, and crevice corrosion, and stress corrosion cracking), a review of corrosion test data taken under prototypic (or near-prototypic) conditions was performed. These data are reviewed herein. Further discussion specific to the susceptibility of carbon steel to pitting corrosion follows discussion of the corrosion data specific to the identified waste streams.

Two primary sources of relevant corrosion data have been identified. These are the DuPont Engineering Test Center (ETC) [9], and the Savannah River Technology Center [10-12]. In many cases, the test environment provides a reasonable match to the actual environment, since the test data were developed in support of materials selection for DWPF components. However, due to improved understanding of the waste stream chemistry, and changes in the anticipated DWPF process chemistry over time the test conditions do not provide an exact match in most cases. Therefore, the best match(es) available is presented for each material / waste stream combination. Some corrosion data for the carbon steel pipe is addressed by testing on A537 carbon steel (used in the waste tanks), while corrosion data for 1018 carbon steel is available for the precipitate slurry. Either material should provide a close approximation of the corrosion behavior of the A53 transfer line carbon steel, since there is no large difference in the composition of the three alloys.

Tables 3 - 5 summarize the test conditions and results that best apply for each waste stream. In some cases, more than one test approximates or bounds the waste stream chemistry, and multiple results are cited. Test coupons are identified by ETC by designations such as F (flat), C (crevice corrosion), UB (U-bend), and I (interface). Average corrosion rates are identified for test coupons. In other words, for corrosion attack of the general surface, the attack is assumed to occur at the same rate over the entire surface. In cases of local attack, the corrosion rate may vary with time. Therefore, corrosion rates are not cited for local attack.

Corrosion Data for Precipitate Slurry:
Test data relevant to the precipitate slurry are summarized in Table 3. The two 3B-4 test solutions appear to give overly conservative results for the carbon steels due to the high temperature and high chloride levels. Test solutions 6C-1 and 6C-3 are not as conservative, and provide more realistic results. They indicate the possibility of local attack in a vapor space above the waste solution, if such a space exists. Note that inhibitor concentrations might easily change near the surface and

within a vapor region. A general corrosion rate for carbon steel in the precipitate slurry solution of 1 mil/year is considered reasonable. This same conclusion holds for the precipitate slurry prior to late wash (see further discussion below).

The only significant attack on the stainless steel was seen for ETC solution 3B-4(A). Comparing this solution with ETC solution 3B-4(C), the only difference is the chemical form of mercury. Since the waste solution mercury is identified as mostly insoluble, HgO (in solution 3B-4(C)) is the more appropriate form to consider here. (Both of these solutions are presented to illustrate that the form of mercury has much less effect on the corrosion behavior of the carbon steel.) Therefore, no significant attack of the stainless steel is expected from the precipitate slurry solution.

Table 3. Data Summary for Precipitate Slurry

	Actual Environment	ETC test sol'n 3B-4(C)	ETC test sol'n 3B-4(A)	ETC test sol'n 6C-3	ETC test sol'n 6C-1	WSRC-TR-91-138 [11] test sol'n 2
Temp. (C)	30	90	90	40	40	30 - 60
pH	> 11	12	12	13.3	13.1	12
NO3- (wt%)	0.0010	0.1	0.1	0.06	0	0.17
NO2- (wt%)	0.040	0	0	0.1	0	0.11
SO4(-2) (wt%)	0.025 most insol.	0.08	0.08	0.025	0.025	0.017
COOH- (wt%)	0	0	0	0	0	0
PO4(-3) (wt%)	0.0005	0	0	0	0	0.001
F- (wt%)	0.0005	0.03	0.03	0.005	0.005	0.0007
Cl- (wt%)	0.001	0.25	0.25	0.05	0.05	0.0018
Hg/Hg(+2) (wt%)	0.060 most insol.	0.1 (as HgO)	0.1 (as HgCl2)	0	0.04 (HgCl2)	0
Cu(+2) (wt%)	0	0	0	0	0	0
OH- (wt%)	0.025	0.04	0.04	0.85	0.85	0.12
other (wt%)		0.003 I	0.003 I	0.002 I	0.002 I	0.016 Na2CO3
Test Results on 304L		no wt. loss, C, weld	4.4 mpy, C, with crevice attack			no attack in cyclic polarization test
Test Results on 1018 carbon steel		12 mpy, C 16 mpy, F 8.9 mpy, UB	7.1 mpy, C 16 mpy, F, with intergranular attack 6.9 mpy, UB			
Test Results on A537-1 carbon steel				0.1 mpy, C, with crevice attack (1 of 2 coupons) 0.2 mpy, I, with vapor space attack (1 of 2 coupons)	0.2 mpy, C, with crevice attack (1 of 2 coupons) 0.2 mpy, I, with vapor space attack (2 of 2 coupons)	crevice and uniform corr. in cyclic polarization tests (not quantified)

Corrosion Data for Sludge:

Test data relevant to the sludge are summarized in Table 4. For the carbon steel, the two ETC test solutions listed in Table 4 result in significantly different corrosion behavior. The much higher corrosion rates in solution 6A-11 are likely the result of the higher test temperature and relatively high chloride levels. The pitting observed in solution 6A-11 is not indicative of actual sludge behavior because of the large difference in the [NO_2-]/[NO_3-] ratio (see discussion below). Based on the more prototypic chemistry of test solution 6C-5, relatively little general corrosion of carbon steel is expected, although some vapor space attack was observed. A general corrosion rate of 1 mil/year is therefore recommended for carbon steel in sludge. Some additional local attack in any vapor space might occur. The cyclic polarization test on the reference 11 test solution 6 further confirms that little corrosion attack is expected.

The cyclic polarization test also indicated no significant susceptibility of 304L stainless steel to corrode in the sludge environment. No quantified corrosion rates were identified, but a rate of less than 0.5 mil/year is judged to be a reasonable upper bound.

Table 4. Data Summary for Sludge

	Actual Environment	ETC test solution 6A-11	ETC test solution 6C-5	WSRC-TR-91-138 [11] test solution 6
Temp. (C)	60	90	70	30 - 60
pH	> 11	10.1	13.3	13.1
NO3- (wt%)	0.04	0.2	0.06	7.7
NO2- (wt%)	1.3	0.6	0.2	1.9
SO4(-2) (wt%)	0.08	0.08	0.25	0.77
COOH- (wt%)	0	0	0	0
PO4(-3) (wt%)	0.3	0	0	0.046
F- (wt%)	0.005	0.03	0.005	0.029
Cl- (wt%)	0.005	0.25	0.05	0.058
Hg/Hg(+2) (wt%)	0.06 most insol.	0.1 (as HgCl2)	0	0
Cu(+2) (wt%)	0.005 most insol.	0	0	0
OH- (wt%)	0.15	0.017	0.85	2.4
other (wt%)		0.003 I	0.002 I	0.78 Na2CO3
Test Results on 304L				no attack in cyclic polarization test
Test Results on A537-1 carbon steel		8 - 12 mpy, C, with crev. att. & NUGC* 4 - 10 mpy, F, with pitting and NUGC 19 - 41 mpy, I, with vapor space attack and NUGC	0.1 - 0.4 mpy, C (crevice attack at 90C, not at 70C) 0.1 - 0.3 mpy I, with vapor space attack (2 of 4 coupons)	no attack in cyclic polarization test

* NUGC - Non-Uniform General Corrosion

Corrosion Data for Recycle Waste Stream

Test data relevant to the recycle waste stream are summarized in Table 5. The results for carbon steel in the recycle stream environment indicate a susceptibility to corrosion in a vapor space. The reason for the difference in corrosion behavior between test solutions 7 and 8 is not obvious, but the possibility of crevice corrosion and uniform corrosion is indicated. It is significant that when the NO_2^- concentration in test solution 1 was reduced (giving a $[NO_2-]/[NO_3-]$ ratio very close to that identified for the recycle stream chemistry, pitting was observed in the vapor space. On the other hand, the higher temperature for test solution 1 would tend to increase any corrosion activity. Reference 12 notes that the corrosion rate of up to 15 mil/year exceeds the corrosion rate identified in the ETC tests (5 mil/year) since the ETC results assume that the local corrosion observed in the vapor space were uniformly distributed over the entire specimen. The actual penetration rate is expected to be higher, as noted in test solution 1. Allowing for the higher temperature of test solution 1, a corrosion rate of 5 mil/year is considered reasonable for carbon steel in the recycle stream. Pitting and crevice corrosion are also expected, especially in a vapor space.

The cyclic polarization test and interface coupon indicated no significant susceptibility of 304L stainless steel to corrode in the recycle stream environment. The interface coupon tested at 90 °C showed a light tarnish, but this would be at least partially related to the higher temperature of this test. No quantified corrosion rates were identified, but a rate of 0.5 mil/year is judged to be a reasonable upper bound.

Table 5. Data Summary for Recycle Waste Stream

	Actual Environment	WSRC-TR-92-375 [12] test solution 1	WSRC-TR-91-138 [11] test solution 8	WSRC-TR-91-138 [11] test solution 7
Temp. (C)	50	93	30 - 60	30 - 60
pH	13	not reported	12.7	12.9
NO3- (wt%)	0.3	0.06	6.0	4.5
NO2- (wt%)	0.62	0.2	0.48	0.67
SO4(-2) (wt%)	0.003	0.025	0.094	0.07
COOH- (wt%)	0	0	0	0
PO4(-3) (wt%)	0.0005	0	0.17	0.23
F- (wt%)	0.0005	0.005	0	0
Cl- (wt%)	0.0005	0.05	0.0076	0.0057
Hg/Hg(+2) (wt%)	0.060 (Hg)	0.04 (Hg(NO3)2)	0	0
Cu(+2) (wt%)	0.0005	0	0	0
OH- (wt%)	1.0	0.85	0.6	0.82
other (wt%)		0.002 I	1.0 Na2CO3	1.4 Na2CO3
Test Results on 304L		I, tarnish on submerged surfaces	no attack on I coupons or cyclic polarization	no attack in cyclic polarization test
Test Results on A537-1 carbon steel		≤15 mpy, I, in vapor space (~ no corrosion of liquid or interface regions) Pitting in vapor space with NO2- reduced to 0.03 ppm	severe crevice and uniform corr. in cyclic polarization tests I, isolated regions of corrosion in vapor region	no attack in cyclic polarization test

For each of the three waste stream environments, similar results are obtained. None of these environments is expected to attack the stainless steel primary containment at any significant rate. The stainless steel pipe is governed by pipe code P240, which provides for zero corrosion allowance. Structural Mechanics should verify based on actual load conditions that sufficient margin exists to provide an "as-built corrosion allowance". Such a corrosion allowance, combined with an upper bound corrosion rate of 1 mil/year, will define a lower bound service life. The carbon steel is likely to be attacked more rapidly by any of the waste streams, especially in any vapor space above the waste solution. Note, however, that such attack would only occur in the unlikely event that the stainless steel inner pipe were breached.

A corrosion rate for the carbon steel might be in the range of 1 - 5 mil/year, with localized corrosion proceeding at a greater rate. Any corrosion of the carbon steel at a rate exceeding 1 mil/year is associated with the vapor space. Penetration of the wall within the vapor space would not cause leakage to the environment unless the level within the carbon steel pipe subsequently rose. Using a nominal corrosion rate of 1 mil/year and a corrosion allowance of 0.05 inch (per piping code P51B), the carbon steel pipe would be expected to last 50 years following leakage of the inner pipe.

Pitting of Carbon Steel Pipe:
General corrosion of carbon steels exposed to precipitate, sludge, and DWPF recycle waste are expected to be insignificant due to high pH. This is demonstrated in the data cited above. Other localized corrosion mechanisms (i. e. pitting) are more likely to occur in the carbon steel outer transfer pipe in the event of inner pipe leakage. However, some of the chemical species present in the various waste streams (NO_2-, OH- and PO_4-) act to inhibit localized attack in carbon steel. Experimental work has been performed to determine the required inhibitor levels for wastes in carbon steel tanks during the In-Tank Precipitation Process (ITP) [13] and the Extended Sludge Process (ESP) [14]. Inhibitor levels have also been determined for the DWPF recycle waste stream for storage in carbon steel tanks in H area [2].

The laboratory tests (cyclic polarization and coupon tests) show that hydroxide concentrations greater than 1 M will prevent pit initiation. They also identify the amount of nitrite required to prevent pit initiation with lower hydroxide levels present - this amount varies depending on the concentrations of sulfate and chloride ions present. In the cases of the sludge, precipitate slurry, and recycle waste streams, the hydroxide concentrations are all less than 1 M. The relevant impurities in these streams, and the correlations defining the nitrite levels required to prevent pitting, and summarized in Table 6.

Table 6. Summary of conditions required to prevent pit initiation

Ion Concentration	Nitrite Concentration Correlation to Prevent Pitting [13, 15, 16, 17]	Required NO_2^- Concentration
Sludge		
0.0060 M NO_3^- 0.3110 M NO_2^- 0.0088 M $SO_4^{=}$ 0.0012 M Cl^-	$[NO_2^-]$ = Most limiting of: $1.5 * 10^{0.041(T-40)}\ 10^{(0.0675 + 0.835 \log[SO_4^{=}])}$, $1.5 * 10^{0.041(T-40)}\ 10^{(2.25 + 1.34 \log[Cl^-])}$, or $0.038\ [NO_3^-] * 10^{(0.041T)}$ based on data for 23 - 60 C and 0.01 - 1.0 M NO_3^-	0.2214 M, for T = 60 C (equation for sulfate is most limiting)
Precipitate Slurry		
0.0002 M NO_3^- 0.0097 M NO_2^- 0.0002 M $SO_4^{=}$ (soluble) 0.0003 M Cl^-	$[NO_2^-]$ = Most limiting of: $1.5 * 10^{0.02(T-40)}\ 10^{(-0.22 + 0.61 \log[SO_4^{=}])}$, $1.5 * 10^{0.02(T-40)}\ 10^{(1.35 + 1.03 \log[Cl^-])}$, or $0.11\ [NO_3^-]^{0.72} * 10^{(0.02T)}$ based on data for 40 - 80 C and 0.007 - 0.83 M NO_3^-	0.0046 M, for T = 30 C (equation for chloride is most limiting)
Recycle Waste		
0.0494 M NO_3^- 0.6000 M OH^-	$[NO_2^-] = -0.0192 + 3.17 * [NO_3^-]$ based on data for ≤ 90 C, ≤ 0.5M OH^-, and 0.01 - 0.1 M NO_3^-	0.14 M
	* The above equations use concentrations [x] in moles/liter and temperature (T) in degrees C.	

Comparing the nitrite concentrations required to prevent pitting with the actual nitrite concentrations in the sludge and the precipitate slurry, one sees that both of these solutions have sufficient nitrite concentrations to prevent pitting. The nitrite concentration required to prevent pitting in the recycle waste stream has been identified to DWPF, and will be incorporated into the appropriate operating practices (i.e., nitrites will be added to the recycle waste stream to maintain this level). In each of the waste streams, the estimated concentrations and/or temperature fall beyond the range of laboratory data for which the Table 6 correlations were developed. However, it is judged that these deviations are not sufficiently large as to disqualify the conclusion that pitting should not occur. Accordingly, pitting is not expected in any of the carbon steel piping in the event the inner pipe should leak.

Since the primary purpose of the LWF is to remove the nitrites from the precipitate slurry, the general and pitting corrosion assessments were made using the composition following late wash. However, the concentrations of corrosive species also is reduced by LWF. A comparison of key chemical species before and after late wash is provided in Table 7. Significant reductions in both the nitrate and nitrite concentrations occur during late wash. According to the equations in Table 6, a minimum nitrite concentration of 0.023 M is required to prevent pitting in the pre-LWF solution (the sulfate-based equation is most limiting in this case). This is easily met by the identified composition. Further, using the ratio between the concentrations before and after LWF, the Table 3 data shows that ETC test solution 6C-3 provides a reasonable match for the before LWF solution. In this solution, carbon steel had a general corrosion rate of 0.1 - 0.2 mil/yr. (As was noted above, local attack might occur within a vapor space above the pre-LWF precipitate slurry.)

Table 7. Concentration of key species in the precipitate slurry before and after LWF

Species	Concentration (M) Before LWF	Concentration (M) After LWF
NO3-	0.0020	0.0002
NO2-	0.1240	0.0097
SO4(-2)	0.0050	0.0029
Cl-	0.0004	0.0003

Mitigative Measures:
Having identified that several degradation mechanisms may be active in the carbon steel pipe, it is also noted that the following mitigative measures are in place:

- The pipe in buried in Gilsulate 500,
- The pipe has an inorganic zinc coating,
- Cathodic protection is provided for the carbon steel pipe, and
- A leak detection system is installed to identify any leakage into the carbon steel pipe.

Each of these measures is discussed in reference 18. The Gilsulate 500 engineered backfill provides the primary protection of the carbon steel pipe. Properly applied, it provides an effective barrier to exclude water from contacting the pipe. In the absence of moisture, the carbon steel will not corrode.

The zinc coating provides a backup barrier to prevent moisture from contacting the pipe. In 1993, portions of the inter-area transfer line were excavated during modifications at the auxiliary pump pit. Numerous breaches of the coating were seen, with superficial rusting of the carbon steel pipe at these locations. Most of these breaches were on the top side if the pipe, probably resulting from personnel walking on the pipe after placement, or from damage during excavation [18]. Since this coating is not the primary protective measure, repair of only those areas where the coating was completely removed and new weld areas was recommended [18, 19]. Accordingly, most of the pipe surface remains protected with a zinc coating.

A third layer of defense against carbon steel corrosion is provided by an impressed current cathodic protection system. With such a system, an electric current is actively applied to the pipe to render the pipe noble with respect to corrosion in groundwater. This protection is provided only during the periods in which the system is in operation. The cathodic protection system might be turned off during maintenance, modifications, and at other times.

The inside surface of the carbon steel pipe should normally be dry, since nothing is intentionally added to the annular space of the transfer lines. However, a leak in the inner pipe can create a corrosive environment for the carbon steel inner surface. Such leakage should be detected as the liquid drains to leak detection boxes. It is noted that water was found in one transfer line in 1989, apparently left from the original hydrotest two years earlier [20]. Subsequent inspections of the line (motivated by a concern for microbiologically influenced corrosion of the stainless steel) showed no significant degradation and a subsequent hydrotest was successfully completed.

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Technical Review: P.E. Zapp

Appendix 3.

Copy of SRT-MTS-955152, "Materials Degradation of DWPF Chemical Tanks and Piping"

Westinghouse Savannah River Company
MATERIALS TECHNOLOGY SECTION

Materials Consultation

Subject Describers:
SRT-MTS-955152
DWPF
Tank
Pipe
Corrosion
Retention: 20 years

August 8, 1995

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MATERIALS DEGRADATION OF DWPF CHEMICAL TANKS AND PIPING (U)

Summary

The susceptibility of DWPF chemical tanks and associated piping to in-service degradation has been reviewed as part of the DWPF Structural Integrity Program. No significant reduction in mechanical properties is expected from service conditions; however, several components are predicted to experience a loss of net section due to corrosion. General corrosion rates for all components evaluated are modest (less than 2 mils/year in every case). Table 1 summarizes the expected corrosion behavior and estimated service life for each component. The estimated service life is greater than 25 years for all components.

Also provided in Table 1 are recommended actions that will maintain the conditions on which this assessment is based. For example, the absence of corrosion on the outer surfaces of carbon steel components depends on maintaining a protective coating (i.e., paint or galvanized coating). Accordingly, periodic visual inspections are recommended to verify the continued integrity of such coatings. In two cases where a nominal corrosion allowance of zero is specified for piping, it is recommended that Structural Mechanics verify that some corrosion allowance can be justified based on actual applied loads. The remaining recommendations to continue the existing diesel fuel oil sampling program and to track the cumulative amount of time the cathodic protection system is inactive will provide confidence that the diesel fuel oil tanks and associated underground pipe are not degrading.

Table 1. Summary of Degradation Assessment of DWPF Chemical Tanks and Piping

Component	General Corrosion Rate (mil/yr)	Service Life Estimate (years)	Recommendations[1]
OWST Inner Tank	< 2	> 60	- - -
OWST Outer Tank	variable (see text)	high[2]	A
OECT / OWST Transfer Pipe	< 2	> 25	- - -
Formic Acid Storage Tanks #1 & #2	< 1	> 60	- - -
Organic Acid Drain Catch Tank	< 1	> 60	- - -
Formic Acid Dilution Tank	< 2[3]	> 60	- - -
Dilute Formic Acid Feed Tank	< 2[3]	> 60	- - -
Formic Acid Feed Tank and piping	< 1	> 60	B (piping)
Organic Acid Neutralization Waste Tanks #1 and #2	< 1	> 60	- - -
Nitric Acid Feed Tank and piping	< 2	> 25	- - -
Nitric Acid Waste Hold Tank	< 2	> 30	- - -
Acid Drain Catch Tank	< 2	> 60	- - -
Nitric Acid Dilution Tank and piping	< 2	> 25	B (outlet pipe)
Canned motor pumps	~0	high[2]	- - -
Diesel Fuel Oil Storage Tanks #1 & 2 and underground pipe	~ 0, unless water is present	high[2]	C, D
Diesel Fuel Oil Day Tanks #1 and #2		high[2]	A, C
Diesel Fuel Oil System piping		high[2]	A
Diesel Generator Lube Oil piping		high[2]	A
Diesel Generator Air piping		high[2]	A
Diesel Generator Water piping	~0	high[2]	A
Purge System piping and jumpers	~0	high[2]	A (piping)
Purge System tanks	~0	high[2]	A (outer tank)
Purge System vaporizers	~0	high[2]	- - -

[1] Key to recommended actions:
- A - Perform a periodic visual check to verify that the paint and/or galvanized coating on outer surfaces of carbon steel components is unbroken and intact.
- B - Structural Mechanics should identify a corrosion allowance based on actual applied loads.
- C - Continue existing fuel oil sampling program to identify water and sediment contamination.
- D - Track the cumulative time that the cathodic protection system is not active. If this time exceeds several years, need to assess the possibility of corrosion of protected components.

[2] Service life should not be limited by any identified materials degradation.

[3] These tanks might experience local attack (pitting, crevice corrosion, or end grain attack) in addition to the identified general corrosion rate.

Background

The DWPF Structural Integrity Team has identified a number of components for evaluation based on their designation as safety class or safety significant [1]. This report evaluates the possibility of material degradation of chemical storage tanks and associated piping, and purge system components. These components are listed in Table 2, along with the materials of construction and chemical environment.

Table 2. Components addressed in this report

Component	Material of Construction	Chemical Contents	Corrosion Allowance
OWST Inner Tank	304L stainless steel	95 wt% benzene	1/8 inch
OWST Outer Tank	A283C Grade CS carbon steel	benzene, water, etc., only if leakage occurs	NA
OECT / OWST Transfer Pipe	304L stainless steel	95 wt% benzene	0.05 inch
Formic Acid Storage Tanks #1 and 2	316L stainless steel	90 wt% formic acid	1/8 inch
Organic Acid Drain Catch Tank	316L stainless steel	≤ 90 wt% formic acid *	1/8 inch
Formic Acid Dilution Tank	304L stainless steel	90 wt% formic acid	1/8 inch
Dilute Formic Acid Feed Tank	304L stainless steel	1.5 wt% formic acid	1/8 inch
Formic Acid Feed Tank	316L stainless steel	90 wt% formic acid	1/16 inch
Formic Acid Feed Tank piping	316L stainless steel	90 wt% formic acid	0 inch
Organic Acid Neutralization Waste Tanks #1 and #2	316L stainless steel	≤ 90 wt% formic acid *	1/16 inch
Nitric Acid Feed Tank	304L stainless steel	50 wt% nitric acid	1/16 inch
Nitric Acid Feed Tank piping	304L stainless steel	50 wt% nitric acid	0.05 inch
Nitric Acid Waste Hold Tank	304L stainless steel	≤ 50 wt% nitric acid *	1/16 inch
Acid Drain Catch Tank	304L stainless steel	≤ 50 wt% nitric acid *	1/8 inch
Nitric Acid Dilution Tank	304L stainless steel	12 - 50 wt% nitric acid	1/16 inch
Nitric Acid Dilution Tank piping	304L stainless steel	50 wt% nitric acid (in) 12 wt% nitric acid (out)	0.05 in. (in) 0 inch (out)
Canned motor pumps for various tanks	304L stainless steel	formic or nitric acid as listed above	NA **
Diesel Fuel Oil Storage Tanks #1 and #2 and underground pipe	SA36 carbon steel	diesel fuel	1/8 inch
Diesel Fuel Oil Day Tanks #1 and #2	carbon steel	diesel fuel	NA
Diesel Generator System piping	carbon steel	air, lube oil, or water	NA
Diesel Fuel Oil System piping	ASTM A106 B	diesel fuel	0.05 inch
Purge System Piping and Jumpers:			
LWF Primary (P) & Backup (BU),	304L stainless, Hastelloy C-276 ASTM A53, A106, or equiv. carbon steel, galvanized, and ASTM B88 copper	nitrogen	0.03 - 0.05 inch, C steel 0 inch, S steel, C-276 & copper
CPC Safety Grade (SG) & BU,			
LPPP SG & P, OWST SG & P,			
SPC SG			
PPT/SPT Chem. Feed (LPPP SG)			
SPC P & BU		carbon dioxide	
CPC P		air	
Purge System Tanks and Vaporizers:			
CPC SG, LPPP SG, OWST SG, SPC SG, LWF P & BU, 422-S Supply tanks & vaporizers	9% Ni steel inner tank carbon steel outer tank Al vaporizer	nitrogen	NA
SPC P tank	A612 carbon steel	carbon dioxide	NA
CPC P tank	carbon steel	air	NA

* These tanks can contain both strong acid and acid that has been neutralized to pH 6 - 9 by NaOH.

** NA - not available.

Discussion

This report identifies potential degradation mechanisms and rates for the DWPF chemical storage tanks, associated piping, and related components. These degradation mechanisms are based primarily on the available literature and standard industry experience. Additional laboratory data is cited in some cases. The various degradation mechanisms that could potentially be active have been summarized in other reports [2, for example]. Many of these mechanisms are not applicable to the components addressed in this report. For example, there are no significant sources of radiation or hydrogen to cause embrittlement. Degradation mechanisms that warrant consideration for the chemical storage tanks and piping include the following. Note that most components will be susceptible to only a few of these mechanisms.

General Corrosion - uniform attack that results in gradual thinning of the material.

Stress Corrosion Cracking (SCC) - cracking that occurs due to the combined action of stress, a susceptible material, and environment. Such cracking can be intergranular or transgranular. Austenitic stainless steels are susceptible to SCC in the presence of chlorides, while carbon steels can undergo SCC in the presence of NaOH at high pH, or nitrates at low pH [3].

Pitting Corrosion - localized attack typically leading to relatively small throughwall holes.

Crevice Corrosion - localized attack at crevice locations due to isolation from the bulk chemistry.

Galvanic Corrosion - corrosion of the more active of 2 metals in contact with each other in the presence of an electrolyte.

End Grain Corrosion - preferential attack of inclusions, grain boundaries and other defects which are more numerous on surfaces transverse to the rolling direction.

Low Temperature Embrittlement - a loss of ductility and toughness of carbon steels due to a reduction in temperature below the nil-ductility temperature.

Liquid Metal Embrittlement - a loss of ductility and strength due to the presence of certain liquid metals which preferentially attack the grain boundaries.

Microbiologically Influenced Corrosion - localized attack due to the chemical environment created by microbiological activity.

The Table 2 components fall into 4 major groupings, based on the chemical environment. These include components for handling benzene, formic and nitric acid, diesel generator support, and purge gases. Each of these groups is discussed separately below.

In some cases, especially with relatively low corrosion rates, the literature identifies bounding corrosion rates. In these cases, the actual corrosion rate may be much less than that reported, but the actual rate has not been quantified.

Corrosion of components in contact with benzene:
The OWST inner tank and OECT / OWST transfer line are continuously exposed to benzene (liquid and/or vapors). In addition, the OWST outer tank could be exposed to benzene in the event the inner tank leaks. Table 3 summarizes the compatibility data between benzene and the materials of these components. Essentially no corrosion of the stainless steel is expected (since the actual temperature will be much less than 200 °F, the corrosion rate will also be reduced from the 2 mil/yr bounding corrosion rate cited). With a corrosion allowance of 1/8 inch for the OWST inner tank, a service life in excess of 60 years is expected. The use of the low carbon grade of 304 stainless steel (i. e. 304L) should avoid the levels of sensitization associated with IGSCC. Similarly, the

OECT / OWST transfer line should experience low corrosion rates. Since transfers are performed as batch transfers and the transfer line is sloped to drain into the OWST, essentially no corrosion attack is expected during the intervals between transfers (vapors might be present continuously, but liquid benzene is present only intermittently). With a corrosion allowance of 0.05 inch, and the use of corrosion evaluated, low carbon 304L stainless steel, the transfer line service life is estimated to be in excess of 25 years. It is also noted that the P code governing the transfer line (P266) invokes Specification 5992 (superseded by site Standard 05950-03-R) which limits the chloride content of materials contacting stainless steels to 250 ppm.

The carbon steel OWST outer tank might be subject to measurable corrosion rates. Note, however, that the carbon steel OWST outer tank should be exposed to benzene only in the unlikely event that the inner tank should leak. A level detection system is in place to identify leakage into the outer tank. Given the low likelihood of the outer tank being exposed to benzene for long periods of time, and the reasonably low corrosion rates suggested by the literature cited in Table 3, degradation from benzene is not expected to limit the life of the OWST outer tank.

Also of concern to the OWST outer tank is the possibility of atmospheric corrosion of the outside surfaces. The tank is nominally protected from the weather by a protective coating (paint), but this coating is subject to scratching, peeling, or other damage. The inside surface of the outer tank is also painted. No corrosion due to atmospheric exposure is expected as long as the paint is intact. If the paint is damaged, corrosion may occur. Carbon steel exposed to the atmosphere can corrode at a rate of about 1 - 2 mil/yr (see discussion of purge gas components below), although higher rates can occur in regions where water (rain, condensation, etc.) can collect. Periodic visual inspection of the outer tank surfaces to verify the integrity of the paint will provide confidence that the outer tank is not corroding.

Table 3. Material corrosion data for benzene

Chemical / Material	Chemical Conc.	Temperature	Corrosion Rate	Reference
Benzene in contact with ...				
304 stainless steel	all conc.	< 200 °F	< 2 mil/yr	3
carbon steel	100 wt%	< 200 °F	< 20 mil/yr	3
carbon steel (Cu free)	100 wt%	< 840 °F	"satisfactory use"	4

Another potential form of degradation for the carbon steel outer tank is low temperature embrittlement. The tank is exposed to outside ambient temperatures, which can drop to 20 °F or lower in the winter. The possibility of sudden rupture is defined by the fracture toughness of the carbon steel. Very conservative values for K_{IC} (fracture toughness) are given in reference 5 for several pressure vessel steels. This identifies a fracture toughness of 54 ksi√in at the NDTT (nil ductility transition temperature), and 42 ksi√in at (NDTT - 40 °F). While the NDTT of the OWST outer tank is not known, it is unlikely that the tank will be exposed to a temperature more than 40 °F below the NDTT. (Reference 6 documents the fracture toughness of several carbon steel pipe materials at 40 °F with values ranging from 138 to 205 ksi√in, suggesting a NDTT below 40 °F. The outer tank composition is a closer match to these piping materials than to the steels cited in reference 5. Therefore, (NDTT - 40 °F) for the outer tank is estimated to be below 0 °F.)

The fracture toughness can be used to estimate the flaw size required for sudden, catastrophic fracture of the tank. For the lower bound fracture toughness (42 ksi√in), and assuming a stress in the tank equal to the yield strength (30 ksi), the critical crack length (2a) for a throughwall flaw is given by:

$$2a = 2\,(K_{IC} / \sigma_y)^2 / \pi = 1.25 \text{ inch}$$

Given the very low probability of a crack of this size existing in the outer tank, brittle fracture of the outer tank is not expected. Note that the use of a more realistic fracture toughness value such as 100 ksi√in increases the critical crack length to 7 inches.

Corrosion of components in contact with formic or nitric acid:
Both 304 and 316 stainless steels exhibit excellent corrosion resistance to formic acid at all concentrations at ambient temperature [7]. These materials tend to passivate (form a thin protective oxide layer) in formic acid [8, 9]. Accordingly, the results cited in Table 4, which generally reflect short term corrosion testing, would tend to overestimate the long term corrosion rates.

The corrosion rates in formic acid are strongly dependent on temperature. These chemicals are stored at ambient temperature, but increases in temperature can result during neutralization and dilution. The temperature of the organic waste neutralization tanks is limited by procedure to 40 °C (104 °F) - the neutralization rate is controlled so as to not exceed this temperature. Neutralization of formic acid waste is typically performed about once every 2-3 weeks [10]. Therefore, the time spent at elevated temperatures (40 °C max.) is minimal, and an average corrosion rate based on ambient (room temperature) data is appropriate. No temperature limit is specified for the formic acid dilution tank during dilution, and the degree of any temperature rise was not identified. However, this operation should not produce temperature increases as severe as those during neutralization. Dilution is typically performed about once per week [11], and a net corrosion rate based on ambient temperature is considered reasonable.

The identified corrosion allowance for 316L stainless steel tanks in formic acid service is 1/16 inch or greater. With a bounding corrosion rate of 1 mil/yr, a service life in excess of 60 years is expected. The formic acid feed tank piping has a corrosion allowance of zero, per piping code P212. While no guarantee can be made that the formic acid piping will not experience any corrosion, it is considered likely that it will not experience sufficient corrosion to impact its structural integrity. Structural Mechanics personnel should confirm that this pipe has a wall thickness in excess of that required to sustain applied loads (in effect, that it has a built-in corrosion allowance).

One precaution that is noted for formic acid service is the detrimental effect of impurities. For example, small amounts of chloride and sulfate produce local attack and increased general corrosion rates in 304L stainless steel [13], and formaldehyde can cause pitting in stainless steels [12]. Specification impurity limits for formic acid are listed in Table 5. The chloride and sulfate limits of 100 ppm fall within the range of impurities in the reference 13 test solutions. The closest match to these impurity levels is for test solutions 4A-10 and 4B-1, with 45 - 50 ppm chloride and 600 ppm sulfate. 304L stainless steel coupons in both of these test solutions experienced general corrosion rates of 1 - 3 mil/yr and localized attack (crevice corrosion and pitting). 316L stainless steel did not experience any local corrosion in solution 4B-1 (and was not tested in the other solution). Therefore, the possibility of accelerated corrosion due to impurities applies only to the 304L stainless steel tanks (formic acid dilution tank and dilute formic acid feed tank).

It is noted that the formic acid dilution tank will contain diluted acid part of the time, and that the impurities in the 90% formic acid will likely be less than the limits identified in Table 5. After dilution to 1.5 wt%, considering the typical impurity levels identified in Table 5 for process water, the chloride and sulfate levels should be reduced to less than 5 ppm. This low level should not produce any local attack of the 304L stainless steel. Similarly, the dilute formic acid feed tank should not experience any local attack from the impurities in 1.5 wt% formic acid. The 304L stainless steel tanks in formic acid service have a corrosion allowance of 1/8 inch. Assuming a bounding corrosion rate of 2 mil/yr gives a service life in excess of 60 years.

The 304L stainless steel nitric acid tanks can be assigned a bounding corrosion rate of 2 mil/yr. Since the nitric acid is stored at ambient temperature, and this bounding rate applies to temperatures up to 150 °F, the actual corrosion rate should be much lower than this bounding rate. The corrosion allowance for the nitric acid tanks is 1/16 inch or greater, giving a minimum service life of greater than 30 years. The nitric acid feed tank piping has a corrosion allowance of 0.05 inch (per code P61), giving an estimated service life in excess of 25 years.

The nitric acid dilution tank (located outside the mercury cell in Building 221-S) is used to dilute nitric acid from 50 wt% to 12 wt%. The tank and the nitric acid inlet piping have a corrosion allowance of 0.062 and 0.05 inch, respectively. With the bounding corrosion rate of 2 mil/yr, a service life in excess of 25 years is expected. The outlet piping, which handles only 12 wt% nitric acid, is schedule 10S pipe and has a corrosion allowance of 0 inch, per code P145. While this corrosion allowance does not allow for any wall loss (beyond the minimum fabricated thickness), the actual corrosion rate is expected to be much less than the bounding value of 2 mil/yr. No guarantee can be made that the nitric acid dilution tank outlet piping will not experience any corrosion. However, it is considered likely that it will not experience sufficient corrosion to impact its structural integrity. Structural Mechanics personnel should confirm that this outlet pipe has a wall thickness in excess of that required to sustain applied loads (in effect, that it has a built-in corrosion allowance).

Table 4. Material corrosion data for formic and nitric acid

Chemical / Material	Chemical Conc.	Temperature	Corrosion Rate	Reference
Formic acid in contact with ...				
316 stainless steel	90 wt%	RT	0.002 mil/yr	8
		boiling	13 & 16.5 mil/yr	7, 8
	50 wt%	RT	0.006 mil/yr	8
		boiling	20 & 24 mil/yr	7, 8
	5 wt%	RT	0.004 mil/yr	8
		boiling	1.5 & 6 mil/yr	7, 8
	all conc.	RT	< 2 mil/yr	3
		200 °F	20 - 50 mil/yr	3
	7.5 wt%	194 °F	0.1 - 0.3 mil/yr **	13
304 stainless steel	50 wt%	boiling	168 mil/yr	7
	20 wt%	boiling	43 & 76 mil/yr	7, 9
	all conc.	RT	< 2 mil/yr	3
		200 °F	> 50 mil/yr	3
304L stainless steel	10 wt%	140 °F	0.1 - ~100 mil/yr *	13
	7.5 wt%	194 °F	0.1 - 2.7 mil/yr **	13
Nitric acid in contact with ...				
304 stainless steel	up to 50 wt%	< 150 °F	< 2 mil/yr	3
		250 °F	< 20 mil/yr	3
304L stainless steel	up to 40 wt%	boiling	< 5 mil/yr	12
	40 - 70 wt%	up to 175 °F	< 5 mil/yr	12

* The reported corrosion rates vary with impurities present. The lowest corrosion rates (< 1 mil/yr) are in solutions with 0.0045 wt% Cl- or less (solutions 4A-11 and 4A-9). Increasing amounts of Cl- and SO4- (solutions 4A-10, 4A-12, and 4A-1) lead to higher corrosion rates, crevice corrosion, pitting and end grain attack.

** This data is based on test solution 4B-1, which contains 0.005 wt% Cl- and 0.06 wt% SO4-. Corrosion rates for 304L above 0.3 mil/yr also experienced crevice corrosion.

It is noted that the P codes governing the formic acid and nitric acid piping (P61, P145, P212) invoke Specification 5992 (superseded by site Standard 05950-03-R) which limits the chloride content of materials contacting stainless steels to 250 ppm. This reduces the likelihood of IGSCC resulting from contact with foreign materials. In addition, the use of the low carbon grades of stainless steel (304L and 316L) should avoid the levels of sensitization associated with IGSCC.

The 304L stainless steel casing on the canned motor pumps is exposed to the atmosphere. A black coating is applied to the casing, but it is not continuous over the entire surface. Reference 12 identifies that 304 stainless steel should not experience any corrosive attack in rural atmospheres, but can rust in an industrial atmosphere containing chloride pollutants. While rust was observed on specimens within 1800 feet of several industrial plants that use or produce chlorine compounds, no attack was observed at another location 2 miles away. Surfaces that are partially shielded from rainwater were more susceptible to corrosion. With no strong source of chloride pollutants in the immediate vicinity of DWPF, corrosion of the canned motor pump casings is not expected. The bounding corrosion rates of 1 and 2 mil/yr discussed above would be applicable to the pump casing inner surfaces. Pump casings are typically much thicker than required for structural purposes, in order to provide the high rigidity required for proper operation. Accordingly, even with the bounding corrosion rates, a significant service life can be expected for the canned pump casings.

Table 5. Impurity levels for formic and nitric acid.

Impurity	Impurity Limits (ppm) for Formic Acid [11]	Nitric Acid [11]	Typical Impurities (ppm) for Process Water * [14]
Chloride	100	100	0.5
Sulfate	100	100	< 1.5
Phosphate	10	---	< 0.1
Iron	100	100	< 0.1
Aluminum	10	---	---
Chromium	10	---	---
Nitrogen oxide	---	500	---
Residue on evaporation	---	200	---
Residue on ignition	---	100	---

* Process Water is used to dilute formic and nitric acid.

Corrosion of diesel generator support components:

An upper bound corrosion rate for carbon steel in contact with diesel fuel is provided in Table 6. Reference 15 states that fuels (including diesel fuel) are generally not corrosive to steel storage tanks. Rather, water or other impurities that might be introduced during transport and handling are the typical source of corrosion.

Several measures are employed to ensure the purity of diesel fuel on site and to protect diesel fuel tanks from corrosion [16]:

- Diesel fuel received on site is tested for sediment and water per ASTM D1796. A maximum of 0.05 vol. % sediment and water is allowed.

- Diesel fuel received on site receives a copper corrosion test per ASTM D130. A maximum rating of 3 (indicating the relative corrosivity of the fuel) is allowed.

- DWPF diesel fuel tanks are checked monthly - the bottom of the tank is checked for standing water, and the fuel is sampled for water and sediment content. Even if water is not detected, any corrosion of the tank would be indicated by an increase in sediment levels.

- In the event that the DWPF did not perform periodic sampling of the diesel fuel tanks, a CSWE program would sample them every 6 months.

- The possibility of microbiological influenced corrosion from microorganisms in the fuel is eliminated by keeping water out of the fuel.

- The underground storage tanks are cathodically protected to preclude corrosion by groundwater.

In one example of corrosion of a diesel fuel tank at SRS, up to 6 mils wall loss was recorded in a carbon steel diesel fuel tank that was in service for about 20 years [17]. The wall thickness was checked following detection of a high level of sediment in the fuel. Also found in the fuel was 0.02 % water. This tank supports a diesel generator that is used infrequently, and had not seen many fuel changes. The length of time the water was in the tank is unknown, but the corrosion likely resulted from water in the bottom of the tank, which was the area of measured wall thickness loss. The sides of the tank showed no measurable loss from the nominal wall thickness. This tank was singled out for inspection following the detection of a high level of sediment.

In addition to corrosion of the diesel tank inner surfaces from the fuel, the possibility exists for corrosion of the outside surfaces. The diesel fuel storage tanks, and the transfer pipe from the tanks to Building 292-S, are underground and subject to groundwater corrosion. As noted above, these tanks are protected under the area's impressed current cathodic protection system, and should therefore not experience any corrosion attack. This cathodic protection system is described in reference 18. In the event that the cathodic protection were lost (turned off), the storage tanks would be susceptible to corrosion, but only during the periods that the cathodic protection is not active. Inspections of the cathodic protection to verify proper operation are performed monthly, semi-annually, and annually [19]. It is recommended that the cumulative period of time for which the cathodic protection system is not active be tracked. If this becomes large (i. e. several years), then the tank wall thickness might need to be checked.

The diesel fuel oil day tanks are not buried, and are subject to atmospheric corrosion. Both the day tanks and the associated piping are painted to protect the metal from atmospheric corrosion. Periodic visual inspection of the day tank and piping to verify the integrity of the paint will provide confidence that they are not corroding.

The diesel generator system piping does not contain fuel oil, but is included in this section for convenience. This piping is carbon steel and is associated with the cooling water, lube oil, and air for the diesel generators. Limited data was located for the diesel generator system piping. However, considerable industry experience exists in such applications, and minimal degradation should be expected over a reasonable lifetime of 20 years or more. The cooling water circulates within a closed loop and should contain inhibitors to avoid corrosion. The lube oil will act much like the diesel fuel and protect the steel from corrosion unless water contamination is present. The air lines should experience minimal corrosion as discussed below for the purge gas piping. Periodic visual checks should be made to ensure that the paint on the diesel generator piping remains intact to preclude corrosion of the outside surfaces.

Table 6. Material corrosion data for diesel fuel

Chemical / Material	Chemical Conc.	Temperature	Corrosion Rate	Reference
Diesel fuel oil in contact with .. carbon steel	100 wt%	< 220 °F	< 20 mil/yr	20

Corrosion of components in contact with purge gases:
Purge gases include nitrogen, carbon dioxide and air. Piping for the various purge gas systems is specified to be in accordance with several P Codes, which leads to the use of several different piping materials: carbon steel, copper, and 304L stainless steel. A detailed review of the purge gas

piping layout was not made - rather it was conservatively assumed that each of these materials is used in each of the purge systems. The purge system jumpers are constructed of either 304L stainless steel or Hastelloy C-276. The purge system tanks are constructed of 9% nickel steel (nitrogen inner tanks) and carbon steel (nitrogen outer tanks and air tank), while the vaporizers are aluminum.

The purge system jumpers are exposed to purge gas on the inside, and are potentially exposed to vapors from process spills on the outside. Due to the noncorrosive nature of the purge gases (as discussed below), the primary concern for the jumpers is corrosion from the outside. Since the material of construction for the jumpers is the same as that for the process tanks in their respective cells, and other evaluations [2, 21] have shown general corrosion rates for the process tanks of 1 mil/yr or less, no significant corrosion of the jumpers is expected. It is also noted that any vapors that might be present in the process cells will be more dilute than those in the process tanks.

No data directly related to corrosion in a nitrogen atmosphere was found, nor is any expected since nitrogen is relatively inert with respect to corrosion. Corrosion rates for the nitrogen purge systems are bounded with data for atmospheric corrosion, since the atmosphere consists of approximately 78% nitrogen. In this case, moisture (humidity) and various pollutants are the primary source of corrosion, and the most representative data will be that with the least pollutants and low humidity. Nominally, no corrosion is expected for any of the purge system components in contact with nitrogen. However, should moisture or other impurities be present, corrosion rates should be less than 1 mil/yr for both carbon steel, and less than 0.1 mil/yr for copper and aluminum, based on the Table 7 data. Stainless steel should not experience any corrosion in the nitrogen purge system, even with moisture or other impurities likely to be present, based on the above discussion of the canned motor pumps.

The purity of the nitrogen gas was identified as 99.5 wt% [22]. If the remaining 0.5 wt% were all water, the purge gas would have a dew point of about 39 °F (assuming the nitrogen to have the same saturation properties as air) [23]. Alternatively, the relative humidity would be about 33% at 70 °F. In practice, the actual moisture content is expected to be much less than the bounding value of 0.5 wt%. Accordingly, no condensation should form within the nitrogen purge system piping, and no corrosion is expected.

The SPC primary and backup purge systems use carbon dioxide. Carbon dioxide can become mildly corrosive when dissolved in water (producing carbonic acid). Therefore, if any moisture were to enter the SPC purge systems and condense inside the piping, corrosion of copper or carbon steel piping can be expected. The purity of carbon dioxide gas used was identified as at least 99.5 wt%, indicating that an upper bound on moisture content is 0.5 wt%. (The same discussion of dew point (or relative humidity) used for the nitrogen purge systems applies in principle to the carbon dioxide systems. However, the dew point and relative humidity values would be different, since carbon dioxide has different saturation properties.) In practice, the moisture content should be much less than 0.5 wt% and no condensation within the piping is anticipated.

Bounding corrosion rate data for the purge system materials are provided in Table 7. With a bounding rate of 2 mils/yr, and for purge system temperatures that will be significantly less than the cited temperature of 400 °F, essentially no corrosion of the SPC purge systems from carbon dioxide is expected. Reference 3 shows a significant increase in the corrosion rate for copper and carbon steel in a 10% aqueous solution. However, any moisture that condenses from a near-pure carbon dioxide atmosphere will likely be saturated in carbon dioxide (i.e. a high concentration of carbonic acid). Therefore, no significant corrosion from carbon dioxide is expected.

With the different materials being used in the purge system piping, the possibility of galvanic corrosion exists. However, for the purge gas piping and components, all connections between dissimilar metals are made using flanged joints, with nonmetallic gaskets [22]. Therefore, no direct metal-to-metal contact exists and galvanic corrosion will not occur.

Carbon steel piping is used downstream of the vaporizers. Since the temperature of the vaporizers can be very low due to expansion of the liquid nitrogen, the attached piping can also be exposed to low temperatures. The vendor identified that the minimum temperature of the attached pipe should not be less than -30 °F. Similar to the discussion above for the OWST outer tank, this minimum temperature should be no more than 70 degrees below NDTT. For such a temperature, reference 5 identifies a minimum fracture toughness of about 39 ksi$\sqrt{\text{in}}$. The corresponding critical crack length for a throughwall flaw (conservatively ignoring the curvature of the piping) is a minimum of 1 inch. Since a flaw of this size should not be present, brittle fracture is not expected.

The P codes for the purge gas piping specify no corrosion allowance for the stainless steel and copper piping. In general, none should be needed. Neither of these materials should experience any significant corrosion on the outside (atmospheric corrosion), and the copper will corrode on the inside only if moisture condenses from the carbon dioxide gas and collects in a low spot (SPC purge piping only). The low moisture level dictated by the specified purity should preclude internal condensation. The corrosion allowance for the carbon steel piping ranges from 0.03 inch to 0.05 inch, depending on the P code. The inside surfaces should not experience any corrosion unless moisture condenses and collects at a low point. The outside surfaces would be subject to a corrosion rate of about 1 - 2 mil/yr; however, the pipe is galvanized and weld joints are painted with a zinc-based paint. Therefore, no significant corrosion of the carbon steel piping is expected. Similarly, other purge system components made of these materials should not experience significant corrosion either. Periodic visual inspection of carbon steel purge system components to verify the integrity of the zinc/paint coating will provide confidence that they are not corroding from the outside.

Table 7. Material corrosion data for purge gases

Chemical / Material	Chemical Conc.	Temperature	Corrosion Rate	Reference
Air in contact with ...				
carbon steel	low pollution	ambient	0.06 - 0.5 mil/yr *	24
carbon steel	varying pollution levels	ambient	0.8 - 2.8 mil/yr **	25
copper	varying pollution levels	ambient	0.03 - 0.08 mil/yr **	25
aluminum	varying pollution levels	ambient	≤ 0.03 mil/yr **	25
CO2 in contact with ...				
carbon steel, copper, and 304 stainless steel	100 wt% (aqueous sol'n)	< 400 °F	< 2 mil/yr	3
carbon steel	10 wt%	RT	> 50 mil/yr	3
copper	10 wt%	RT	< 20 mil/yr	3

* The lower corrosion rate was measured in Cuzco, Peru, while the higher rate is from South Bend, Pa. Both areas have very low pollutant levels. In addition, Cuzco has considerable rainfall and humidity levels. In comparison, a corrosion rate of 0.2 mil/yr was measured in Phoenix, Az., which has a very low average moisture level.

** These corrosion rates were measured in various locations throughout Great Britain. Pollution and moisture levels varied considerably.

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Technical Review: ____________

Appendix 4.

Copy of SRT-MTS-955214, "Degradation of DWPF Concrete and Steel Structures"

Westinghouse Savannah River Company
MATERIALS TECHNOLOGY SECTION

Materials Consultation

Subject Describers:
SRT-MTS-955214
DWPF
Concrete
Steel
Corrosion
Retention: 20 years

September 8, 1995

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Materials Technology Section

DEGRADATION OF DWPF CONCRETE AND STEEL STRUCTURES (U)

Summary

The potential for degradation of safety class and safety significant concrete and steel structures has been evaluated. In general, little or no degradation is expected from projected service conditions. Table 1 summarizes recommended inspections and other actions to ensure the continued integrity of these structures.

Table 1. Summary of recommended inspections and other actions

Structure	Recommendation
Concrete structures (general)	Survey and document any shrinkage cracks or other cracks in the manner done for the sand filter
Concrete structures (general)	Ensure procedures are in place for the prompt cleanup of chemical spills
FESV	Evaluate whether any degradation has occurred after the source of water intrusion is identified
Vitrification Building	Reevaluate likelihood of groundwater damage if the water table is found to have risen above the elevation of the building base
LWF cells, LPPP cells & cell covers, GWSB vault supports, sand filter, FESV	Confirm that the lifetime radiation exposures for these concrete structures is less than 10^{10} rads
Coated concrete structures	Periodic visual inspection to verify protective coatings are intact. Damage from radiation or chemical exposure, and mechanical damage is possible.
GWSB Vault Supports	Reevaluate potential for high temperature degradation after GWSB thermal analysis is complete
Steel Structures (general)	Periodic inspection to verify protective coatings are intact
Steel Structures (general)	Confirm that steel structures are not in contact with dissimilar metals likely to lead to galvanic corrosion
GWSB Canister Supports	Confirm that lifetime radiation exposure is less than 4×10^{10} rads

Background

The DWPF Structural Integrity Team has identified a number of components for evaluation based on their designation as safety class or safety significant [1]. This report evaluates the possibility of material degradation of concrete and steel structures that have been identified as such. These structures are listed in Table 2.

Table 2. Structures evaluated in this report

Location	Concrete Structures	Steel Structures
Vitrification Building	Building Structure Remote Process Cell Walls Canyon Walls Crane Maint. Shield Door Structural Support Main Process Cell Crane Structural Support Nitric Acid Dilution Tank Dikes Formic Acid Feed Tank Dikes Organic Acid Floor Drain Catch Tank Dikes Nitric Acid Feed Tank Dikes	Building Structure SPC/CPC Removable Wall Remote Process Cell Covers Melt Cell Crane Rails and Superstructure
GWSB	Vault Supports	Canister Supports
LWF	Cells, Cell Covers	Crane Rails and Superstructure
LPPP	Cells, Cell Covers Crane Operator Station	Process Cell Crane Rails and Superstructure
Zone 1 Vent. Sys	Sand Filter, Zone 1 Exhaust Tunnel	Zone 1 Exhaust Tunnel
Fan House	Building Structure	Crane Rails and Superstructure
FESV	Vaults	
422-S	Acid Tank Dikes	Superstructures
980-S	Organic and Nitric Dikes	

Discussion

The various structures are categorized into several groups for purposes of evaluation, based on the environment they are exposed to. Concrete structures can be categorized as one or more of the following:

- Underground structures - exposed to soil and groundwater at ambient temperature.
- General service structures - exposed to normal atmosphere at ambient temperature.
- Chemical service structures - exposed to process chemicals or waste streams at ambient temperature in the event of a spill.
- Radiation service structures - exposed to high levels of ionizing radiation.
- Heated structures - exposed to normal atmosphere at temperatures above ambient.

The steel structures are similarly grouped identified as either general service or chemical / radiation service structures. Each group of structures is potentially subject to different forms of degradation, and may require protective measures. Each group of structures is discussed separately.

Degradation of Concrete Structures:
Many of the structures fall under more than one category. The structures listed specifically as general service are those structures that do not fall into any of the other categories. All structures are potentially susceptible to the degradation mechanisms identified for general service structures.

Reference 2 evaluates the susceptibility of the SRS waste tanks to aging degradation, and identifies a number of degradation mechanisms applicable to concrete structures. These degradation mechanisms are summarized below. Applicable degradation mechanisms are grouped according to the service conditions in which they might be active. Two concrete degradation mechanisms described in reference 2 will not be discussed further since they are not considered applicable to the DWPF structures. These are chemical reactions between certain reactive aggregate types, and abrasion / cavitation due to fast-flowing water.

Degradation of General Service Concrete
The following degradation mechanisms are applicable to general service concrete structures.

- Freeze / Thaw Cycling - Water freezing within the pores of concrete creates hydraulic pressure which can lead to cracking, scaling, or spalling, after a number of freeze / thaw cycles. This mechanism is applicable to concrete exposed to the weather (rain water) or to underground concrete that is located above the frost line (exposed to groundwater). Freeze / thaw cycling is applicable to concrete sections exposed to the weather.

- Leaching - Water flowing through concrete (through cracks or inadequately prepared joints) can dissolve calcium compounds in the concrete. Calcium hydroxide is the most readily soluble compound. Following this leaching, the remaining constituents of the cement paste break down, resulting in little or no remaining strength. Leaching increases the porosity and permeability of concrete, increasing the susceptibility to other forms of attack. Groundwater or rainwater, if flowing through the concrete (not just filling cracks), can cause leaching.

- Shrinkage - Shrinkage results from the loss of water from concrete. The resulting tensile stresses can lead to cracking, which in turn can expose the interior (including embedded steel) to corrosion. Most shrinkage (98%) occurs in the first 5 years of service.

This section applies generically to all concrete structures. It specifically applies to those structures that are not intended for exposure to harmful chemicals, radiation, high temperature, or groundwater. These are:

MPC Crane Structural Support
LWF Crane Structural Support
Crane Maintenance Shield Door Structural Support
Low Point Pump Pit Crane Structural Support

General service applications include external structures exposed to the weather, or internal structures exposed only to ambient air. Building external surfaces are generally bare concrete, with no special protective measures in place. Experience with other bare concrete structures on site shows that long service lives can be expected. For example, the sides of the reactor buildings are generally in very good condition, with little or no degradation of the concrete evident after 40 years of service. The outer walls of cooling water basins still appear sound, despite heavy weathering in places (they have a constant supply of water on hand to promote leaching or freeze/thaw cycles). Accordingly, no significant degradation of outside concrete surfaces is expected. Interior surfaces exposed to ambient atmosphere will experience even less severe ranges of temperature and moisture, and should likewise not experience any significant degradation.

While the sand filter is discussed further in the other sections below, it contains cracking and other degradation not associated with radiation levels or its underground location. A number of cracks have led to leaking through the roof and to dampness within the roof slab [3]. The primary cause of these cracks is attributed to shrinkage (cracks at corners), consolidation, finishing and curing techniques (cracks over columns due to premature drying & shrinkage), and peeling of concrete when forms were removed (spalling at roof joints). Further cracking was not expected since most shrinkage occurs in the first year after placement [3]. The other concrete structures should be surveyed to identify the presence of any cracks from shrinkage (or other sources). Since the DWPF concrete structures have all been in place for a few years, no further shrinkage cracks are expected.

Degradation of Underground Concrete:
The following degradation mechanisms are specific to underground concrete structures:

- Chemical Attack - Strong acids will degrade concrete, which is highly alkaline (pH > 12.5). Groundwater with a pH of less than 5.5 can attack concrete, as can acidic chemicals. Chemical attack increases the porosity and permeability of concrete, increasing its susceptibility to further attack. In the soil or groundwater, sulfates can attack the aluminate phase in the cement. Chlorides can attack both the concrete and reinforcing steel. Steel embedded in the concrete (or lining the concrete) can be the source of aggressive chemical condensates if the surface temperature is below the dew point.

- Corrosion of Embedded Steel - While the high alkalinity of concrete generally protects the embedded steel from corrosion, the steel is susceptible to attack if the concrete pH is reduced below 11.5 or by the presence of aggressive ions such as chlorides in the presence of oxygen. Aggressive ions could be carried by groundwater or spilled onto the concrete. With a reduced pH of the concrete (due to leaching or exposure to acidic chemicals), caustic or nitrate stress corrosion cracking could occur. Corrosion of embedded steel leads to cracking and spalling of the concrete. Excessive corrosion will also weaken the steel (and therefore, also weaken the concrete structure).

The underground concrete structures addressed in this section are:

Vitrification Building
422-S Dikes (Formic & Nitric)
980-S Organic and Nitric Dikes
Sand Filter
Zone 1 Exhaust Tunnel
Fan House Structure
Low Point Pump Pit Cells
LWF Cells
Failed Equipment Storage Vaults

The portion of an underground structure that is exposed to soil and groundwater is subject to degradation from freeze/thaw cycling, leaching, chemical attack, and corrosion of embedded steel. The use of an adequate moisture barrier can preclude exposure and eliminate these degradation mechanisms. Freeze/thaw cycling will occur only near the surface, above the frost line.

Reference 4 provides soil/groundwater chemistry data measured at a number of locations around S and H areas. These data show the subsurface soil pH in some locations is low enough (5.0) to cause acid attack. However, the concentrations of chlorides (7.5 mg/L max.) and sulfates (195 mg/L max.) are below the threshold levels required for attack by these chemicals (500 and 1500 ppm, respectively [2]). Accordingly, chemical attack of underground concrete is not expected to be significant.

Once backfill is placed around a structure, it is this near-surface region that would be most susceptible to damage. Also, if the final grade ends up a little higher than the moisture barrier, this region will again be exposed to the above degradation mechanisms. Most of the underground concrete structures are provided with moisture protection, as summarized in Table 3.

Despite the waterproofing measures cited in reference 5 for the FESV, the vaults are reported to have accumulated about 2 feet of water in about 2 months time, with their covers in place [6]. The source of this water intrusion is currently under investigation. The limited evidence suggests the waterproofing on the underground surfaces may have been breached and the water table may have risen in recent years, but other causes cannot be ruled out. While tests from several years ago identified the water table to be about 5 ft or so below the bottom of the FESV, groundwater levels can vary over time. Due to the observed water in the FESV, the degradation is possible due to either leaching or corrosion of embedded steel. The extent of such degradation, if any, should be evaluated after the source of the water is identified.

When further information is available on the source of water in the FESV, any potential impact on other underground structures should be reevaluated. For example, Reference 7 identifies that the base of the vitrification building is about 20 ft above the water table. At an elevation of 269 ft 6 in, the base of the vitrification building is about 16 ft higher than the FESV vault floor. If the water table has risen significantly, the vitrification building, with no identified moisture barrier, may be subject to groundwater damage. The base of the 980-S and 422-S dikes are at higher elevations than the base of the vitrification building, at 282 ft 8 in [8] and 283 ft 3 in [9], respectively, and should remain well above the water table. The base of the pump pits is at an elevation of about 241 ft, which is about 12 ft lower than the FESV floor. The LPPP is reported to have had significant water intrusion during construction, but has remained dry since. As long as the pump pits continue to remain dry, no degradation of the pump pit cells is expected. The possibility of degradation should be reconsidered if significant exposure to moisture occurs (from process leaks and spills, or groundwater in-leakage).

Table 3. Summary of underground concrete protective measures

Structure	Protective Measure for Underground Moisture	Ref.
Vitrification Bldg. Structure	no moisture barrier cited, but base of building is ~20 ft above the water table *	7
LPPP & LWF Cells	waterproofing membrane on floor and outer walls	10
Zone 1 Exhaust Tunnel	dampproofing (6 mil polyethylene) on exterior surfaces	11
Sand Filter	dampproofing on all exterior below grade surfaces	3
Fan House Structure	dampproofing under the slab on grade	12
FESV	waterproofing on bottom and sides *	5
422-S Acid Tank Dikes	none identified, but positioned well above water table	9
980-S Organic & Nitric Dikes	none identified, but positioned well above water table	8

* See the discussion in the text regarding the FESV and water table elevation.

Degradation of Chemical Service Concrete
The following degradation mechanisms are specific to chemical service concrete structures:

- Chemical Attack - see above description
- Corrosion of Embedded Steel - see above description

The chemical service concrete structures addressed in this section are:

Remote Process Cell Walls
Remote Process Cell Covers
Low Point Pump Pit Cells and Cell Covers
Canyon Walls
LWF Cells and Cell Covers
All dikes
Zone 1 Exhaust Tunnel
Sand Filter

In general, the concrete structures that are potentially exposed to chemical liquids (due to spills, leaks, etc.) are provided with floors that slope to trenches, sumps, dikes, drains or other containment structures. Accordingly, any exposure of the structures to corrosive chemicals occurs during spills, leaks, or decontamination operations and is limited in duration. In some structures (such as the pump pit cells), leak detection monitors check for any leakage past the protective liners.

The dikes and canyon walls are subject to exposure from acid/caustic spills and any resulting vapors, while the remaining structures can be exposed to process vapors. Each of the structures within the zone 1 ventilation system (remote process cell walls and covers, zone 1 exhaust tunnel, and sand filter) would see diluted process vapors, due to the ventilation air flow maintained in these areas. The LWF and LPPP are also ventilated, and any spills/leaks in these areas should not lead to any concentrated vapor buildup either.

Table 4 summarizes the protective measures that are in place to minimize the absorption of liquids into the concrete, and to facilitate decontamination. This typically consists of a coating system, or stainless steel liner. While several candidate coating systems are permitted, a vinyl ester system has been generally used in the thicker applications. Given the limited exposure to corrosive vapors that is likely, both stainless steel and the identified coating systems are considered adequate to protect the concrete.

The potential for stainless steel corrosion in the presence of the precipitate slurry was shown to be low [13]. In addition, formic acid is added in the process vessels. Type 304 stainless steel has a typical corrosion rate of less than 20 mil/yr when exposed to concentrated formic acid vapors, and greater than 50 mil/yr when exposed to formic acid [14]. Given the limited duration exposure likely to result from leaks/spills, the stainless steel liners are considered adequate to prevent such leaks/spills from reaching the underlying concrete structures.

All of the identified concrete coating systems are designed for splash and spill conditions and not for immersion purposes. This means that when a spill occurs, it should be cleaned up within the current work shift per a clean-up procedure. If this is not done, coating degradation will occur. The coatings should stand up to the radiation exposure as specified in the drawings.

Of the specific coatings identified, Ceilcoat 6650, 2500S and 2500B are suitable for the splash and spill conditions of short term exposure to nitric acid, formic acid, and sodium hydroxide [15]. The other specific coating products reviewed (i.e. Plasite 4004-5, now Plasite 4100; Plasite 7122; Flakeline 222HT Flakeline 300, and Carboline 195) have specific recommendations against immersion in sodium hydroxide, nitric acid, formic acid, and sodium hypochlorite, but will be suitable for splash/spill service [15, 16, 17]. The remaining coating systems are assumed to behave similarly. Since these coatings should be exposed to a corrosive environment only in the form of spills or leaking fumes, acceptable corrosion resistance is expected.

During a walkdown of several of the concrete structures in July 1995, it was observed that leakage from a caustic feed pump (in the tank storage area, 3rd level, west service corridor of the vitrification building) had run down to the grout base under the pump. The protective coating on the grout (and the rest of the surrounding floor and dike sides) was pulled away from the pump base plate, allowing liquid to seep into the grout / concrete below. This particular observation does not indicate an adverse impact on the concrete structural integrity, since the concrete is alkaline and should not react with caustic. However, similar breaches in the coating might exist at other locations, allowing acid spills to enter the concrete. Periodic inspections should be performed to identify whether other such breaches of the coating have occurred, and determine whether repair is necessary. This will help ensure proper protection of the concrete.

Table 4. Summary of protective measures for chemical service concrete structures

Structure	Protective Measure *	Ref.
RPC Walls		
CDC, REDC, CDMC	1/4 or 3/8 inch thick 304L on floor, 1/4 inch thick 304L walls	7, 18, 19
SPC, CPC, MC	0.1 inch (min.) coating on walls and floor	18, 19
WTC, Canister Exit Transfer Tunnel	0.1 inch (min.) coating on floor, 0.012 inch (min.) coating on walls	18, 19
Laydown Area	1/4 inch thick 304L on floor, 0.1 inch (min.) coating on walls	7, 18, 19
LPPP & LWF Cells	3/8 inch thick 304L plate on floor, 3/8 inch plate up to 18 inches on walls, and 1/4 inch plate above that	10
LPPP & LWF Cell Covers	~~concrete (grout) is contained in a steel box which is coated with radiation service paint~~ none identified, but fumes from the high pH waste streams should not attack the concrete.	~~20~~
Canyon Walls	paint or 0.004 inch (min.) coating is typical for corridors and general personnel areas	18, 19
980-S Dikes	0.1 inch (min.) coating on floor and 4 inch up sides	8
422-S Dikes	0.1 inch (min.) coating **	9, 21
Vit. Bldg. Dikes	0.035 inch (min.) or thicker coating	18, 19
Zone 1 Exhaust Tunnel	0.1 inch (min.) coating on floor, 0.035 inch (min) coating on walls and ceiling	18
Sand Filter	0.035 inch (min.) coating on floor & wainscot	22

* Several candidate coating systems are allowed for the structures listed above [23]. These include specific products from the following generic coating types:

Vinyl ester - 0.1 and 0.035 inch thicknesses
Epoxy - all thicknesses
Polyurethane - 0.035 and 0.012 inch thicknesses
Polyester - 0.012 thickness

** While not located within Building 422-S, the 50% nitric acid portable storage tank is identified as a 422-S structure (ID # S422-010-010-T). The dike for this tank has no protective coating, based on walkdown observations.

Degradation of Radiation Service Concrete

The following degradation mechanisms are specific to radiation service concrete structures:

- Radiation Effects - Radiation exposure can cause decomposition (loss) of water and thermal warming of the concrete. In addition to water loss caused directly by radiation, heating the concrete leads to further water loss. An integrated gamma dose exceeding 10^{10} rads (or an incident energy flux greater than 10^{10} MeV/cm^2-sec) is required for significant damage.

The radiation service concrete structures addressed in this section are:

LWF Cells	GWSB Vault Supports
Remote Process Cell Walls	Sand Filter
Low Point Pump Pit Cells and Cell Covers	Zone 1 Exhaust Tunnel
Canyon Walls	Failed Equipment Storage Vaults

The maximum estimated radiation exposure over the service life of the vitrification building is 7 x 10^9 rads, with the melt cell receiving the highest exposure levels [18, 19]. Exposure levels for the zone 1 exhaust tunnel and sand filter are much lower that this value (3 x 10^7 rads [18, 22]). The estimated exposures for the other concrete structures (LWF cells, LPPP cells and cell covers, GWSB vault supports, and FESV) are also expected to be less than the maximum exposure for the vitrification building, but specific estimates were not identified prior to issuing this report. If the radiation exposures for all the concrete structures listed above are confirmed to be less than 10^{10} rads, then no significant degradation should result from radiation exposure.

While radiation shouldn't damage the concrete directly, damage of the coatings on concrete structures can leave the structure vulnerable to chemical attack. The coatings discussed above should provide resistance for radiation exposures on the order of 5 x 10^9 rad [24]. At about this level, blistering and spalling can occur. With exposure to chemical vapors or elevated temperature, degradation can begin at lower exposures. The melt cell will receive an exposure of about 7 x 10^9 rad, while several other cells will be exposed to 1 - 4 x 10^9 rad [18]. Visual inspection of the coated surfaces in these cells is recommended. If degradation of the coating is noted, rapid cleanup of spills becomes imperative to minimize the time available for liquids to soak into the concrete.

Degradation of Heated Concrete

The following degradation mechanisms are specific to heated concrete structures:

- Elevated Temperature Degradation - Exposure to elevated temperature can lead to the loss of moisture in the cement paste and possible thermal incompatibilities between the paste and aggregate. Degradation is manifested as decreases in the compressive strength and stiffness (modulus of elasticity) of the concrete. The threshold temperature for such degradation is about 95 °C (200 °F).

- Creep - Creep is the time-dependent accumulation of plastic strain under an applied load. Elevated temperatures can increase creep rates. While the deformation caused by creep is not considered in this report, it is noted that creep can cause cracking at the aggregate/cement interface. However, these cracks are usually small and do not significantly affect the concrete properties.

The heated concrete structures addressed in this section are:
GWSB Vault Supports
Failed Equipment Storage Vaults

The GWSB will normally be cooled by a forced air circulation system to maintain temperatures close to ambient. However, these structures have the potential for exposure to elevated temperatures in the event the air circulation system fails for a period of time. The maximum temperature reached will depend on the duration of the cooling air outage. Reference 25 presents preliminary estimates of the GWSB vault roof temperature following such an event, and shows that the lower surface of the vault roof can increase by several hundred degrees Fahrenheit within a few days. (Since this reference is based on preliminary data, specific results are not cited.) The conclusions reached in this report should be reevaluated after qualified temperature estimates are available.

The failed equipment storage vaults are similarly heated by radioactive decay, but they do not have forced circulation cooling. The maximum concrete temperature calculated for the concrete vaults is 153 °F [26].

The degradation of concrete mechanical properties due to elevated temperatures has been reported for Hanford waste tank structures [27]. No significant degradation occurs for temperatures below 200 °F. For higher temperatures, Table 5 summarizes the observed decrease in compressive strength and elastic modulus for concrete with a 28 day compressive strength rating of 3 ksi. Note that the actual compressive strength was much higher than 3 ksi, with a lower confidence band strength of 5.39 ksi at 100 °F. Note also that the instantaneous (0 day) strength and elastic modulus drop with increasing temperature. This drop is related strictly to temperature and should be recovered as the temperature drops. Only that portion of the total decrease associated with time at temperature would not be recovered.

The GWSB vault cover is constructed of precast concrete panels with a concrete topping, while the walls and floor are reinforced concrete [28]. Reference 29 identifies that these two forms of concrete are required to have a minimum compressive strength at 28 days of 5 ksi and 4 ksi, respectively. Given the likelihood that the actual concrete strength is well in excess of the required minimum values, it is not likely that the strength will decrease to a point that will compromise structural margins. The effect of changes in the elastic modulus is less certain. With the relatively large decrease due to high temperature alone, structural margins might be compromised during the time that high temperatures are present. Structural Mechanics should determine whether any structural margins could be compromised as a result of the decrease in elastic modulus at high temperature.

Another high temperature effect to be considered is creep of concrete. This review is nominally restricted to the degradation of material properties, so creep will be left for Structural Mechanics to address. However, it is noted that creep strains on the order of 0.1% or less have been reported for up to 90 days at temperatures up to 300 °F [30].

Table 5. Mechanical properties vs time at temperature (from Reference 27)

		Mechanical Property Value			Change in Value after 7 Days	
Mechanical Property *	Temp. (°F)	Instantaneous Value	Value at 1.8 days	Value at 7 days	Total Change from RT value	Non-recoverable change
Compressive Strength (ksi)	100 (RT)	5390	5390	5390	0 %	0 %
	250	5380	5300	5200	3.5 %	3.3 %
	350	5380	5160	4970	7.8 %	7.6 %
	450	4920	4730	4500	17 %	8.5 %
Elastic Modulus (10^6 psi)	100 (RT)	4.15	4.15	4.15	0 %	0 %
	250	3.82	3.66	3.48	16 %	8.9 %
	350	3.14	2.99	2.80	33 %	11 %
	450	2.47	2.30	2.14	48 %	13 %

* Lower 95% confidence band values are given in this table

Degradation of Steel Structures:

Degradation mechanisms applicable to steel have been described in other reports (13, for example). Given the service conditions likely to be experienced by the steel structures considered in this report, the following degradation mechanisms are considered:

General Corrosion - uniform attack that results in gradual thinning of the material.

Pitting Corrosion - localized attack typically leading to relatively small throughwall holes.

Crevice Corrosion - localized attack at crevice locations due to isolation from the bulk chemistry.

Galvanic corrosion - corrosion of the more active of 2 metals in contact with each other in the presence of an electrolyte.

Low Temperature Embrittlement - a loss of ductility and toughness due to a reduction in temperature below the nil-ductility temperature.

Radiation Embrittlement - a loss of ductility and toughness due to radiation interactions that disrupt the metal lattice structure.

Degradation of General Service Steel:
Of the above degradation mechanisms, general service steel structures are potentially susceptible to general corrosion, galvanic corrosion, and low temperature embrittlement. All of the identified steel structures are considered susceptible to the degradation mechanisms for general service steel. Those structures that are not exposed to a severe operating environment (chemical or radiation) are:

Vitrification Building (part of roof structure)
Melt Cell Crane Rails and Superstructure
LWF Crane Rails and Superstructure
LPPP Process Cell Crane Rails and Superstructure
Zone 1 Exhaust Tunnel (steel portion downstream of the sand filter)
Fan House Crane Rails and Superstructure
422-S Superstructures

General corrosion rates of carbon steel in ambient atmospheric conditions can vary widely. References 31 and 32 report corrosion rates ranging from less than 0.2 mil/year to about 3 mil/year at a number of locations throughout the United States and Great Britain. Additional values above and below this range are possible depending on moisture and pollutant levels [33]. However, the higher corrosion rates generally occur in heavily industrialized areas and would not be expected from atmospheric exposure at the Savannah River Site. For carbon steel that is provided with a protective coating (paint, polymer, etc.), essentially no corrosion should occur unless that coating is damaged. Once damaged, a corrosion rate of 1 to 2 mil/year is considered reasonable for unprotected areas. In general, the above steel structures have a protective coat and should be inspected periodically to ensure the coating is intact. The zone 1 exhaust tunnel has an epoxy coating over latex and zinc primer coats. The epoxy has blisters (not broken open), but the underlying layers are intact [34]. Continued monitoring per reference 34 is recommended. The crane rails would typically not be coated, but light oxidation of the crane rails should not impair their operability or structural integrity.

Galvanic corrosion will only occur is the steel structure is in contact with another type of metal. The required electrolyte could be provided by condensation or other moisture sources. If a review of the structures identifies that no non-steel metal parts (bolts, connector plates, wires, etc.) are in contact with the steel structures, then galvanic corrosion cannot occur.

The possibility of low temperature embrittlement was considered in reference 33 for the organic waste storage tank outer shell. For temperatures as low as 0 °F, a lower bound fracture toughness (K_{IC}) of 42 ksi$\sqrt{\text{in}}$, and stress of 30 ksi, the critical flaw length (2a) required for sudden fracture from a throughwall flaw is given by:

$$2a = 2\,(K_{IC} / \sigma_y)^2 / \pi = 1.25 \text{ inch}$$

The use of more realistic fracture toughness values as described in reference 33 (i. e., above 100 $\text{ksi}\sqrt{\text{in}}$) increases the critical flaw length to 7 inches or greater. For flaws that are only part-throughwall, even greater lengths are required for sudden failure.

Only those portions of the steel structures that are outside ambient air temperature would be subject to low temperature embrittlement. This would be primarily limited to steel beams in the roof of the vitrification building. These beams will also be partially warmed by heat from inside the building conducting through the roof. It is unlikely that the structural steel beams would contain cracks of the size calculated above. It is possible that weld defects such as lack of fusion could exist that would approximate a part-throughwall crack. However, proper fabrication and inspection practices should minimize the likelihood of their existence. Since only limited portions of the beams would be exposed to low temperatures and it is unlikely that flaws approaching the critical flaw length exist, low temperature embrittlement is not considered likely.

Degradation of Chemical / Radiation Service Steel:
The following steel structures are potentially exposed to a corrosive chemical environment and high radiation levels:
SPC/CPC Removable Wall
Canyon Cell Covers
GWSB Canister Supports

Structures such as crane rails and superstructures will be exposed to radiation fields during periods when the cell covers are removed. However, these periods should be short compared to the time that the cell covers are in place, providing some degree of shielding from the radiation sources. Therefore, radiation damage to these structures will not be significant.

The structures listed above are potentially exposed to corrosive chemicals and significant radiation levels. Radiation levels in the various process cells range from 7×10^8 to 7×10^9 rad lifetime exposure[18].

In the waste tanks, over 99% of the radiation damage to the tank walls is from gammas with 0.66 MeV energy or greater [35]. While some changes in nuclide concentrations will occur as the waste is processed, this gamma energy will provide a bounding estimate of the radiation damage to the steel structures. Assuming that all gammas contributing to the 7×10^9 rad dose have this lower bound energy gives a conservative estimate of the total number of gammas interacting with the steel structures:

$$\begin{aligned} S &= (7 \times 10^9 \text{ rad}) \, [(100 \text{ erg/g})/\text{rad}] \, (6.24 \times 10^5 \text{ MeV/erg}) \, (7.9 \text{ g/cm}^3) \, / \, (0.66 \text{ MeV}/\gamma) \\ &= 5.2 \times 10^{18} \, \gamma/\text{cm}^3 \end{aligned}$$

The damage caused by this gamma source term is calculated using the gamma interaction cross section for iron. Since the cross section is energy dependent (its value increases with gamma energy), an upper bound cross section of 0.011 barn/electron (corresponding to a gamma energy of 2.2 MeV) is assumed for all gammas. Therefore, the damage is:

$$\begin{aligned} \text{Damage} &= [5.2 \times 10^{18} \, \gamma/\text{cm}^3 / \, 2(0.4 \text{ cm}^2/\text{g})] \, (0.011 \text{ barn}/e^-) \, (26 \, e^-/\text{Fe atom}) \, (10^{-24} \text{ cm}^2/\text{barn}) \\ &= 1.8 \times 10^{-6} \text{ dpa} \end{aligned}$$

Reference 35 identifies that carbon steels do not experience any significant degradation at radiation levels of 1×10^{-5} dpa or less. Accordingly, the canyon cell covers and SPC/CPC removable wall will not experience any significant radiation degradation.

The estimated radiation level for the GWSB canister supports was not available prior to issuing this report. This value should be identified. If the radiation exposure for the canister supports exceeds 4×10^{10} rads, additional evaluation might be warranted. If it is less than this value, no significant degradation should occur from radiation exposure.

The possibility of chemical attack exists for the SPC/CPC removable wall, and the canyon cell covers. The process vessel vent system maintains a vacuum in process equipment relative to the canyon cells in order to limit leakage of vapors to the cells. In the event that spills or leakage do release corrosive liquids or vapors to the cells, the zone 1 ventilation system provides fresh air ventilation to these areas to prevent the buildup of vapors. Corrosive species that might be released include water vapor, mercury, and formic acid. Similar to the concrete structures, these steel structures also have protective coatings. Periodic inspection to verify that the coatings are intact are recommended.

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Technical Review: 9/20/95

APPENDIX 8

DWPF & IDMS NEGATIVE NUMBERS

APPENDIX 8

DWPF & IDMS Negative Numbers

Date	Negative Number		Description (specific)
Aug-95	WSRC-FM- 95-0009	1	IDMS
Aug-95	WSRC-FM- 95-0009	2	IDMS
Aug-95	WSRC-FM- 95-0009	3	IDMS
Aug-95	WSRC-FM- 95-0009	4	IDMS
Aug-95	WSRC-FM- 95-0009	5	IDMS Off-Gas Line
Aug-95	WSRC-FM- 95-0009	6	IDMS QUENCHER OUTLET
Aug-95	WSRC-FM- 95-0009	7	STACK (1/1)
Aug-95	WSRC-FM- 95-0009	8	STACK (1/1)
Aug-95	WSRC-FM- 95-0009	9	OFF-GAS CONDENSER DRAIN (1/1)
Aug-95	WSRC-FM- 95-0009	10	OFF-GAS CONDENSER DRAIN (1/1)
Aug-95	WSRC-FM- 95-0009	11	SAS DRAIN (1/1)
Aug-95	WSRC-FM- 95-0009	12	SAS DRAIN (1/1)
Aug-95	WSRC-FM- 95-0009	13	HEME OUTLET (1/1)
Aug-95	WSRC-FM- 95-0009	14	IDMS MELT POOL THERMOWELL (Alumina insulator before removal with hammer)
Aug-95	WSRC-FM- 95-0009	15	IDMS MELT POOL THERMOWELL (Alumina insulator before removal with hammer)
Aug-95	WSRC-FM- 95-0009	16	IDMS MELT POOL THERMOWELL (Alumina insulator after removal with hammer)
Aug-95	WSRC-FM- 95-0009	17	IDMS MELT POOL THERMOWELL (Alumina insulator after removal with hammer)
Aug-95	WSRC-FM- 95-0009	18	IDMS MELT POOL THERMOWELL (Alumina insulator after removal with hammer)
Aug-95	WSRC-FM- 95-0009	19	IDMS MELT POOL THERMOWELL (under alumina insulator)
Aug-95	WSRC-FM- 95-0009	20	IDMS MELT POOL THERMOWELL (under alumina insulator)
Aug-95	WSRC-FM- 95-0009	21	IDMS QUENCHER (INLET)
Aug-95	WSRC-FM- 95-0009	22	IDMS QUENCHER (INLET) fuzzy
Aug-95	WSRC-FM- 95-0009	23	IDMS QUENCHER (INLET)
Aug-95	WSRC-FM- 95-0009	24	IDMS QUENCHER (OUTLET)
Aug-95	WSRC-FM- 95-0009	25	IDMS Quencher Outlet (looking back up at nozzle)
Aug-95	WSRC-FM- 95-0009	26	IDMS Quencher Outlet (looking back up at nozzle)
Aug-95	WSRC-FM- 95-0009	27	HEPA INLET (1/1)
Aug-95	WSRC-FM- 95-0009	28	HEPA INLET (1/1)
Aug-95	WSRC-FM- 95-0009	29	HEME INLET (1/1)
Aug-95	WSRC-FM- 95-0009	30	HEME INLET (1/1)
Aug-95	WSRC-FM- 95-0009	31	HEME INLET (1/1)
Aug-95	WSRC-FM- 95-0009	32	Stainless Steel Melt MTS WR 95-15
Aug-95	WSRC-FM- 95-0009	33	Stainless Steel Melt MTS WR 95-15
Aug-95	WSRC-FM- 95-0009	34	Stainless Steel Melt MTS WR 95-15
Aug-95	WSRC-FM- 95-0009	35	Stainless Steel Melt MTS WR 95-15
Aug-95	WSRC-FM- 95-0009	36	IDMS CAMERA PORT COUPON RACK (rack only)
Aug-95	WSRC-FM- 95-0009	37	IDMS CAMERA PORT COUPON RACK (rack only)
Jul-95	WSRC-FM- 95-0008	1	IDMS - Melter Drain Valve before removal of glass (bottom of melter looking up)
Jul-95	WSRC-FM- 95-0008	2	IDMS - Melter Drain Valve
Jul-95	WSRC-FM- 95-0008	3	IDMS - Melter Drain Valve before removal of glass (bottom of melter looking up)
Jul-95	WSRC-FM- 95-0008	4	IDMS - Vent Line, Original Film Cooler, & Replacement Film Cooler
Jul-95	WSRC-FM- 95-0008	5	IDMS - Original Film Cooler
Jul-95	WSRC-FM- 95-0008	6	IDMS - Original Film Cooler
Jul-95	WSRC-FM- 95-0008	7	IDMS - Replacement Film Cooler
Jul-95	WSRC-FM- 95-0008	8	IDMS - Vent Line
Jul-95	WSRC-FM- 95-0008	9	IDMS - Vent Line, Original Film Cooler, & Replacement Film Cooler
Jul-95	WSRC-FM- 95-0008	10	IDMS - Original Film Cooler
Jul-95	WSRC-FM- 95-0008	11	IDMS - Original Film Cooler
Jul-95	WSRC-FM- 95-0008	12	IDMS - Original Film Cooler
Jul-95	WSRC-FM- 95-0008	13	IDMS - Vent Line
Jul-95	WSRC-FM- 95-0008	14	IDMS - Vent Line (looking up pipe at obstructions)
Jul-95	WSRC-FM- 95-0008	15	IDMS - Vent Line (looking up pipe at obstructions)
Jul-95	WSRC-FM- 95-0008	16	IDMS - Feed Tube
Jul-95	WSRC-FM- 95-0008	17	IDMS - Feed Tube
Jul-95	WSRC-FM- 95-0008	18	IDMS - Feed Tube (Crack just below alumina insulator)
Jul-95	WSRC-FM- 95-0008	19	IDMS - Feed Tube (Crack just below alumina insulator)
Jul-95	WSRC-FM- 95-0008	20	IDMS - Feed Tube (Crack just below alumina insulator)
Jul-95	WSRC-FM- 95-0008	21	IDMS - Feed Tube (Crack just below alumina insulator)
Jul-95	WSRC-FM- 95-0008	22	IDMS - Feed Tube (Tip)

Date	Negative Number		Description (specific)
Jul-95	WSRC-FM- 95-0008	23	IDMS - Feed Tube (Tip)
Jul-95	WSRC-FM- 95-0008	24	IDMS - Feed Tube (Tip)
Jul-95	WSRC-FM- 95-0008	25	IDMS - Borescope
Jul-95	WSRC-FM- 95-0008	26	IDMS - Borescope
Jul-95	WSRC-FM- 95-0008	27	IDMS - Melter Drain Valve before removal of glass (bottom of melter looking up)
Jul-95	WSRC-FM- 95-0008	28	IDMS - Melter Drain Valve before removal of glass (bottom of melter looking up)
Jul-95	WSRC-FM- 95-0008	29	IDMS - Melter Drain Valve before removal of glass (bottom of melter looking up)
Jul-95	WSRC-FM- 95-0032	1	CIRCUIT BOARD MELT TEST MATERIALS LAB WR #95-14
Jul-95	WSRC-FM- 95-0032	2	CIRCUIT BOARD MELT TEST MATERIALS LAB WR #95-14
Jul-95	WSRC-FM- 95-0032	3	CIRCUIT BOARD MELT TEST MATERIALS LAB WR #95-14
Jul-95	WSRC-FM- 95-0032	4	CIRCUIT BOARD MELT TEST MATERIALS LAB WR #95-14
Jul-95	WSRC-FM- 95-0032	5	CIRCUIT BOARD MELT TEST MATERIALS LAB WR #95-14
Jul-95	WSRC-FM- 95-0032	6	MISC. DOD ELECTRONIC COMPONENTS
Jul-95	WSRC-FM- 95-0032	7	MISC. DOD ELECTRONIC COMPONENTS
Jul-95	WSRC-FM- 95-0032	8	MISC. DOD ELECTRONIC COMPONENTS
Jul-95	WSRC-FM- 95-0032	9	MISC. DOD ELECTRONIC COMPONENTS
Jul-95	WSRC-FM- 95-0032	10	IDMS Melter Lid Heaters and Upper Electrodes (before cleaning)
Jul-95	WSRC-FM- 95-0032	*11*	*IDMS Melter Lid Heaters (penetration into refractory)*
Jul-95	WSRC-FM- 95-0032	12	IDMS Melter Upper Electrodes and Melter Bottom (fuzzy)
Jul-95	WSRC-FM- 95-0032	13	IDMS Melter Lid Heaters (penetration into refractory)
Jul-95	WSRC-FM- 95-0032	14	IDMS Camera Port Corrosion Rack (necking of rack beneath I 625 coupon)
Jul-95	WSRC-FM- 95-0032	15	IDMS Camera Port Corrosion Rack ST6BLC 5 VAPOR SPACE
Jul-95	WSRC-FM- 95-0032	16	IDMS Camera Port Corrosion Rack ST6BLC 5 VAPOR SPACE
Jul-95	WSRC-FM- 95-0032	17	IDMS Melter Refractory (prior to cleaning)
Jul-95	WSRC-FM- 95-0032	18	IDMS Melter Lid Heaters
Jul-95	WSRC-FM- 95-0032	19	IDMS Melter Upper Electrodes and Melter Bottom
Jul-95	WSRC-FM- 95-0032	20	IDMS Melter Lid Heaters
Jul-95	WSRC-FM- 95-0032	21	IDMS Melter Upper Electrodes and Melter Bottom
Jul-95	WSRC-FM- 95-0032	22	IDMS Melter Upper Electrodes and Melter Bottom
Jul-95	WSRC-FM- 95-0051	1	IDMS Level Probe
Jul-95	WSRC-FM- 95-0051	2	IDMS Level Probe
Jul-95	WSRC-FM- 95-0051	3	IDMS Thermowell - Melt Pool
Jul-95	WSRC-FM- 95-0051	4	IDMS Thermowell - Melt Pool
Jul-95	WSRC-FM- 95-0051	5	IDMS Level Probe
Jul-95	WSRC-FM- 95-0051	6	IDMS Vapor Space Thermowell in Melter Lid
Jul-95	WSRC-FM- 95-0051	7	IDMS Vapor Space Thermowell in Melter Lid
Jul-95	WSRC-FM- 95-0051	8	IDMS Vapor Space Thermowell in Melter Lid
Jul-95	WSRC-FM- 95-0051	9	IDMS Thermowell - Melt Pool
Jul-95	WSRC-FM- 95-0051	10	IDMS Level Probe & Melt Pool Thermowell
Jul-95	WSRC-FM- 95-0051	11	IDMS Lid Heaters
Jul-95	WSRC-FM- 95-0051	12	Feed Tube
Jul-95	WSRC-FM- 95-0051	13	IDMS Vapor Space Thermowell in Melter Lid
Jul-95	WSRC-FM- 95-0051	14	Off Gas Vent Line
Jul-95	WSRC-FM- 95-0051	15	IDMS Film Cooler & Vent Line
Jul-95	WSRC-FM- 95-0051	16	General 700-A Area
Jul-95	WSRC-FM- 95-0051	17	General 700-A Area
Jul-95	WSRC-FM- 95-0051	18	General 700-A Area
Jul-95	WSRC-FM- 95-0051	19	IDMS Film Cooler & Coupons
Jul-95	WSRC-FM- 95-0051	20	IDMS Film Cooler & Coupons
Jul-95	WSRC-FM- 95-0051	21	IDMS Film Cooler & Coupons
Jul-95	WSRC-FM- 95-0051	22	Off Gas Vent Line
Jul-95	WSRC-FM- 95-0051	23	Off Gas Vent Line
Jul-95	WSRC-FM- 95-0051	24	IDMS Thermowell Melt Pool
Jul-95	WSRC-FM- 95-0051	25	IDMS Melt Pool Thermowell & Level Probe (Flange Ends)
Jul-95	WSRC-FM- 95-0051	26	IDMS Camera Port - Splash Zone Coupons
Jul-95	WSRC-FM- 95-0051	27	IDMS Lid Heaters
Jul-95	WSRC-FM- 95-0051	28	IDMS Off Gas Vent Line - IDMS Film Cooler
Jul-95	WSRC-FM- 95-0051	29	IDMS Film Cooler & Coupons

Date	Negative Number		Description (specific)
Jul-95	WSRC-FM- 95-0051	30	IDMS Camera Port - Vapor Space Coupons
Jul-95	WSRC-FM- 95-0051	31	IDMS Camera Port - Splash Zone Coupons
Jul-95	WSRC-FM- 95-0051	32	IDMS Camera Port - Vapor Space Coupons
Jul-95	WSRC-FM- 95-0051	33	IDMS Camera Port Coupon Rack (Entire Rack)
Jul-95	WSRC-FM- 95-0051	34	IDMS Camera Port - Splash Zone Coupons
Jul-95	WSRC-FM- 95-0051	35	IDMS Camera Port - Vapor Space Coupons
Jul-95	WSRC-FM- 95-0051	36	IDMS Lid Heaters
Jul-95	WSRC-FM- 95-0051	37	IDMS Lid Heaters
Jul-95	WSRC-FM- 95-0051	38	IDMS Lid Heaters
Jul-95	WSRC-FM- 95-0051	39	IDMS Electrodes and Lid Heaters
Jul-95	WSRC-FM- 95-1521	1	IDMS Camera Port Vapor Space
Jul-95	WSRC-FM- 95-1521	2	IDMS Camera Port Vapor Space
Jul-95	WSRC-FM- 95-1521	3	IDMS Camera Port Splash Zone
Jul-95	WSRC-FM- 95-1521	4	IDMS Camera Port Splash Zone
Jul-95	WSRC-FM- 95-1521	5	IDMS Film Cooler
Jul-95	WSRC-FM- 95-1521	6	Unknown
Jul-95	WSRC-FM- 95-1521	7	IDMS Quencher Outlet
Jul-95	WSRC-FM- 95-1521	8	IDMS Quencher Outlet
Jul-95	WSRC-FM- 95-1521	9	IDMS Quencher Inlet
Jul-95	WSRC-FM- 95-1521	10	IDMS Quencher Inlet
Jul-95	WSRC-FM- 95-1521	11	IDMS Vapor Space - Splash Zone
Jul-95	WSRC-FM- 95-1521	12	IDMS Vapor Space - Splash Zone
Jul-95	WSRC-FM- 95-1521	13	IDMS Camera Port Coupon Rack
Sep-95	WSRC-FM- 95-0044	1	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	2	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	3	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	4	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	5	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	6	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	7	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	8	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	9	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	10	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	11	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	12	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	13	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	14	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	15	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	16	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	17	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	18	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	19	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	20	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	21	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	22	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	23	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	24	DWPF SME COIL
Sep-95	WSRC-FM- 95-0044	25	DWPF SME Condenser to SMECT Jumper
Sep-95	WSRC-FM- 95-0044	26	DWPF SME Condenser to SMECT Jumper
Sep-95	WSRC-FM- 95-0044	27	DWPF SME Condenser to SMECT Jumper
Sep-95	WSRC-FM- 95-0044	28	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	29	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	30	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	31	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	32	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	33	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	34	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	35	DWPF SME Coil

DWPF & IDMS Negative Numbers

Date	Negative Number		Description (specific)
Sep-95	WSRC-FM- 95-0044	36	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	37	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	38	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	39	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	40	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	41	DWPF SME Coil
Sep-95	WSRC-FM- 95-0044	42	DWPF SMECT Dip Leg Jumper
Sep-95	WSRC-FM- 95-0044	43	DWPF SMECT Dip Leg Jumper
Sep-95	WSRC-FM- 95-0044	44	DWPF SMECT Dip Leg Jumper
Sep-95	WSRC-FM- 95-0044	45	DWPF SMECT Dip Leg Jumper
Sep-95	WSRC-FM- 95-0044	46	DWPF SMECT Dip Leg Jumper
Sep-95	WSRC-FM- 95-0044	47	DWPF SMECT Dip Leg Jumper
Sep-95	WSRC-FM- 95-0044	48	DWPF SMECT Dip Leg Jumper
Mar-95	WSRC-FM- 95-0050	1	DWPF MELTER Borescope Outer Housing
Mar-95	WSRC-FM- 95-0050	2	DWPF MELTER Borescope Outer Housing and Orifice
Mar-95	WSRC-FM- 95-0050	3	DWPF MELTER Borescope Orifice
Mar-95	WSRC-FM- 95-0050	4	DWPF MELTER Borescope Orifice
Mar-95	WSRC-FM- 95-0050	5	DWPF MELTER Borescope Orifice Outer Housing Large Pit (Side View)
Mar-95	WSRC-FM- 95-0050	6	DWPF MELTER Borescope
Mar-95	WSRC-FM- 95-0050	7	DWPF MELTER Borescope Outer Housing Cut
Mar-95	WSRC-FM- 95-0050	8	DWPF MELTER Borescope Orifice
Mar-95	WSRC-FM- 95-0050	9	DWPF MELTER Borescope Orifice
Mar-95	WSRC-FM- 95-0050	10	DWPF MELTER Borescope Orifice
Mar-95	WSRC-FM- 95-0050	11	DWPF MELTER Borescope Orifice
Mar-95	WSRC-FM- 95-0050	12	DWPF MELTER Borescope Orifice (Looking Straight At Orifice)
Mar-95	WSRC-FM- 95-0050	13	DWPF MELTER Borescope Orifice
Mar-95	WSRC-FM- 95-0050	14	DWPF MELTER Borescope Orifice
Mar-95	WSRC-FM- 95-0050	15	DWPF MELTER Borescope Outer Housing and Orifice
Mar-95	WSRC-FM- 95-0050	16	DWPF MELTER Borescope Outer Housing
Mar-95	WSRC-FM- 95-0050	17	DWPF MELTER Borescope Outer Housing and Orifice (cut)
Mar-95	WSRC-FM- 95-0050	18	DWPF MELTER Borescope Orifice
Mar-95	WSRC-FM- 95-0050	19	DWPF MELTER Borescope Orifice
Mar-95	WSRC-FM- 95-0050	20	DWPF MELTER Borescope Outer Housing
Mar-95	WSRC-FM- 95-0050	21	DWPF MELTER Borescope Outer Housing
Mar-95	WSRC-FM- 95-0050	22	DWPF MELTER Borescope Outer Housing
Mar-95	WSRC-FM- 95-0050	23	DWPF MELTER Borescope Outer Housing
Mar-95	WSRC-FM- 95-0050	24	DWPF MELTER Borescope Outer Housing
Mar-95	WSRC-FM- 95-0050	25	DWPF MELTER Borescope Outer Housing
Mar-95	WSRC-FM- 95-0050	26	DWPF MELTER Borescope Camera Housing (blurry)
Mar-95	WSRC-FM- 95-0050	27	DWPF MELTER Borescope Outer Housing 25A
Mar-95	WSRC-FM- 95-0050	28	DWPF MELTER Borescope Outer Housing 26A
Mar-95	WSRC-FM- 95-0050	29	DWPF MELTER Borescope Outer Housing
Mar-95	WSRC-FM- 95-0050	30	DWPF MELTER Borescope Outer Housing
Mar-95	WSRC-FM- 95-0050	31	DWPF MELTER Borescope Outer Housing 26A
Mar-95	WSRC-FM- 95-0050	32	DWPF MELTER Borescope Outer Housing
Mar-95	WSRC-FM- 95-0050	33	DWPF MELTER Borescope Outer Housing
Mar-95	WSRC-FM- 95-0050	34	DWPF MELTER Borescope Outer Housing 25A
Mar-95	WSRC-FM- 95-0050	35	DWPF MELTER Borescope Outer Housing 26A
Mar-95	WSRC-FM- 95-0050	36	DWPF MELTER Borescope Outer Housing - New
Mar-95	WSRC-FM- 95-0050	37	DWPF MELTER Borescope Outer Housing - New
Mar-95	WSRC-FM- 95-0050	38	DWPF MELTER Borescope Outer Housing - New
Mar-95	WSRC-FM- 95-0050	39	DWPF MELTER Borescope
Mar-95	WSRC-FM- 95-0050	40	DWPF MELTER Borescope Outer Housing 25A
Mar-95	WSRC-FM- 95-0050	41	DWPF MELTER Borescope Outer Housing 25A
Mar-95	WSRC-FM- 95-0050	42	DWPF MELTER Borescope Outer Housing 25A
Mar-95	WSRC-FM- 95-0050	43	DWPF MELTER Borescope Outer Housing 25A
Mar-95	WSRC-FM- 95-0050	44	DWPF MELTER Borescope Outer Housing 25A
Mar-95	WSRC-FM- 95-0050	45	DWPF MELTER Borescope Camera Assembly 26 A (Close Up)
Mar-95	WSRC-FM- 95-0050	46	DWPF MELTER Borescope Camera Assembly

DWPF & IDMS Negative Numbers

Date	Negative Number		Description (specific)
Mar-95	WSRC-FM- 95-0050	47	DWPF MELTER Borescope Camera Assembly 26A
Mar-95	WSRC-FM- 95-0050	48	DWPF MELTER Borescope Camera Assembly 26A (Overall)
Mar-95	WSRC-FM- 95-0050	49	DWPF MELTER Borescope Outer Housing
Mar-95	WSRC-FM- 95-0050	50	DWPF MELTER Borescope Cross-Section Outer Housing
Mar-95	WSRC-FM- 95-0050	51	DWPF MELTER Borescope Camera Assembly 26A
Mar-95	WSRC-FM- 95-0050	52	DWPF MELTER Borescope Camera Assembly
Mar-95	WSRC-FM- 95-0050	53	DWPF MELTER Borescope Outer Housing 26A
Mar-95	WSRC-FM- 95-0050	54	DWPF MELTER Borescope Outer Housing
Mar-95	WSRC-FM- 95-0050	55	DWPF MELTER Borescope Outer Housing - Orifice
Mar-95	WSRC-FM- 95-0050	56	DWPF MELTER Borescope Outer Housing 26A
Mar-95	WSRC-FM- 95-0050	57	DWPF MELTER Borescope Outer Housing
Mar-95	WSRC-FM- 95-0050	58	DWPF MELTER Borescope Outer Housing 26A
Mar-95	WSRC-FM- 95-0050	59	DWPF MELTER Borescope Outer Housing
Mar-95	WSRC-FM- 95-0050	60	DWPF MELTER Borescope Outer Housing
Mar-95	WSRC-FM- 95-0050	61	DWPF MELTER Borescope Outer Housing
Mar-95	WSRC-FM- 95-0050	62	DWPF MELTER Borescope Outer Housing
Mar-95	WSRC-FM- 95-0050	63	DWPF MELTER Borescope Outer Housing 26A (Overall)
Mar-95	WSRC-FM- 95-0050	64	DWPF MELTER Borescope Outer Housing
Mar-95	WSRC-FM- 95-0050	65	DWPF MELTER Borescope Outer Housing
Apr-95	WSRC-FM- 95-0049	1	DWPF Facility
Apr-95	WSRC-FM- 95-0049	2	DWPF Primary Off Gas Film Cooler
Apr-95	WSRC-FM- 95-0049	3	DWPF Primary Off Gas Film Cooler
Apr-95	WSRC-FM- 95-0049	4	DWPF Primary Off Gas Film Cooler
Apr-95	WSRC-FM- 95-0049	5	DWPF Primary Off Gas Film Cooler
Apr-95	WSRC-FM- 95-0049	6	DWPF Primary Off Gas Film Cooler
Apr-95	WSRC-FM- 95-0049	7	
Apr-95	WSRC-FM- 95-0049	8	DWPF Primary Off Gas Film Cooler Brush
Apr-95	WSRC-FM- 95-0049	9	DWPF Outside of Building
Apr-95	WSRC-FM- 95-0049	10	DWPF Primary Off Gas Line
Apr-95	WSRC-FM- 95-0049	11	DWPF Primary Off Gas Film Cooler
Apr-95	WSRC-FM- 95-0049	12	DWPF Primary Off Gas Film Cooler
Apr-95	WSRC-FM- 95-0049	13	DWPF Primary Off Gas Film Cooler
Apr-95	WSRC-FM- 95-0049	14	DWPF Primary Off Gas Film Cooler
Apr-95	WSRC-FM- 95-0049	15	DWPF Primary Off Gas Line
Apr-95	WSRC-FM- 95-0049	16	DWPF Primary Off Gas System
Apr-95	WSRC-FM- 95-0049	17	DWPF Primary Off Gas Film Cooler Brush
Apr-95	WSRC-FM- 95-0049	18	DWPF Primary Off Gas Film Cooler Brush
Apr-95	WSRC-FM- 95-0049	19	Unknown
Apr-95	WSRC-FM- 95-0049	20	DWPF Primary Off Gas Film Cooler Brush
Apr-95	WSRC-FM- 95-0049	21	DWPF Primary Off Gas Film Cooler Brush
Apr-95	WSRC-FM- 95-0049	22	DWPF Primary Off Gas Film Cooler Brush
Apr-95	WSRC-FM- 95-0049	23	DWPF Primary Film Cooler Brush
Apr-95	WSRC-FM- 95-0049	24	DWPF Primary Film Cooler Brush
Apr-95	WSRC-FM- 95-0049	25	DWPF Primary Film Cooler Brush
Apr-95	WSRC-FM- 95-0049	26	DWPF Primary Film Cooler Brush
Apr-95	WSRC-FM- 95-0049	27	DWPF Primary Film Cooler Brush
Apr-95	WSRC-FM- 95-0049	28	DWPF Primary Film Cooler Brush
Apr-95	WSRC-FM- 95-0049	29	DWPF Level Probe (Dip Tube Bubbler)
Apr-95	WSRC-FM- 95-0049	30	DWPF Primary Off Gas Line, Film Cooler Brush Side
Apr-95	WSRC-FM- 95-0049	31	DWPF Primary Off Gas Line, Pits just above 90 degree elbow
Apr-95	WSRC-FM- 95-0049	32	DWPF Primary Off Gas Line
Apr-95	WSRC-FM- 95-0049	33	DWPF Primary Off Gas Line Film Cooler Brush End
Apr-95	WSRC-FM- 95-0049	34	DWPF Primary Off Gas Line
Apr-95	WSRC-FM- 95-0049	35	DWPF Primary Off Gas Line, Exit just past CW7M Isolation Valve
Apr-95	WSRC-FM- 95-0049	36	DWPF Primary Off Gas Line, Exit just past isolation valve
Apr-95	WSRC-FM- 95-0049	37	DWPF Primary Off Gas Line, Exit just past CW7M Isolation Valve
Apr-95	WSRC-FM- 95-0049	38	DWPF Primary Off Gas Line, Outlet just past CW7M Isolation Valve
Apr-95	WSRC-FM- 95-0049	39	DWPF Primary Off Gas Line, Outlet just past CW7M Isolation Valve
Apr-95	WSRC-FM- 95-0049	40	DWPF Primary Off Gas Line CW7M Isolation Valve

DWPF & IDMS Negative Numbers

Date	Negative Number	Description (specific)
Apr-95	WSRC-FM- 95-0049 41	DWPF Primary Off Gas Line, Deposits at inlet, taken through Film Cooler Flange
Apr-95	WSRC-FM- 95-0049 42	DWPF Primary Off Gas Line, Deposits at inlet, taken through Film Cooler Flange
Apr-95	WSRC-FM- 95-0049 43	DWPF Primary Off Gas Film Cooler
Apr-95	WSRC-FM- 95-0049 44	DWPF Primary Off Gas Film Cooler
Apr-95	WSRC-FM- 95-0049 45	DWPF Primary Off Gas Line, Film Cooler Brush Flange
Apr-95	WSRC-FM- 95-0049 46	DWPF Primary Off Gas Line, From Film Cooler Brush Entrance
Apr-95	WSRC-FM- 95-0049 47	DWPF Primary Off Gas Line, taken through Film Cooler Brush Flange
Apr-95	WSRC-FM- 95-0049 48	DWPF Primary Off Gas Film Cooler
Apr-95	WSRC-FM- 95-0049 49	DWPF Primary Off Gas Film Cooler
Apr-95	WSRC-FM- 95-0049 50	DWPF Primary Off Gas Film Cooler
Apr-95	WSRC-FM- 95-0049 51	DWPF Isolation Valve Backup Off Gas Line
Apr-95	WSRC-FM- 95-0049 52	DWPF Melter
Apr-95	WSRC-FM- 95-0049 53	DWPF Primary Off Gas Line
Apr-95	WSRC-FM- 95-0049 54	DWPF Backup Off Gas Line (Film Cooler Brush Flange)
Apr-95	WSRC-FM- 95-0049 55	DWPF Backup Off Gas Line (Film Cooler Brush Flange)
Apr-95	WSRC-FM- 95-0049 56	DWPF Backup Film Cooler (Film Cooler Brush Flange)
Apr-95	WSRC-FM- 95-0049 57	DWPF Backup Off Gas Line (Film Cooler Brush Flange)
Apr-95	WSRC-FM- 95-0049 58	DWPF Backup Off Gas Line
Apr-95	WSRC-FM- 95-0049 59	DWPF Melter
Apr-95	WSRC-FM- 95-0049 60	DWPF Backup Film Cooler Brush
Apr-95	WSRC-FM- 95-0049 61	DWPF Backup Film Cooler Brush
Apr-95	WSRC-FM- 95-0049 62	DWPF Backup Film Cooler Brush
Apr-95	WSRC-FM- 95-0049 63	DWPF Primary Off Gas Line
Apr-95	WSRC-FM- 95-0049 64	DWPF Backup Film Cooler
Apr-95	WSRC-FM- 95-0049 65	DWPF Backup Film Cooler
Apr-95	WSRC-FM- 95-0049 66	DWPF Backup Film Cooler
Apr-95	WSRC-FM- 95-0049 67	DWPF Backup Film Cooler
Apr-95	WSRC-FM- 95-0049 68	DWPF Backup Film Cooler
Apr-95	WSRC-FM- 95-0049 69	DWPF Backup Film Cooler
Apr-95	WSRC-FM- 95-0049 70	DWPF Isolation Valve Backup Off Gas Line
Apr-95	WSRC-FM- 95-0049 71	DWPF Backup Off Gas Line Isolation Valve
Apr-95	WSRC-FM- 95-0049 72	DWPF Backup Off Gas Line Exit Just past isolation valve
Apr-95	WSRC-FM- 95-0049 73	DWPF Backup Off Gas Line Exit Just Below Isolation Valve
Apr-95	WSRC-FM- 95-0049 74	DWPF Backup Off Gas Line
Apr-95	WSRC-FM- 95-0049 75	DWPF Backup Film Cooler
Apr-95	WSRC-FM- 95-0049 76	DWPF Melter Feed Tube A
Apr-95	WSRC-FM- 95-0049 77	DWPF Melter Feed Tube A
Apr-95	WSRC-FM- 95-0049 78	DWPF Melter Feed Tube A
Apr-95	WSRC-FM- 95-0049 79	DWPF Melter Feed Tube A
Apr-95	WSRC-FM- 95-0049 80	DWPF Melter Feed Tube B
Apr-95	WSRC-FM- 95-0049 81	DWPF Melter Feed Tube B
Apr-95	WSRC-FM- 95-0049 82	DWPF Melter Feed Tube B
Apr-95	WSRC-FM- 95-0049 83	DWPF Melter Feed Tube B
Apr-95	WSRC-FM- 95-0049 84	Unknown
Apr-95	WSRC-FM- 95-0049 85	DWPF Melter Side Thermowell
Apr-95	WSRC-FM- 95-0049 86	DWPF Melter Side Thermowell
Apr-95	WSRC-FM- 95-0049 87	DWPF Melter Side Thermowell
Apr-95	WSRC-FM- 95-0049 88	DWPF Melter Side Thermowell
Apr-95	WSRC-FM- 95-0049 89	DWPF Melter Thermowell (Center)
Apr-95	WSRC-FM- 95-0049 90	DWPF Melter Thermowell (Center)
Apr-95	WSRC-FM- 95-0049 91	DWPF Melter Thermowell (Center)
Apr-95	WSRC-FM- 95-0049 92	DWPF Level Probe (Dip Tube Bubbler)
Apr-95	WSRC-FM- 95-0049 93	DWPF Level Probe (Dip Tube Bubbler)
Apr-95	WSRC-FM- 95-0049 94	DWPF Level Probe (Dip Tube Bubbler)
Apr-95	WSRC-FM- 95-0049 95	DWPF Level Probe (Dip Tube Bubbler)
Apr-95	WSRC-FM- 95-0049 96	Unknown
Apr-95	WSRC-FM- 95-0049 97	DWPF Melter Thermowell (Center)
Apr-95	WSRC-FM- 95-0049 98	DWPF Melter Thermowell (Center)
Apr-95	WSRC-FM- 95-0049 99	DWPF Melter Thermowell (Center)
Apr-95	WSRC-FM- 95-0049 100	DWPF Melter Thermowell (Center)

Date	Negative Number		Description (specific)
Apr-95	WSRC-FM- 95-0049	101	DWPF Melter Thermowell (Center)
Apr-95	WSRC-FM- 95-0049	102	DWPF Melter Thermowell (Center)
Apr-95	WSRC-FM- 95-0049	103	DWPF Melter Thermowell (Center)
Apr-95	WSRC-FM- 95-0049	104	DWPF Melter Thermowell (Center)
Apr-95	WSRC-FM- 95-0049	105	DWPF Melter Thermowell (Center)
Apr-95	WSRC-FM- 95-0049	106	DWPF Melter Thermowell (Center)
Apr-95	WSRC-FM- 95-0049	107	Unknown
Apr-95	WSRC-FM- 95-0049	108	DWPF Primary Quencher
Apr-95	WSRC-FM- 95-0049	109	DWPF Primary Quencher
Apr-95	WSRC-FM- 95-0049	110	DWPF Primary Quencher
Apr-95	WSRC-FM- 95-0049	111	DWPF Primary Quencher
Apr-95	WSRC-FM- 95-0049	112	DWPF Primary Quencher
Apr-95	WSRC-FM- 95-0049	113	DWPF Vapor Space Thermowell
Apr-95	WSRC-FM- 95-0049	114	DWPF Vapor Space Thermowell
Apr-95	WSRC-FM- 95-0049	115	DWPF Vapor Space Thermowell
Apr-95	WSRC-FM- 95-0049	116	DWPF Vapor Space Thermowell
Apr-95	WSRC-FM- 95-0049	117	DWPF Melter Backup MOG Line
Apr-95	WSRC-FM- 95-0049	118	DWPF
Sep-95	WSRC-FM- 95-0048	1	DWPF Melter Diagram
Sep-95	WSRC-FM- 95-0048	2	DWPF SRAT Sample Pump Impeller
Sep-95	WSRC-FM- 95-0048	3	DWPF SRAT Sample Pump Impeller
Sep-95	WSRC-FM- 95-0048	4	DWPF SRAT Sample Pump Impeller
Sep-95	WSRC-FM- 95-0048	5	DWPF SRAT Sample Pump Impeller
Sep-95	WSRC-FM- 95-0048	6	DWPF SME Agitator Upper Blade B
Sep-95	WSRC-FM- 95-0048	7	DWPF SME Agitator Upper Blade B
Sep-95	WSRC-FM- 95-0048	8	DWPF SME Agitator Front of Beveled Lower blade D
Sep-95	WSRC-FM- 95-0048	9	DWPF SME Agitator Overall
Sep-95	WSRC-FM- 95-0048	10	DWPF SME Agitator Back of Lower Blade C (Not Beveled)
Sep-95	WSRC-FM- 95-0048	11	DWPF SME Agitator Back of Lower Blade B (Not Beveled)
Sep-95	WSRC-FM- 95-0048	12	DWPF SRAT Agitator Lower Blades
Sep-95	WSRC-FM- 95-0048	13	DWPF SRAT Agitator Overall Lower and Upper Blades
Sep-95	WSRC-FM- 95-0048	14	DWPF SRAT Agitator Front Of Lower Beveled blade
Sep-95	WSRC-FM- 95-0048	15	DWPF SRAT Agitator Back Of Lower blade
Sep-95	WSRC-FM- 95-0048	16	DWPF SRAT Agitator Overall Of Upper Blades
Sep-95	WSRC-FM- 95-0048	17	DWPF SRAT Sample Pump Corrosion Coupons
Sep-95	WSRC-FM- 95-0048	18	DWPF SRAT Sample Pump Corrosion Coupons
Sep-95	WSRC-FM- 95-0048	19	DWPF SRAT Agitator
Sep-95	WSRC-FM- 95-0048	20	DWPF SRAT Agitator Back Side Of Lower Blade
Sep-95	WSRC-FM- 95-0048	21	DWPF SRAT Agitator Back Side Of Lower Blade
Sep-95	WSRC-FM- 95-0048	22	DWPF SRAT Sample Pump Corrosion Coupons
Sep-95	WSRC-FM- 95-0048	23	DWPF SRAT Sample Pump Corrosion Coupons
Sep-95	WSRC-FM- 95-0048	24	DWPF SME Agitator Upper Side Of Upper Hydrofoil Blade C
Sep-95	WSRC-FM- 95-0048	25	DWPF SME Agitator Upper Side Of Upper Hydrofoil Blade C
Sep-95	WSRC-FM- 95-0048	26	DWPF SME Agitator Upper Side Of Upper Hydrofoil Blade B
Sep-95	WSRC-FM- 95-0048	27	DWPF SME Agitator Upper Side Of Upper Hydrofoil Blade B
Sep-95	WSRC-FM- 95-0048	28	DWPF SME Agitator Upper Side Of Upper Hydrofoil Blade A
Sep-95	WSRC-FM- 95-0048	29	DWPF SME Agitator Upper Side Of Upper Hydrofoil Blade A
Sep-95	WSRC-FM- 95-0048	30	DWPF SME Agitator Bottom Side Of Upper Hydrofoil Blade C
Sep-95	WSRC-FM- 95-0048	31	DWPF SME Agitator Bottom Side Of Upper Hydrofoil Blade A
Sep-95	WSRC-FM- 95-0048	32	DWPF SME Agitator Upper Blade Leading Edge
Sep-95	WSRC-FM- 95-0048	33	DWPF SME Agitator Upper Blade Leading Edge
Sep-95	WSRC-FM- 95-0048	34	DWPF SME Agitator Back Side Of lower Blade D
Sep-95	WSRC-FM- 95-0048	35	DWPF SME Agitator D Picture of Lower Edge Using Mirror
Sep-95	WSRC-FM- 95-0048	36	DWPF SME Agitator D Picture of Lower Edge Using Mirror
25-Aug	WSRC-FM- 95-0047	1	IDMS Melter looking up melter where drain valve would be installed
25-Aug	WSRC-FM- 95-0047	2	IDMS Melter looking up melter where drain valve would be installed
25-Aug	WSRC-FM- 95-0047	3	IDMS Melter looking up melter where drain valve would be installed
25-Aug	WSRC-FM- 95-0047	4	IDMS Melter Lid Heaters after Bead Blasting

Date	Negative Number	Description (specific)
25-Aug	WSRC-FM- 95-0047 5	IDMS Melter Upper and Lower Electrodes after Bead Blasting
25-Aug	WSRC-FM- 95-0047 6	IDMS Melter Lid Heaters after Bead Blasting
25-Aug	WSRC-FM- 95-0047 7	IDMS Melter Upper and Lower Electrodes after Bead Blasting
25-Aug	WSRC-FM- 95-0047 8	IDMS Melter Drain Valve
25-Aug	WSRC-FM- 95-0047 9	IDMS Melter Drain Valve
25-Aug	WSRC-FM- 95-0047 10	IDMS Melter Drain Valve
25-Aug	WSRC-FM- 95-0047 11	IDMS Melter Drain Valve
25-Aug	WSRC-FM- 95-0047 12	IDMS Melter Drain Valve
25-Aug	WSRC-FM- 95-0047 13	IDMS Melter Lid Heaters after cleaning
Oct-95	WSRC-FM- 95-0045 1	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 2	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 3	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 4	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 5	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 6	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 7	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 8	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 9	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 10	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 11	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 12	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 13	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 14	Unknown
Oct-95	WSRC-FM- 95-0045 15	Unknown
Oct-95	WSRC-FM- 95-0045 16	Unknown
Oct-95	WSRC-FM- 95-0045 17	Unknown
Oct-95	WSRC-FM- 95-0045 18	Unknown
Oct-95	WSRC-FM- 95-0045 19	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 20	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 21	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 22	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 23	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 24	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 25	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 26	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 27	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 28	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 29	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 30	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 31	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 32	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 33	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 34	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 35	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 36	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 37	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 38	DWPF Region Above Bellows
Oct-95	WSRC-FM- 95-0045 39	DWPF Region Above Bellows
Nov-95	WSRC-FM- 95-0046 1	DWPF Off Gas Line (Film Cooler Brush Flange)
Nov-95	WSRC-FM- 95-0046 2	DWPF Off Gas Line (Below Film Cooler Brush Flange)
Nov-95	WSRC-FM- 95-0046 3	DWPF Off Gas Line (Below Film Cooler Brush Flange)
Nov-95	WSRC-FM- 95-0046 4	DWPF Primary Quencher Inlet (Before Cleaning)
Nov-95	WSRC-FM- 95-0046 5	DWPF Primary Quencher Inlet (Before Cleaning)
Nov-95	WSRC-FM- 95-0046 6	DWPF Primary Quencher Nozzle
Nov-95	WSRC-FM- 95-0046 7	DWPF Primary Quencher Nozzle
Nov-95	WSRC-FM- 95-0046 8	DWPF
Nov-95	WSRC-FM- 95-0046 9	DWPF Primary Quencher Inlet Weld
Nov-95	WSRC-FM- 95-0046 10	DWPF Primary Quencher Outlet

DWPF & IDMS Negative Numbers

Date	Negative Number		Description (specific)
Nov-95	WSRC-FM- 95-0046	11	DWPF Primary Quencher Outlet
Nov-95	WSRC-FM- 95-0046	12	DWPF
Nov-95	WSRC-FM- 95-0046	13	DWPF SRAT Feed Orifice Plate Jumper ASX (12.ITP) 3
Nov-95	WSRC-FM- 95-0046	14	DWPF SRAT Feed Orifice Plate Jumper ASX (12.ITP) 3
Nov-95	WSRC-FM- 95-0046	15	Unknown
Nov-95	WSRC-FM- 95-0046	16	DWPF Primary Quencher Inlet Weld
Nov-95	WSRC-FM- 95-0046	17	DWPF Primary Quencher Outlet, Salt Deposits
Nov-95	WSRC-FM- 95-0046	18	DWPF Primary Quencher Inlet
Nov-95	WSRC-FM- 95-0046	19	DWPF Primary Quencher Inlet
Nov-95	WSRC-FM- 95-0046	20	DWPF Primary Quencher outlet, Salt Deposits
Nov-95	WSRC-FM- 95-0046	21	DWPF Primary Quencher Inlet (Before Cleaning)
Nov-95	WSRC-FM- 95-0046	22	DWPF Primary Quencher Inlet (Before Cleaning)
Sep-95	WSRC-FM- 95-0006	1	DWPF SME Sample Pump
Sep-95	WSRC-FM- 95-0006	2	DWPF SME Sample Pump
Sep-95	WSRC-FM- 95-0006	3	DWPF SME Sample Pump
Sep-95	WSRC-FM- 95-0006	4	DWPF SME Sample Pump
Sep-95	WSRC-FM- 95-0006	5	DWPF SME Sample Pump
Sep-95	WSRC-FM- 95-0006	6	DWPF SME Sample Pump
Sep-95	WSRC-FM- 95-0006	7	DWPF SME Sample Pump
Sep-95	WSRC-FM- 95-0006	8	DWPF SME Sample Pump
Sep-95	WSRC-FM- 95-0006	9	DWPF SME Sample Pump
Sep-95	WSRC-FM- 95-0006	10	DWPF SME Agitator A
Sep-95	WSRC-FM- 95-0006	11	DWPF SME Agitator B
Sep-95	WSRC-FM- 95-0006	12	Unknown
Sep-95	WSRC-FM- 95-0006	13	DWPF SME Agitator A
Sep-95	WSRC-FM- 95-0006	14	DWPF SME Agitator D
Sep-95	WSRC-FM- 95-0006	15	DWPF SME Agitator A
Sep-95	WSRC-FM- 95-0006	16	DWPF SME Agitator A
Sep-95	WSRC-FM- 95-0006	17	DWPF SME Agitator D
Sep-95	WSRC-FM- 95-0006	18	DWPF SME Agitator
Sep-95	WSRC-FM- 95-0006	19	DWPF SME Agitator B
Sep-95	WSRC-FM- 95-0006	20	DWPF SME Agitator D
Sep-95	WSRC-FM- 95-0006	21	DWPF SME Agitator C
Sep-95	WSRC-FM- 95-0006	22	DWPF SME Agitator B
Sep-95	WSRC-FM- 95-0006	23	DWPF SME Agitator C
Sep-95	WSRC-FM- 95-0006	24	DWPF SME Agitator A
Sep-95	WSRC-FM- 95-0006	25	DWPF SME Agitator D
Sep-95	WSRC-FM- 95-0006	26	DWPF SME Agitator D
Sep-95	WSRC-FM- 95-0006	27	DWPF SRAT Sample Pump
Sep-95	WSRC-FM- 95-0006	28	DWPF SRAT Sample Pump
Sep-95	WSRC-FM- 95-0006	29	DWPF SRAT Sample Pump
Sep-95	WSRC-FM- 95-0006	30	DWPF SRAT Sample Pump
Sep-95	WSRC-FM- 95-0006	31	Unknown
Sep-95	WSRC-FM- 95-0006	32	DWPF SME Sample Pump
Sep-95	WSRC-FM- 95-0006	33	DWPF SME Sample Pump
Sep-95	WSRC-FM- 95-0006	34	DWPF SME Sample Pump
Sep-95	WSRC-FM- 95-0006	35	DWPF SME Sample Pump
Nov-95	WSRC-FM- 95-0063	1	Lower agitator blade front face
Nov-95	WSRC-FM- 95-0063	2	Lower agitator blade back face of blade with large stellite mound for balancing
Nov-95	WSRC-FM- 95-0063	3	Lower agitator blade back face
Nov-95	WSRC-FM- 95-0063	4	Lower agitator blade front and back faces
Nov-95	WSRC-FM- 95-0063	5	Lower agitator blade front and back faces (blurry)
Nov-95	WSRC-FM- 95-0063	6	Lower agitator blade back face (blurry)
Nov-95	WSRC-FM- 95-0063	7	Lower agitator blade front and back faces
Nov-95	WSRC-FM- 95-0063	8	Lower agitator blade front face (close up, not good)
Nov-95	WSRC-FM- 95-0063	9	Lower agitator blade front face (blurry) (close up, not good)
Nov-95	WSRC-FM- 95-0063	10	Lower agitator blade front face
Nov-95	WSRC-FM- 95-0063	11	Hub assembly

DWPF & IDMS Negative Numbers

Date	Negative Number		Description (specific)
Nov-95	WSRC-FM- 95-0063	12	Lower agitator blade back face
Oct-94	WSRC-FM- 95-0063	1	Bad picture
Oct-94	WSRC-FM- 95-0063	2	Top upper blade 3
Oct-94	WSRC-FM- 95-0063	3	Top upper blade
Oct-94	WSRC-FM- 95-0063	4	Top upper blade
Oct-94	WSRC-FM- 95-0063	5	Top upper blade
Oct-94	WSRC-FM- 95-0063	6	Top upper blade
Oct-94	WSRC-FM- 95-0063	7	Top upper blade
Oct-94	WSRC-FM- 95-0063	8	Top upper blade
Oct-94	WSRC-FM- 95-0063	9	Top upper blade
Oct-94	WSRC-FM- 95-0063	10	Top upper blade
Oct-94	WSRC-FM- 95-0063	11	Top upper blade
Oct-94	WSRC-FM- 95-0063	12	Entire agitator
Oct-94	WSRC-FM- 95-0063	13	Entire agitator
Oct-94	WSRC-FM- 95-0063	14	Top upper blade 1
Oct-94	WSRC-FM- 95-0063	15	Top upper blade 1
Oct-94	WSRC-FM- 95-0063	16	Top upper blade 1
Oct-94	WSRC-FM- 95-0063	17	Top upper blade 2
Oct-94	WSRC-FM- 95-0063	18	Top upper blade 2
Oct-94	WSRC-FM- 95-0063	19	Top upper blade 2
Oct-94	WSRC-FM- 95-0063	20	Top upper blade 2
Oct-94	WSRC-FM- 95-0063	21	Top upper blade 3
Oct-94	WSRC-FM- 95-0063	22	Top upper blade 3
Oct-94	WSRC-FM- 95-0063	23	Top upper blade 3
Oct-94	WSRC-FM- 95-0063	24	Upper and lower blades looking down
Oct-94	WSRC-FM- 95-0063	25	Upper and lower blades looking down
Oct-94	WSRC-FM- 95-0063	26	Upper and lower blades looking down
Oct-94	WSRC-FM- 95-0063	27	Upper and lower blades looking down
Oct-94	WSRC-FM- 95-0063	28	Upper and lower blades looking down
Oct-94	WSRC-FM- 95-0063	29	Upper and lower blades looking down
Oct-94	WSRC-FM- 95-0063	30	Upper and lower blades looking down
Oct-94	WSRC-FM- 95-0063	31	Upper and lower blades looking down
Oct-94	WSRC-FM- 95-0063	32	Entire agitator
Oct-94	WSRC-FM- 95-0063	33	Entire agitator
Oct-94	WSRC-FM- 95-0063	34	Entire agitator
Oct-94	WSRC-FM- 95-0063	35	Entire agitator
Oct-94	WSRC-FM- 95-0063	36	Back of lower blade at tab
Oct-94	WSRC-FM- 95-0063	37	Back of lower blade at tab
Oct-94	WSRC-FM- 95-0063	38	Back of lower blade at tab
Oct-94	WSRC-FM- 95-0063	39	Back of lower blade at tab
Oct-94	WSRC-FM- 95-0063	40	Back of lower blade #3 at tab
Oct-94	WSRC-FM- 95-0063	41	Back of lower blade #3 at tab
Oct-94	WSRC-FM- 95-0063	42	Back of lower blade #3 at tab
Oct-94	WSRC-FM- 95-0063	43	Back of lower blade #3 at tab
Oct-94	WSRC-FM- 95-0063	44	Back of lower blade #4 at tab
Oct-94	WSRC-FM- 95-0063	45	Back of lower blade #4 at tab
Oct-94	WSRC-FM- 95-0063	46	Back of lower blade #4 at tab
Dec-95	WSRC-FM- 96-0072	1	IDMS Melt Pool Thermowell Prior to Sectioning in Met Lab (Overall)
Dec-95	WSRC-FM- 96-0072	2	IDMS Melt Pool Thermowell Prior to Sectioning in Met Lab (Overall)
Dec-95	WSRC-FM- 96-0072	3	IDMS Melt Pool Thermowell Prior to Sectioning in Met Lab (Overall)
Dec-95	WSRC-FM- 96-0072	4	IDMS Feed Tube Sectioned Pieces (top and core end piece)
Dec-95	WSRC-FM- 96-0072	5	IDMS Feed Tube Sectioned Pieces (top and core end piece)
Dec-95	WSRC-FM- 96-0072	6	IDMS Melt Pool Thermowell After Sectioning in Met Lab (Overall)
Dec-95	WSRC-FM- 96-0072	7	IDMS Melt Pool Thermowell After Sectioning in Met Lab (Overall)
Dec-95	WSRC-FM- 96-0072	8	IDMS Melt Pool Thermowell After Sectioning in Met Lab (Overall)
Dec-95	WSRC-FM- 96-0072	9	IDMS Feed Tube Sectioned (close up of top around large pit)
Dec-95	WSRC-FM- 96-0072	10	Bad Picture

Date	Negative Number	Description (specific)
Dec-95	WSRC-FM- 96-0072 11	IDMS Melt Pool Thermowell After Sectioning in Met Lab (Overall)
Dec-95	WSRC-FM- 96-0072 12	IDMS Melt Pool Thermowell After Sectioning in Met Lab (Overall)
Dec-95	WSRC-FM- 96-0072 13	IDMS Melt Pool Thermowell After Sectioning in Met Lab (Overall)
Dec-95	WSRC-FM- 96-0072 14	IDMS Feed Tube (top portion with outer housing removed)
Dec-95	WSRC-FM- 96-0072 15	IDMS Feed Tube (top portion with large pit and core end piece)
Dec-95	WSRC-FM- 96-0072 16	IDMS Feed Tube (top portion with large pit and core end piece)
Dec-95	WSRC-FM- 96-0072 17	IDMS Feed Tube (top portion with large pit and core end piece)
Dec-95	WSRC-FM- 96-0072 18	IDMS Feed Tube (top portion with large pit and core end piece)
Dec-95	WSRC-FM- 96-0072 19	IDMS Feed Tube (top portion with large pit and core end piece)
Dec-95	WSRC-FM- 96-0072 20	IDMS Feed Tube (top portion with large pit and core end piece)
Dec-95	WSRC-FM- 96-0072 21	IDMS Feed Tube (top portion with large pit and core end piece)
Dec-95	WSRC-FM- 96-0072 22	IDMS Feed Tube (top portion with large pit and core end piece)
Dec-95	WSRC-FM- 96-0072 23	IDMS Feed Tube (top portion with large pit and core end piece)
Dec-95	WSRC-FM- 96-0072 24	IDMS Melt Pool Thermowell After Sectioning in Met Lab (Overall)
Dec-95	WSRC-FM- 96-0072 25	IDMS Melt Pool Thermowell After Sectioning in Met Lab (Overall)
Dec-95	WSRC-FM- 96-0072 26	IDMS Melt Pool Thermowell After Sectioning in Met Lab (Overall)
Dec-95	WSRC-FM- 96-0072 27	IDMS Melt Pool Thermowell After Sectioning in Met Lab (Overall)
Dec-95	WSRC-FM- 96-0072 28	IDMS Melt Pool Thermowell After Sectioning in Met Lab (Overall)
Dec-95	WSRC-FM- 96-0072 29	IDMS Melt Pool Thermowell After Sectioning in Met Lab (Overall)
Dec-95	WSRC-FM- 96-0072 30	IDMS Melt Pool Thermowell After Sectioning in Met Lab (Overall)
Dec-95	WSRC-FM- 96-0072 31	IDMS Melt Pool Thermowell After Sectioning in Met Lab (Overall)
Nov-95	WSRC-FM- 96-0071 1	DWPF MFT Replacement Agitator Lower Blades with Stellite
Nov-95	WSRC-FM- 96-0071 2	DWPF MFT Replacement Agitator Lower Blades with Stellite
Nov-95	WSRC-FM- 96-0071 3	DWPF MFT Replacement Agitator Lower Blades with Stellite
Nov-95	WSRC-FM- 96-0071 4	DWPF MFT Replacement Agitator Back of Lower Blade with Weight
Nov-95	WSRC-FM- 96-0071 5	DWPF MFT Replacement Agitator Back of Lower Blade with Weight
Nov-95	WSRC-FM- 96-0071 6	DWPF MFT Replacement Agitator Back of Lower Blade with Weight
Nov-95	WSRC-FM- 96-0071 7	DWPF MFT Replacement Agitator Front of Lower Blade with Stellite
Nov-95	WSRC-FM- 96-0071 8	DWPF MFT Replacement Agitator Front of Lower Blade with Stellite
Nov-95	WSRC-FM- 96-0071 9	DWPF MFT Replacement Agitator (overall picture of lower blades)
Nov-95	WSRC-FM- 96-0071 10	DWPF MFT Replacement Agitator (weld repair of shaft)
Nov-95	WSRC-FM- 96-0071 11	DWPF MFT Replacement Agitator (weld repair of shaft)
Nov-95	WSRC-FM- 96-0071 12	Upper 700 Area Picture
Nov-95	WSRC-FM- 96-0071 13	Upper 700 Area Picture
Sep-94	WSRC-FM- 95-0064 1	DWPF SME Agitator (top blade #1)
Sep-94	WSRC-FM- 95-0064 2	DWPF SME Agitator (top blade #2)
Sep-94	WSRC-FM- 95-0064 3	DWPF SME Agitator (top blade #3)
Sep-94	WSRC-FM- 95-0064 4	DWPF SME Agitator (lower blade back side #1)
Sep-94	WSRC-FM- 95-0064 5	DWPF SME Agitator (lower blade back side #1)
Sep-94	WSRC-FM- 95-0064 6	DWPF SME Agitator (lower blade back side #1)
Sep-94	WSRC-FM- 95-0064 7	DWPF SME Agitator (lower blade back side #4)
Sep-94	WSRC-FM- 95-0064 8	DWPF SME Agitator (lower blade back side #2)
Sep-94	WSRC-FM- 95-0064 9	DWPF SME Agitator (front edge top blade #2)
Sep-94	WSRC-FM- 95-0064 10	Unknown
Sep-94	WSRC-FM- 95-0064 11	Unknown
Sep-94	WSRC-FM- 95-0064 12	DWPF SME Agitator (lower side of the upper blade #1)
Sep-94	WSRC-FM- 95-0064 13	DWPF SME Agitator (lower side of the upper blade #2)
Sep-94	WSRC-FM- 95-0064 14	DWPF SME Agitator (lower blade back side #2) Should be marked #4
Sep-94	WSRC-FM- 95-0064 15	DWPF SME Agitator (lower blade back side #1)
Sep-94	WSRC-FM- 95-0064 16	DWPF SME Agitator (lower blade back side #4) Should be marked #2
Sep-94	WSRC-FM- 95-0064 17	DWPF SME Agitator (lower blade back side #3)
Sep-94	WSRC-FM- 95-0064 18	DWPF SME Agitator (lower blade back side #1)
Sep-94	WSRC-FM- 95-0064 19	DWPF SME Agitator (lower blade back side #2)
Sep-94	WSRC-FM- 95-0064 20	DWPF SME Agitator (entire agitator)
Sep-94	WSRC-FM- 95-0064 21	Unknown
Sep-94	WSRC-FM- 95-0064 22	DWPF SME Agitator (lower blade back side #2)
Sep-94	WSRC-FM- 95-0064 23	DWPF SME Agitator (lower blade back side #2)
Sep-94	WSRC-FM- 95-0064 24	DWPF SME Agitator (lower blade back side #4)
Sep-94	WSRC-FM- 95-0064 25	DWPF SME Agitator (lower blade back side #4)
Sep-94	WSRC-FM- 95-0064 26	DWPF SME Agitator (lower blade back side #4)

Date	Negative Number			Description (specific)
Sep-94	WSRC-FM-	95-0064	27	Unknown
Sep-94	WSRC-FM-	95-0064	28	Unknown
Sep-94	WSRC-FM-	95-0064	29	Unknown
Sep-94	WSRC-FM-	95-0064	30	DWPF SME Agitator (lower blade front side #2)
Sep-94	WSRC-FM-	95-0064	31	DWPF SME Agitator (lower blade back side #2) Should be marked #4
Sep-94	WSRC-FM-	95-0064	32	DWPF SME Agitator (lower blade back side #3)
Sep-94	WSRC-FM-	95-0064	33	DWPF SME Agitator (lower blade back side #4) Should be marked #2
Sep-94	WSRC-FM-	95-0064	34	DWPF SME Agitator (lower blade back side #3)
Sep-94	WSRC-FM-	95-0064	35	DWPF SME Agitator (entire agitator)
Sep-94	WSRC-FM-	95-0064	36	DWPF SME Agitator (lower blade front side #1)
Sep-94	WSRC-FM-	95-0064	37	DWPF SME Agitator (lower blade front side #1)
Sep-94	WSRC-FM-	95-0064	38	DWPF SME Agitator (lower blade back side #1)
Sep-94	WSRC-FM-	95-0064	39	DWPF SME Agitator (lower blade back side #1)
Sep-94	WSRC-FM-	95-0064	40	Unknown
Sep-94	WSRC-FM-	95-0064	41	DWPF MFT Agitator (front of lower blade number unknown)
Sep-94	WSRC-FM-	95-0064	42	DWPF MFT Agitator (front of lower blade number unknown)
Sep-94	WSRC-FM-	95-0064	43	DWPF MFT Agitator (back of lower blade number unknown)
Sep-94	WSRC-FM-	95-0064	44	DWPF MFT Agitator (back of lower blade number unknown)
Sep-94	WSRC-FM-	95-0064	45	DWPF MFT Agitator (back of lower blade number unknown)
Sep-94	WSRC-FM-	95-0064	46	DWPF MFT Agitator (back of lower blade number unknown)
Sep-94	WSRC-FM-	95-0064	47	DWPF MFT Agitator (outer edge of lower blade number unknown)
Sep-94	WSRC-FM-	95-0064	48	DWPF MFT Agitator (top of upper blade number unknown)
Sep-94	WSRC-FM-	95-0064	49	DWPF MFT Agitator (top of upper blade number unknown)
Sep-94	WSRC-FM-	95-0064	50	DWPF MFT Agitator (bottom of upper blade number unknown)
Sep-94	WSRC-FM-	95-0064	51	DWPF MFT Agitator (lower blades overall)
Sep-94	WSRC-FM-	95-0064	52	DWPF MFT Agitator (entire agitator)
Sep-94	WSRC-FM-	95-0065	1	DWPF SME Agitator (top side of the upper blade #2)
Sep-94	WSRC-FM-	95-0065	2	DWPF SME Agitator (top side of the upper blade #3)
Sep-94	WSRC-FM-	95-0065	3	DWPF SME Agitator (upper side of the upper blade #3)
Sep-94	WSRC-FM-	95-0065	4	DWPF SME Agitator (lower blade back side #3)
Sep-94	WSRC-FM-	95-0065	5	DWPF SME Agitator (lower blade back side #3)
Sep-94	WSRC-FM-	95-0065	6	DWPF SME Agitator (lower blade back side #3)
Sep-94	WSRC-FM-	95-0065	7	DWPF SME Agitator (lower blade back side #3)
Sep-94	WSRC-FM-	95-0065	8	DWPF SME Agitator (top side of the upper blade #2)
Sep-94	WSRC-FM-	95-0065	9	DWPF SME Agitator (top side of the upper blade #2)
Sep-94	WSRC-FM-	95-0065	10	DWPF SME Agitator (top side of the upper blade #1)
Sep-94	WSRC-FM-	95-0065	11	DWPF SME Agitator (top side of the upper blade #1)
Sep-94	WSRC-FM-	95-0065	12	DWPF SME Agitator (top side of the upper blade #3)
Sep-94	WSRC-FM-	95-0065	13	DWPF SME Agitator (top side of the upper blade #3)
Sep-94	WSRC-FM-	95-0065	14	DWPF SME Agitator (top side of the upper blade #3)
Sep-94	WSRC-FM-	95-0065	15	DWPF SME Agitator (top side of the upper blade #2)
Sep-94	WSRC-FM-	95-0065	16	DWPF SME Agitator (top side of the upper blade #1)
Sep-94	WSRC-FM-	95-0065	17	DWPF SME Agitator (top side of the upper blade #1)
Sep-94	WSRC-FM-	95-0065	18	DWPF SME Agitator (top side of the upper blade #1)
Sep-94	WSRC-FM-	95-0065	19	DWPF SME Agitator (top side of the upper blade #1)
Sep-94	WSRC-FM-	95-0065	20	DWPF SME Agitator (top side of the upper blade #1)
Sep-94	WSRC-FM-	95-0065	21	DWPF SME Agitator (top side of the upper blade #1)
Sep-94	WSRC-FM-	95-0065	22	DWPF SME Agitator (entire agitator blurry)
Sep-94	WSRC-FM-	95-0065	23	DWPF SME Agitator (entire agitator looking down)
Sep-94	WSRC-FM-	95-0065	24	DWPF SME Agitator (entire agitator looking down)
Sep-94	WSRC-FM-	95-0065	25	DWPF SME Agitator (entire agitator looking down)
Sep-94	WSRC-FM-	95-0065	26	DWPF SME Agitator (entire agitator looking down)
Sep-94	WSRC-FM-	95-0065	27	DWPF SME Agitator (lower blades)
Sep-94	WSRC-FM-	95-0065	28	CDMC equipment support
Sep-94	WSRC-FM-	95-0065	29	DWPF SME Agitator (lower blades)
Sep-94	WSRC-FM-	95-0065	30	DWPF SME Agitator (lower blade back side #2)
Sep-94	WSRC-FM-	95-0065	31	DWPF SME Agitator (lower blade back side #2)
Sep-94	WSRC-FM-	95-0065	32	DWPF SME Agitator (lower blade back side #2)
Sep-94	WSRC-FM-	95-0065	33	DWPF SME Agitator (lower blade back side #1)
Sep-94	WSRC-FM-	95-0065	34	DWPF SME Agitator (lower blade back side #1)
Sep-94	WSRC-FM-	95-0065	35	DWPF SME Agitator (lower blade back side #1)
Sep-94	WSRC-FM-	95-0065	36	DWPF SME Agitator (lower blade back side #1)
Sep-94	WSRC-FM-	95-0065	37	DWPF SME Agitator (lower blade back side #4)
Sep-94	WSRC-FM-	95-0065	38	DWPF SME Agitator (lower blade back side #4)
Sep-94	WSRC-FM-	95-0065	39	DWPF SME Agitator (lower blade back side #4)

Date	Negative Number			Description (specific)
Sep-94	WSRC-FM-	95-0065	40	DWPF SME Agitator (lower blade back side #4)
Sep-94	WSRC-FM-	95-0065	41	DWPF SME Agitator (lower blade back side #3)
Sep-94	WSRC-FM-	95-0065	42	DWPF MFT Agitator (entire agitator)
Sep-94	WSRC-FM-	95-0065	43	DWPF MFT Agitator (entire agitator)
Sep-94	WSRC-FM-	95-0065	44	DWPF MFT Agitator (upper blades overall)
Sep-94	WSRC-FM-	95-0065	45	DWPF MFT Agitator (lower blades overall)
Sep-94	WSRC-FM-	95-0065	46	DWPF MFT Agitator (upper blade #1)
Sep-94	WSRC-FM-	95-0065	47	DWPF MFT Agitator (upper blade #2)
Sep-94	WSRC-FM-	95-0065	48	DWPF MFT Agitator (upper blade #3)
Sep-94	WSRC-FM-	95-0065	49	DWPF SME Agitator (lower blade back side #1)
Sep-94	WSRC-FM-	95-0065	50	DWPF SME Agitator (lower blade back side #4)
Sep-94	WSRC-FM-	95-0065	51	DWPF SME Agitator (lower blade back side #3)
Sep-94	WSRC-FM-	95-0065	52	DWPF SME Agitator (lower blade back side #2)
Sep-94	WSRC-FM-	95-0065	53	DWPF SME Agitator (lower blade back side #2)
Feb-96	WSRC-FM-	96-294	1	End after 2 months of exposure in DWPF melter
Feb-96	WSRC-FM-	96-294	2	End after 2 months of exposure in DWPF melter
Feb-96	WSRC-FM-	96-294	3	End after 2 months of exposure in DWPF melter
Feb-96	WSRC-FM-	96-294	4	
Feb-96	WSRC-FM-	96-294	5	End after 2 months of exposure in DWPF melter
Feb-96	WSRC-FM-	96-294	6	Orifice after 2 months of exposure in DWPF melter
Feb-96	WSRC-FM-	96-294	7	Orifice after 2 months of exposure in DWPF melter
Feb-96	WSRC-FM-	96-294	8	Orifice after 2 months of exposure in DWPF melter
Feb-96	WSRC-FM-	96-294	9	Orifice after 2 months of exposure in DWPF melter
Feb-96	WSRC-FM-	96-294	10	Orifice after 2 months of exposure in DWPF melter
Feb-96	WSRC-FM-	96-294	11	End after 2 months of exposure in DWPF melter
Feb-96	WSRC-FM-	96-294	12	End in stand after 2 months of exposure in DWPF melter
Feb-96	WSRC-FM-	96-294	13	Entire borescope in holder
Feb-96	WSRC-FM-	96-294	14	Lower portion
Feb-96	WSRC-FM-	96-294	15	Lower portion
Feb-96	WSRC-FM-	96-294	16	Overall
Feb-96	WSRC-FM-	96-294	17	Overall
Feb-96	WSRC-FM-	96-294	18	Lower Portion
Feb-96	WSRC-FM-	96-294	19	Lower Portion
Feb-96	WSRC-FM-	96-294	20	Middle Portion
Feb-96	WSRC-FM-	96-294	21	Overall
Feb-96	WSRC-FM-	96-294	22	Tip
Feb-96	WSRC-FM-	96-294	23	Tip
Feb-96	WSRC-FM-	96-294	24	End after 2 months of exposure in DWPF melter
Feb-96	WSRC-FM-	96-294	25	End after 2 months of exposure in DWPF melter
Feb-96	WSRC-FM-	96-294	26	End after 2 months of exposure in DWPF melter
Mar-96	WSRC-FM	96-358	1	Shows location of the 2 metallurgical specimens
Mar-96	WSRC-FM	96-358	2	Shows location of the 2 metallurgical specimens
Mar-96	WSRC-FM	96-358	3	Shows location of the 2 metallurgical specimens
Mar-96	WSRC-FM	96-358	4	Shows location of the 2 metallurgical specimens
Mar-96	WSRC-FM	96-358	5	Shows location of the 2 metallurgical specimens
Mar-96	WSRC-FM	96-358	6	Shows location of the 2 metallurgical specimens
Mar-96	WSRC-FM	96-358	7	Shows location of the 2 metallurgical specimens
Mar-96	WSRC-FM	96-358	8	Shows location of the 2 metallurgical specimens
Mar-96	WSRC-FM	96-358	9	End of Film Cooler
Mar-96	WSRC-FM	96-358	10	End of Film Cooler
Mar-96	WSRC-FM	96-358	11	End of Film Cooler
Mar-96	WSRC-FM	96-358	12	End of Film Cooler
Mar-96	WSRC-FM	96-358	13	End of Film Cooler
Mar-96	WSRC-FM	96-358	14	Upper portion of thermowell including 690 retaining collar
Mar-96	WSRC-FM	96-358	15	Portion of 690 collar with no attack
Mar-96	WSRC-FM	96-358	16	Portion of 690 collar with no attack
Mar-96	WSRC-FM	96-358	17	Portion of 690 collar with significant attack
Mar-96	WSRC-FM	96-358	18	Portion of 690 collar with significant attack
Apr-96	WSRC-FM	96-359	1	Feed tubes in wooden holders
Apr-96	WSRC-FM	96-359	2	Feed tubes in wooden holders
Apr-96	WSRC-FM	96-359	3	Feed tubes in wooden holders

DWPF & IDMS Negative Numbers

Date	Negative Number			Description (specific)
Apr-96	WSRC-FM	96-359	4	Feed tubes in wooden holders
Apr-96	WSRC-FM	96-359	5	Feed tubes in wooden holders
Apr-96	WSRC-FM	96-359	6	*Side of feed tube in wooden holder*
Apr-96	WSRC-FM	96-359	7	Side of feed tube in wooden holder (S 350-185-15-30-A) 26B
Apr-96	WSRC-FM	96-359	8	Side of feed tube in wooden holder (S 350-185-15-30-A) 26B
Apr-96	WSRC-FM	96-359	9	Side of feed tube in wooden holder (S 999350-15-30A) 25A
Apr-96	WSRC-FM	96-359	10	Side of feed tube in wooden holder (S 999350-15-30A) 25A
Apr-96	WSRC-FM	96-359	11	End showing orifice (S 999-350-15-30-B)
Apr-96	WSRC-FM	96-359	12	Overall (S 999-350-15-30-B)
Apr-96	WSRC-FM	96-359	13	Bad
Apr-96	WSRC-FM	96-359	14	Overall (S 999-350-15-30-B)
Apr-96	WSRC-FM	96-359	15	End showing orifice (S 999-350-15-30-B)
Apr-96	WSRC-FM	96-359	16	End showing orifice (S 999-350-15-30-B)
Apr-96	WSRC-FM	96-359	17	Overall (S 999-350-15-30-B)
Apr-96	WSRC-FM	96-359	18	Overall replacement (from melter 2) primary film cooler brush
Apr-96	WSRC-FM	96-359	19	Replacement (from melter 2) back up film cooler brush (ID on picture wrong)
Apr-96	WSRC-FM	96-359	20	Replacement (from melter 2) primary and back up brushes on trailer
Apr-96	WSRC-FM	96-359	21	Replacement (from melter 2) primary and back up brushes on trailer
Apr-96	WSRC-FM	96-359	22	Overall replacement (from melter 2) primary film cooler brush
Apr-96	WSRC-FM	96-359	23	Overall replacement (from melter 2) primary film cooler brush
Apr-96	WSRC-FM	96-359	24	Replacement (from melter 2) back up film cooler brush
Apr-96	WSRC-FM	96-359	25	Replacement (from melter 2) back up film cooler brush
Apr-96	WSRC-FM	96-359	26	Overall (S 999-350-15-30-B)
Apr-96	WSRC-FM	96-359	27	Overall (S 999-350-15-30-B)
Apr-96	WSRC-FM	96-359	28	End showing orifice (S 999-350-15-30-B)
Apr-96	WSRC-FM	96-359	29	End showing orifice (S 999-350-15-30-B)
Apr-96	WSRC-FM	96-359	30	End showing orifice (S 999-350-15-30-B)
Apr-96	WSRC-FM	96-359	31	End showing orifice (S 999-350-15-30-B)
Apr-96	WSRC-FM	96-359	32	End showing orifice (S 999-350-15-30-B)
Apr-96	WSRC-FM	96-359	33	End showing orifice (S 999-350-15-30-B)
Apr-96	WSRC-FM	96-359	34	End showing orifice (S 999-350-15-30-B)
Apr-96	WSRC-FM	96-359	35	Side of borescope (S 999-350-15-30-B)
Apr-96	WSRC-FM	96-359	36	Overall (S 999-350-15-30-B)
Apr-96	WSRC-FM	96-359	37	Overall (S 999-350-15-30-B)
Jan-96	WSRC-FM	96-357	1	*Upper Section and 690 collar where metallurgical specimens were cut (picture ID wrong)*
Jan-96	WSRC-FM	96-357	2	Upper Section and 690 collar where metallurgical specimens were cut (picture ID wrong)
Jan-96	WSRC-FM	96-357	3	Upper Section and 690 collar where metallurgical specimens were cut (picture ID wrong)
Jan-96	WSRC-FM	96-357	4	Upper Section and 690 collar where metallurgical specimens were cut (picture ID wrong)
Jan-96	WSRC-FM	96-357	5	Upper Section and 690 collar where metallurgical specimens were cut (picture ID wrong)
Jan-96	WSRC-FM	96-357	6	Upper Section and 690 collar where metallurgical specimens were cut (picture ID wrong)
Dec-95	WSRC-FM	96-357	7	PR upper agitator blade
Dec-95	WSRC-FM	96-357	8	PR upper agitator blade
Dec-95	WSRC-FM	96-357	9	PR Lower agitator blade showing mechanical damage on edge
Dec-95	WSRC-FM	96-357	10	PR Lower agitator blade showing mechanical damage on edge
Dec-95	WSRC-FM	96-357	11	PR Lower agitator blade showing mechanical damage on edge
Dec-95	WSRC-FM	96-357	12	PR thermocouple with gold 40 pin electrical connectors
Dec-95	WSRC-FM	96-357	13	PR thermocouple with gold 40 pin electrical connectors
Dec-95	WSRC-FM	96-357	14	PR thermocouple with gold 40 pin electrical connectors
Dec-95	WSRC-FM	96-357	15	Bend in PR thermocouple
Dec-95	WSRC-FM	96-357	16	Bend in PR thermocouple
Dec-95	WSRC-FM	96-357	17	Core end piece sectioned for metallography
Dec-95	WSRC-FM	96-357	18	Core end piece sectioned for metallography
Dec-95	WSRC-FM	96-357	19	*Fatigue crack in support brace*
Dec-95	WSRC-FM	96-357	20	Fatigue crack in support brace
Dec-95	WSRC-FM	96-357	21	Fatigue crack in support brace
Dec-95	WSRC-FM	96-357	22	Lower blades
Dec-95	WSRC-FM	96-357	23	Lower blades
Dec-95	WSRC-FM	96-357	24	Tab on lower blade
Dec-95	WSRC-FM	96-357	25	Core end piece sectioned for metallography
Dec-95	WSRC-FM	96-357	26	Core end piece sectioned for metallography

DWPF & IDMS Negative Numbers

Date	Negative Number			Description (specific)
Dec-95	WSRC-FM	96-357	27	Core end piece sectioned for metallography
Dec-95	WSRC-FM	96-357	28	Corrosion coupons rack
Dec-95	WSRC-FM	96-357	29	Corrosion coupons rack
Dec-95	WSRC-FM	96-357	30	Corrosion coupons rack
Dec-95	WSRC-FM	96-357	31	Corrosion coupons rack
Dec-95	WSRC-FM	96-357	32	PR sample pump brace before PT test
Apr-96	WSRC-FM	96-360	1	DWPF Feed Tube S350-185-13A Severe corrosion no weld repair
Apr-96	WSRC-FM	96-360	2	DWPF Feed Tube S350-185-13A Severe corrosion no weld repair
Apr-96	WSRC-FM	96-360	3	DWPF Feed Tube S350-185-13A Severe corrosion no weld repair
Apr-96	WSRC-FM	96-360	4	DWPF Feed Tube S350-185-13A Severe corrosion no weld repair
Apr-96	WSRC-FM	96-360	5	DWPF Feed Tube S350-185-13A Severe corrosion no weld repair
Apr-96	WSRC-FM	96-360	6	DWPF Feed Tube S350-185-13A Severe corrosion no weld repair
Apr-96	WSRC-FM	96-360	7	DWPF Feed Tube S350-185-13A Severe corrosion no weld repair
Apr-96	WSRC-FM	96-360	8	DWPF Feed Tube Overall
Apr-96	WSRC-FM	96-360	9	DWPF Feed Tube Upper portion just below alumina insert
Apr-96	WSRC-FM	96-360	10	DWPF Feed Tube S350-185-13A Severe corrosion no weld repair
Apr-96	WSRC-FM	96-360	11	DWPF Feed Tube S350-185-13A Severe corrosion no weld repair
Apr-96	WSRC-FM	96-360	12	NA
Apr-96	WSRC-FM	96-360	13	DWPF Feed Tube S999-350-50-40 Weld repaired Tip showing partial plugage
Apr-96	WSRC-FM	96-360	14	DWPF Feed Tube S999-350-50-40 Weld repaired Tip showing partial plugage
Apr-96	WSRC-FM	96-360	15	DWPF Feed Tube S999-350-50-40 Weld repaired Tip showing partial plugage
Apr-96	WSRC-FM	96-360	16	DWPF Feed Tube S999-350-50-40 Alumina insulator
Apr-96	WSRC-FM	96-360	17	DWPF Feed Tube S999-350-50-40 Shows bend in feed tube
Apr-96	WSRC-FM	96-360	18	DWPF Feed Tube S999-350-50-40 Weld repaired tip
Apr-96	WSRC-FM	96-360	19	DWPF Feed Tube S999-350-50-40 Weld repaired tip
Apr-96	WSRC-FM	96-360	20	DWPF Feed Tube S999-350-50-40 Weld repaired tip
Apr-96	WSRC-FM	96-360	21	DWPF Feed Tube S999-350-50-40 Weld repaired tip
Apr-96	WSRC-FM	96-360	22	DWPF Feed Tube S999-350-50-40 Alumina insulator
Apr-96	WSRC-FM	96-360	23	DWPF Feed Tube S999-350-50-40 Overall photo
Apr-96	WSRC-FM	96-360	24	DWPF Feed Tube S350-1815-13A Severe corrosion no weld repair (no label)
Apr-96	WSRC-FM	96-360	25	DWPF Feed Tube S350-1815-13A Severe corrosion no weld repair
Apr-96	WSRC-FM	96-360	26	DWPF Feed Tube S350-1815-13A Severe corrosion no weld repair
Apr-96	WSRC-FM	96-360	27	DWPF Feed Tube S350-1815-13A Severe corrosion no weld repair
Apr-96	WSRC-FM	96-360	28	DWPF Feed Tube S350-1815-13A Severe corrosion no weld repair
Apr-96	WSRC-FM	96-360	29	DWPF Feed Tube S350-1815-13A Severe corrosion no weld repair (no label)
Apr-96	WSRC-FM	96-360	30	DWPF Feed Tube S350-1815-13A Severe corrosion no weld repair
Apr-96	WSRC-FM	96-360	31	DWPF Feed Tube S350-1815-13A Upper portion just below alumina insert
Apr-96	WSRC-FM	96-360	32	DWPF Feed Tube S350-1815-13A Upper portion just below alumina insert
Apr-96	WSRC-FM	96-360	33	DWPF Feed Tube S350-1815-13A Upper portion just below alumina insert
Apr-96	WSRC-FM	96-360	34	DWPF Feed Tube S999-350-50-40 Weld repaired Tip showing partial plugage
Apr-96	WSRC-FM	96-360	35	DWPF Feed Tube S999-350-50-40 Weld repaired Tip showing partial plugage
Apr-96	WSRC-FM	96-360	36	DWPF Feed Tube S999-350-50-40 Weld repaired Tip close up
Apr-96	WSRC-FM	96-360	37	DWPF Feed Tube S999-350-50-40 Weld repaired Tip close up
May-96	WSRC-FM	96-365	1	IDMS SRAT/SME Agitator Overall
May-96	WSRC-FM	96-365	2	IDMS SRAT/SME Agitator Back side of lower blade showing tab
May-96	WSRC-FM	96-365	3	IDMS SRAT/SME Agitator Front side of lower blade
May-96	WSRC-FM	96-365	4	IDMS SRAT/SME Agitator Back side of lower blade stellite weld at tip for balancing
May-96	WSRC-FM	96-365	5	IDMS SRAT/SME Agitator Upper blades
May-96	WSRC-FM	96-365	6	IDMS SRAT/SME Agitator Lower blades
May-96	WSRC-FM	96-365	7	IDMS SRAT/SME Agitator Hub and front and back of lower blades
May-96	WSRC-FM	96-365	8	IDMS MFT Agitator Lower blades
May-96	WSRC-FM	96-365	9	IDMS MFT Vessel (cleaned) Looking through agitator port (coils visible)
May-96	WSRC-FM	96-365	10	IDMS MFT Agitator Hub and front and back of lower blades
May-96	WSRC-FM	96-365	11	IDMS MFT Agitator Overall
May-96	WSRC-FM	96-365	12	IDMS MFT Agitator Hub and front and back of lower blades
May-96	WSRC-FM	96-365	13	IDMS MFT Agitator Back side of lower blade