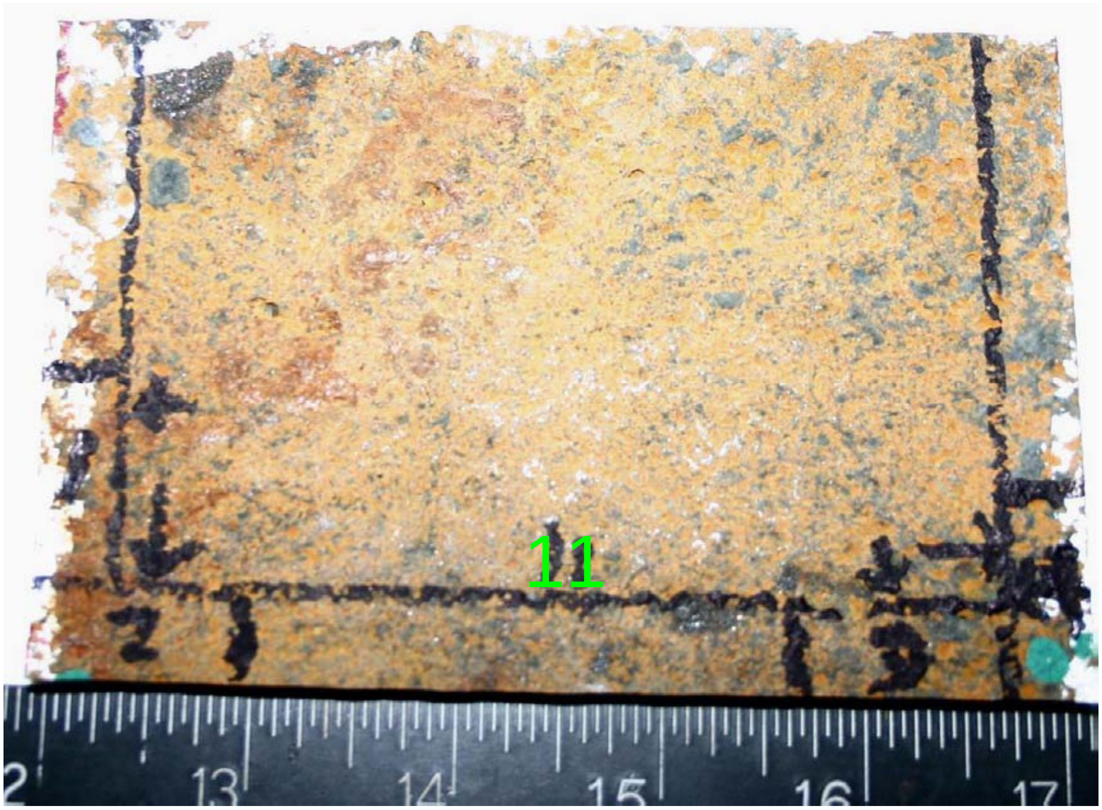
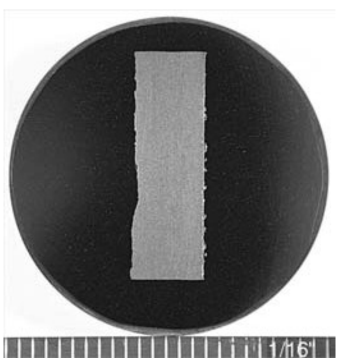
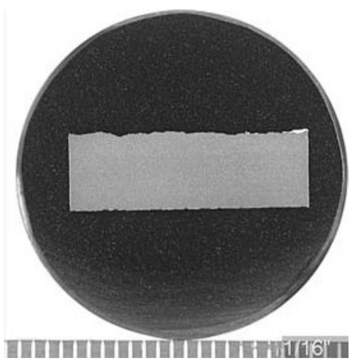
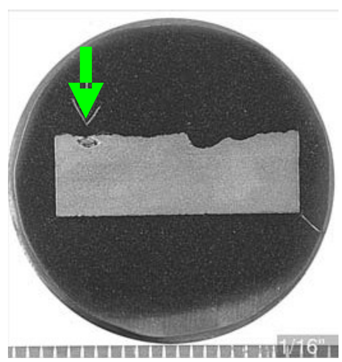




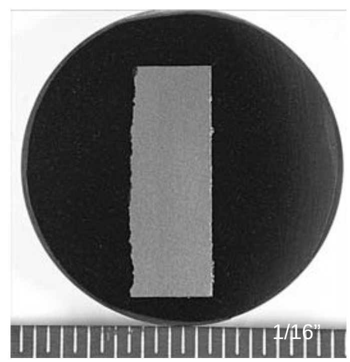
MOUNT #1
THE ESTIMATED MINIMUM WALL THICKNESS IS ~19/64" (0.296").



MOUNT #2
THE ESTIMATED MINIMUM WALL THICKNESS IS ~21/64" (0.328").



MOUNT #3
THE ESTIMATED MINIMUM WALL THICKNESS IS ~19/64" (0.296").
THE ARROW INDICATES AN UNDERCUT PIT.



MOUNT #4
THE ESTIMATED MINIMUM WALL THICKNESS IS ~11/32" (0.343").

FIGURE 14, SAMPLE "A", 1ST METALLOGRAPHIC SAMPLES, 2% NITAL MACRO-ETCH.
ALL SAMPLES ORIENTED BASED ON THE AS-RECEIVED "TOP" MARKING.
THE ESTIMATED UNAFFECTED "NOMINAL" WALL THICKNESS OF THE PLATE IS ~3/8".

Figure CE-5A

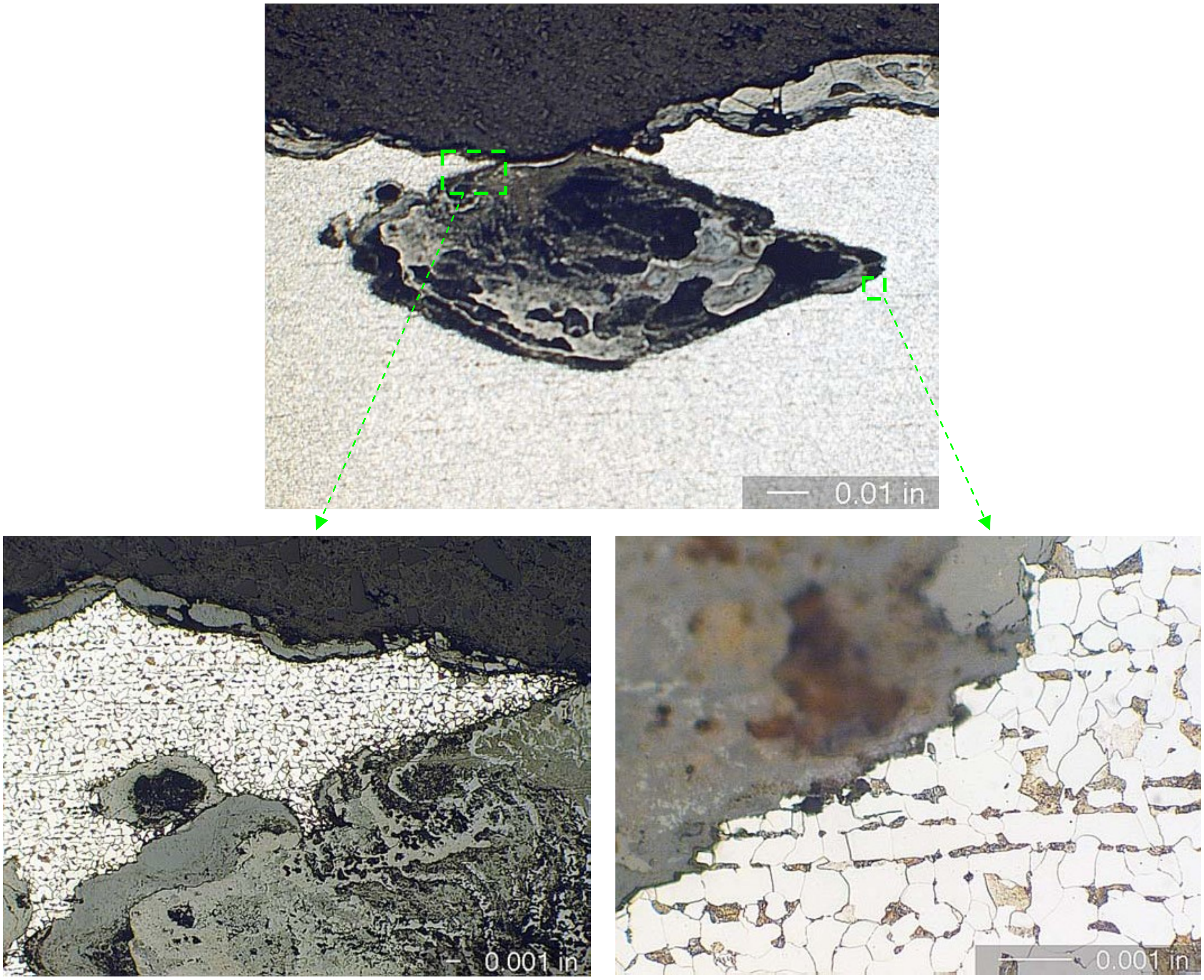


FIGURE 17, SAMPLE " A" , QUADRANT 11, SECTION #3, UNDERCUT OD PIT, 2% NITAL ETCH.

Figure CE-5B

Table 4, Section Chemical Analysis via Standardless SEM-EDS*- performed by C. Holp.

Test Sample^	Chemical Composition, Wt. %														
	O	Na	Mg	Al	Si	S	K	Cl	Ca	Ti	Cr	Mn	Fe		
"A", Q11-#3, Pit-1	23.3	ND	ND	ND	0.3	ND	ND	ND	0.3	ND	ND	0.3	76.6		
"A", Q11-#3, Pit-2	19.0	ND	ND	ND	0.6	ND	ND	ND	ND	ND	ND	0.3	80.2		
"A", Q11-#3, Pit-3	23.7	ND	ND	2.7	1.8	ND	ND	ND	0.5	ND	ND	1.2	70.0		
"B", Q10-#3, Pit-1	ND	ND	ND	ND	0.4	ND	ND	ND	ND	ND	ND	0.6	99.0		
"B", Q10-#3, Pit-2	18.3	ND	ND	0.9	0.6	ND	0.3	ND	0.2	ND	ND	0.4	79.2		

Notes: *The samples were reviewed utilizing Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDS). Any quantitation of spectra is calculated by a Standardless EDS analysis program. Due to the nature of the technique all values should be considered approximations and "For Information Only".

^Metallographic sections, as-polished with aluminum oxide.

ND = Not Detected.

The highlighted line is applicable to Figure CE-5B

Figure CE-5C

Figure CE-6

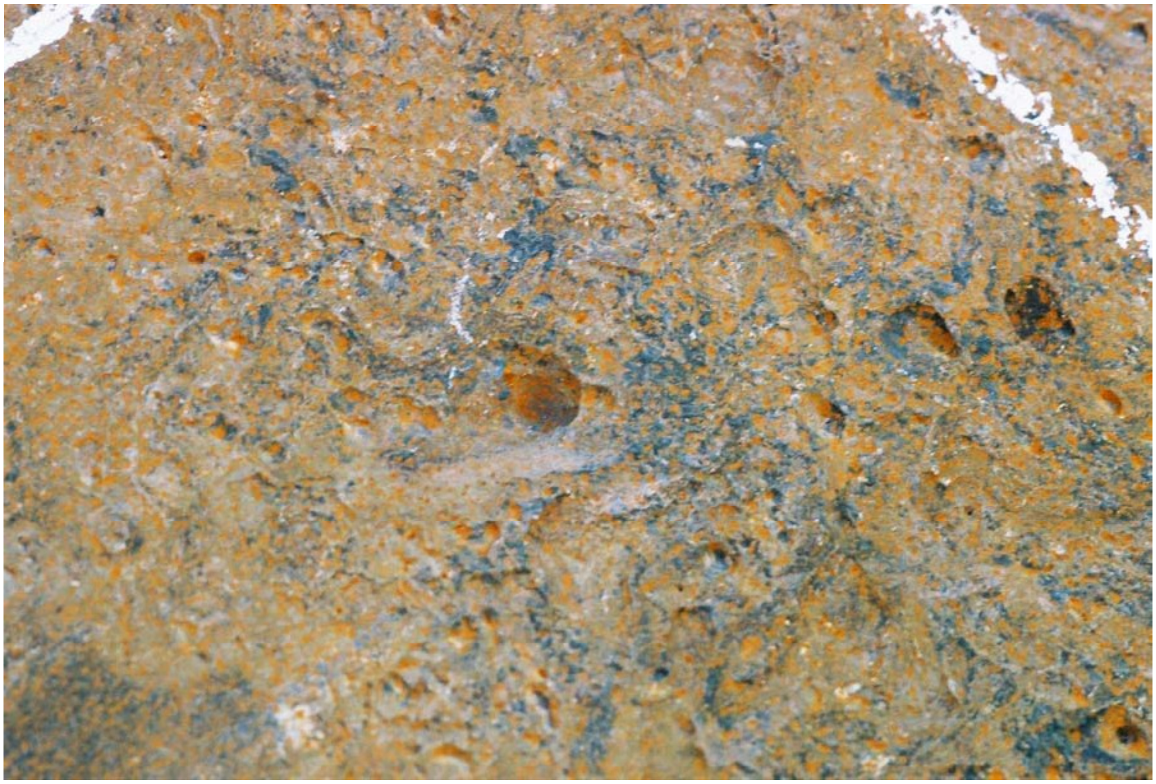
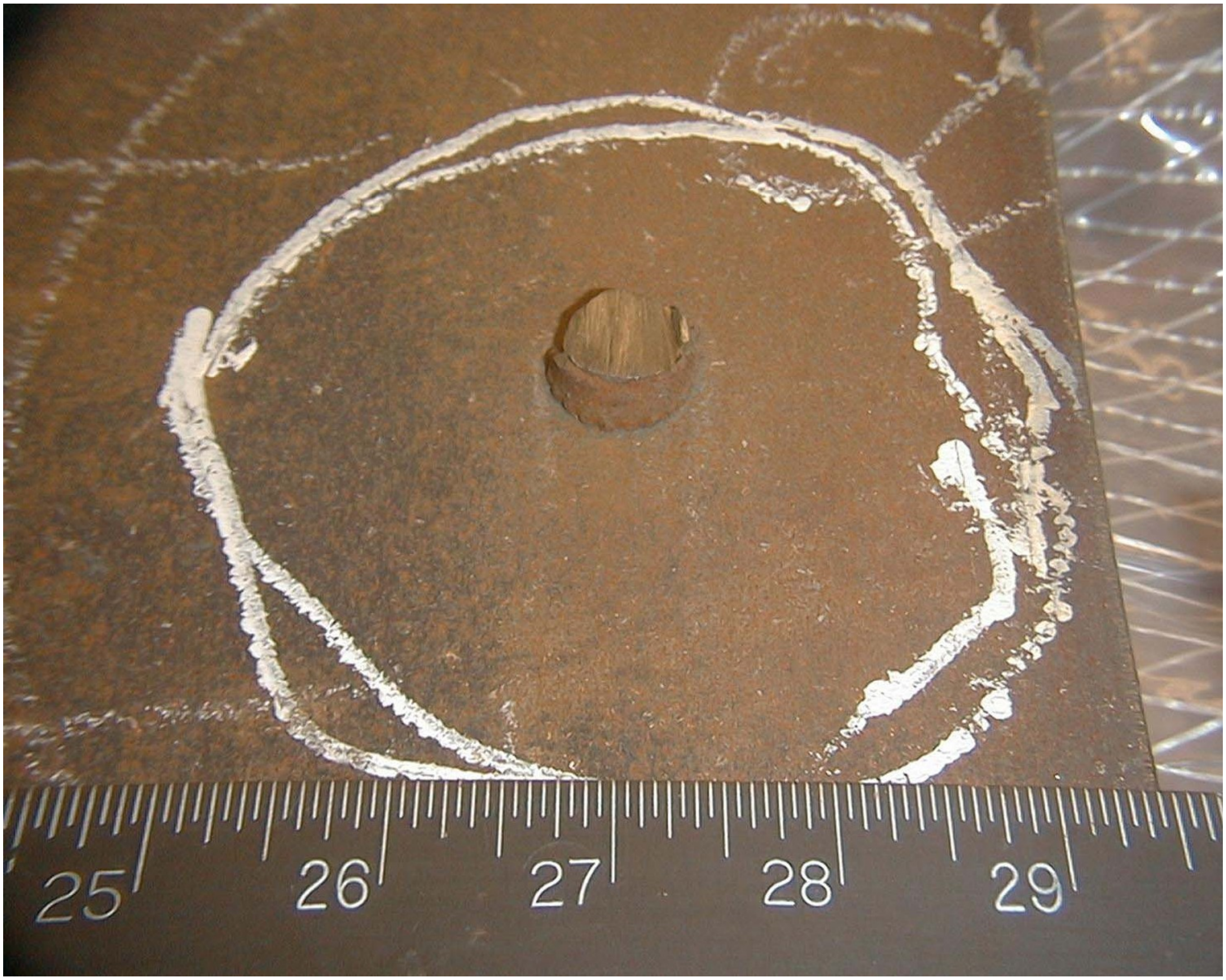
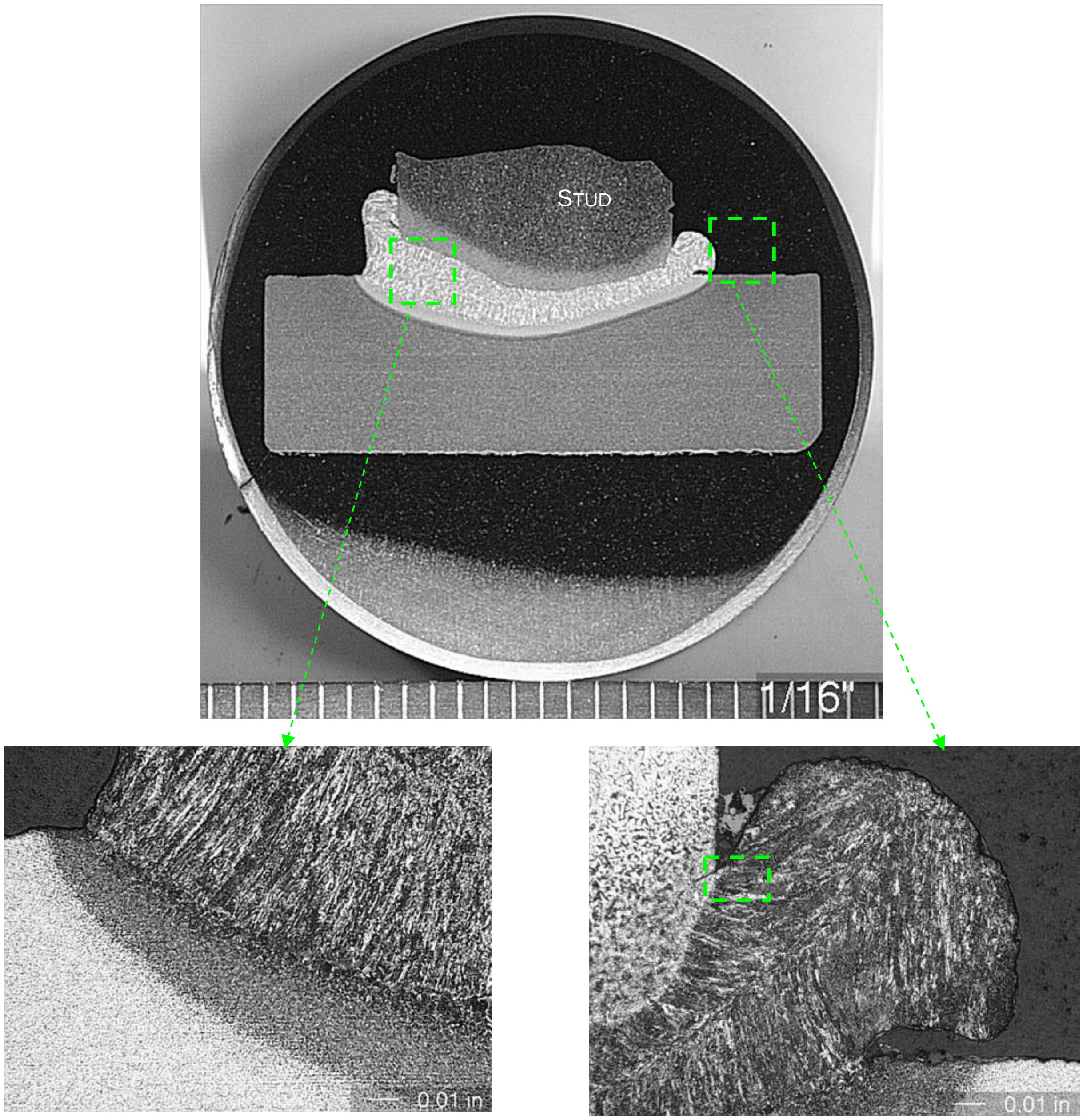


Figure CE-7



CE-8



HEAT AFFECTED ZONE (HAZ) AND COARSE-GRAINED METAL TYPICAL OF A STUD-WELD.

EXTRUDED FLASH TYPICAL OF A STUD-WELD; A SMALL CRACK-LIKE INDICATION IN THE STUD IS BOXED.

CE-9

Attachment 11

Shaw Stone & Webster Report

(23 pages)

Stone & Webster, Inc.

100 Technology Center Drive
Stoughton, MA 02072-4705
617.589.2952
Fax: 617.589.2969

Shaw® Stone & Webster, Inc.

First Energy Nuclear Operating Company
Beaver Valley Power Station
PO Box 4
Rt. 168, BV-RSGP
Shippingport, PA 15077-0004

March 13, 2006

J.O. No. 10117310
SW-BV-0832

WBS: 5.1.3

Response Required: No

Attn: Mr. Robert J. Dulee
(Total pages: 1+enc.)

LINER EVALUATION DEGRADATION
FINAL REPORT TRANSMITTAL
BEAVER VALLEY REPLACEMENT STEAM GENERATOR PROJECT

Attached please find the Containment Liner Degradation Report that was prepared as requested by FENOC. The report determined that the thickness of the remaining metal is adequate to maintain the design safety function of the liner as a leak tight membrane.

If you have questions or require additional information, please contact either the under signed at (617) 589-2952.

Sincerely,

D E Graves

D. E. Graves
Project Engineer

Enc.

cc: T. Sockaci – FENOC
S. Buffington – FENOC
N. Hanley – S&W
W. Griffith – S&W
S. Macie – S&W
W. Pananos – S&W
P. Ward – S&W

Containment Liner Degradation

First Energy Nuclear Operating Company

Beaver Valley Unit 1

Revision 0

Prepared by: Patrick W Ward Patrick W Ward **Date** 3-10-2006

Reviewed by: William J. Pananos WILLIAM J. PANANOS **Date** 13 MARCH 2006

Reviewed by: Arthur Stein **Date** 3-10-2006

Approved by: D E Graves DEGraves **Date** 3/13/06

Shaw Stone & Webster, Inc
Stoughton, MA 02072

Abstract/Summary

During the creation of a construction opening for the Beaver Valley Unit 1 Steam Generators and Reactor Head replacements, the liner was found to have several areas of degradation of which two were determined to require further evaluation. The degradation ranged from areas of deep pitting to areas of liner thinning. The maximum metal loss in the pitted areas was approximately one half the nominal containment liner wall thickness. This was documented by FENOC in Condition Report CR Number 06-01122.

Design basis calculations originally developed for the Beaver Valley Unit 1 containment liner and Attachment 1 are used to demonstrate that the degraded conditions found on the liner do not adversely affect its mechanical/structural function as a leaktight membrane. The evaluation determined that stresses in the liner in the pitted areas meet the acceptance criteria. The evaluation concluded that in service inspection in accordance with the ASME XI should incorporate additional inspection activities as defined in this report.

Table of Contents

Introduction

During the creation of a construction opening for the Beaver Valley Unit 1 Steam Generators and Reactor Head replacements, the liner was found to have several areas of degradation of which two were determined to require further evaluation. The degradation ranged from areas of deep pitting to areas of liner thinning. The maximum metal loss in the pitted areas was approximately one half the nominal containment liner wall thickness. This was documented by FENOC in Condition Report CR Number 06-01122.

This evaluation will review the characterizations of the areas of the containment liner with degradation/corrosion. The characterizations identify the extent of the corroded areas, the remaining liner thickness of the corroded areas, the maximum depth of pits, the thickness of the surrounding liner and other parameters that may impact the containment liner structural performance as a leaktight membrane. The evaluation uses in-situ information and existing FENOC analyses to determine the effects of these areas on the liner function during the postulated DBA and on the ILRT. The evaluation will provide a recommendation for augmented liner inspections under the ASME XI ISI program.

This evaluation considers the results of the FENOC's NDE evaluations and the current calculations 8700 – DSC – 156W, Revision 0, "Liner Minimum Wall Thickness" and 11700-EA-41, Revision 0, "Liner Stress Analysis" to determine the effects of these and other likely corroded areas on the liner function during the postulated DBA and on the ILRT. This data was provided in Design Input Transmittal DIT-Cont-Liner Evaluation, dated 3/4/06 and transmitted by FENOC letter ND1MDE:0338. In addition, the evaluation considers the impact of the additional 20 years of operation as a result of license renewal on the recurring ILRT loading.

Conclusions/Recommendations

This evaluation concludes that the design basis for the containment liner was not adversely affected by the degraded conditions observed on the containment liner. The thickness of the remaining sound metal is adequate to maintain the design safety function of the liner as a leaktight membrane. In addition, the capacity of the concrete containment structure to withstand the Design Basis Accident pressure is not adversely affected by the degraded conditions of the containment liner.

The recommended actions to supplement this evaluation should be implemented in the ASME XI, Sub-Section IWE inspection program. Since Areas 1 and 2 discussed in this report have been replaced with new plate material, the recommendation applies to Area 3. These actions are augmented inspections of Area 3 and documented to date to establish that there is no ongoing corrosion. Examination methods for the augmented inspection areas shall comply with the following criteria.

> The ultrasonic thickness measurements are to be performed using one foot square grids. The number and locations of the grids are to be determined by the Owner. The location of the minimum wall thickness shall be marked such that periodic reexamination of that location can be performed in accordance with the requirements of Table IWE-2500-1, Examination Category E-C.
>
> The area of degradation should be mapped on the inside of the containment liner. This area is to be UT examined with the area of minimum thickness clearly marked for future examinations. The area is to be examined the next 3 inspection periods. If no changes in the liner thickness are identified after the 3 inspections, the area will require no additional inspections. If a change is noted than a follow up engineering evaluation shall be performed.

FENOC ASME XI program should also include the requirement to perform UT examination on any suspected areas of corrosion, such as where paint is blistering and demonstrated to be related to potential liner degradation mechanisms.

Technical Analysis

General Discussion

The BV-1 containment structure is a conventionally reinforced concrete structure with a $^{3}/_{8}$ inch thick carbon steel leaktight membrane on the interior surface. The liner in the area of interest is SA516 Grade 60. The liner is attached to the concrete structure with Nelson headed studs. The containment liner was used as the inner form during containment construction. As such the exterior surface is in direct contact with the concrete.

The replacement of the Steam Generators and Reactor Vessel head requires a construction opening be created in the mid-height of the containment structure consisting of the removal of the concrete and reinforcing steel as well as the containment liner. The concrete was removed by hydrolasing which removes the concrete without degrading the reinforcing steel, Nelson headed studs, or the containment liner. After hydrolasing the steel surface appears as if it were sand blasted, removing all residues of corrosion products which may have been present during operation. Figures 1 and 2 present the general area after concrete and reinforcing steel removal.

Figure 1: BV-1 Containment Construction Opening (Area 2)

Figure 2: BV-1 Containment Construction Opening (Area 1)

Hydrolasing Pattern

The light and dark geometric patterns on the liner plate (Figures 1 and 2) appear to be the result of the hydrolasing method. The areas between the reinforcing steel were subject to the full hydrolasing blast, consisting of nozzle water pressure on the order of 20,000 psi, whereas the areas behind the reinforcing steel was shadowed from the direct blast. The shadowed area allowed for the concrete removal while minimizing the removal of surface oxidation. The lighter surface area is similar to a surface prepared using SSPC-SP6 Commercial Blast Cleaning.

Figure 3 presents similar patterns present at another site during their NSSS component replacement. The concrete area was also removed using the hydrolasing method.

Figure 3: Containment Construction Opening at Another Site

BV-1 Degradation

Figure 4 shows the general configuration of the construction opening and several areas where degradation was observed.

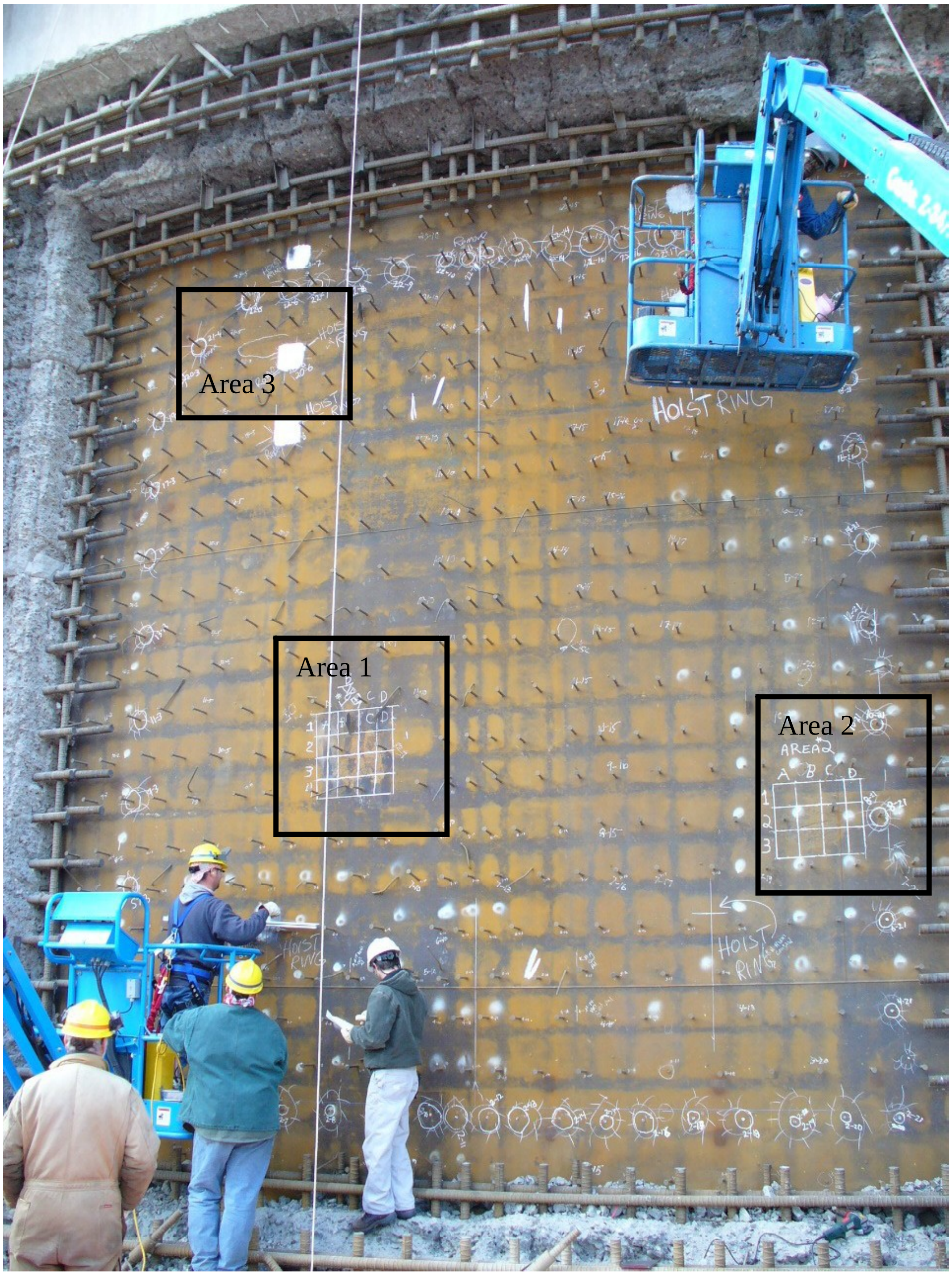


Figure 4: Layout of the Construction Opening and Areas of Interest

Three regions of degradation were found; of which only two areas were determined require further evaluation. Based on visual observations local pitting and general areas of liner thinning were present. The maximum pit depth was approximately one half wall thickness. These regions of degradation are presented in Figures 5 to 7.

Figure 5: Area 1, Degradation within the BV-1 Containment Construction Opening

Figure 6: Area 2, Degradation within the BV-1 Containment Construction Opening

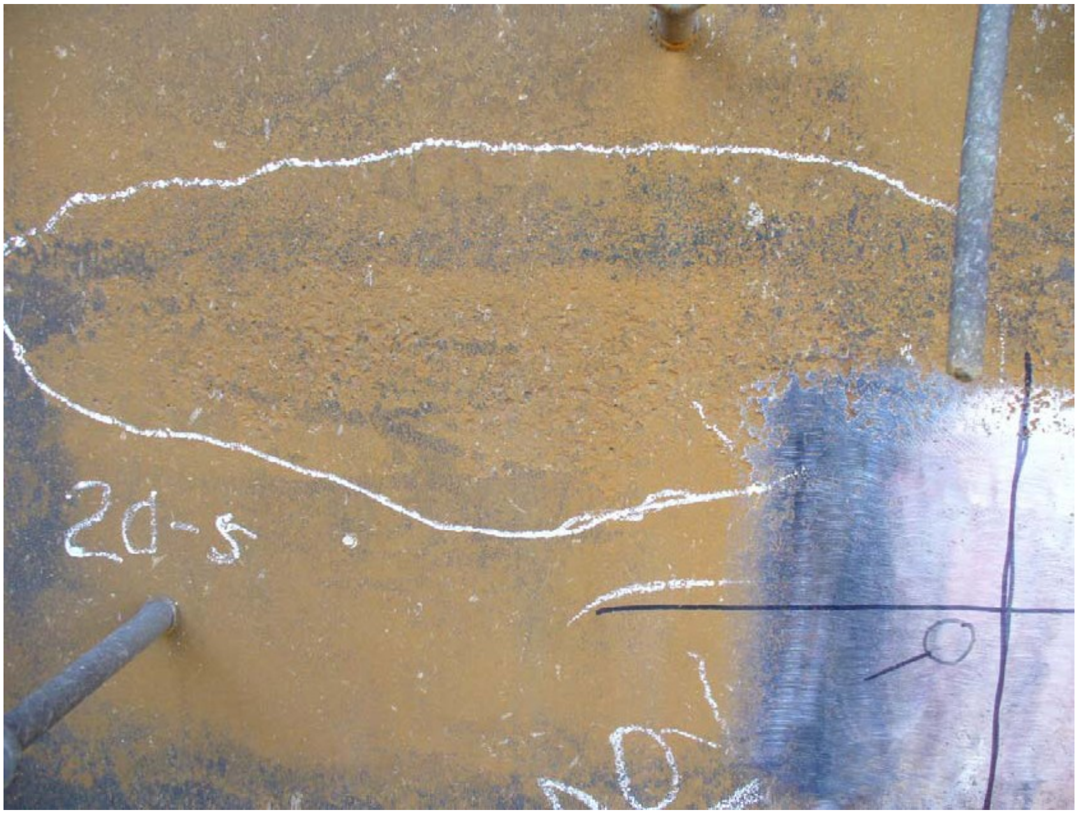


Figure 7: Area 3, Oval of General Near Surface Corrosion within the BV-1 Containment Construction Opening

Evaluation

Liner Environment and Sources of Degradation

The outside surface of the containment liner was exposed to varying environmental conditions during construction and operation, which may contribute to the conditions observed in Figures 5, 6, and 7.

During construction the unprotected liner plate was exposed to the ambient environment prior to erection into its final configuration and prior to concrete placement, a period of up to 2 years, during which time corrosion may begin where conditions were favorable. The process of assembling the plates into the final configuration and placement of the reinforcement and concrete presented additional opportunities for damage to the plate by random welding arc strikes, impact by other plates and rebar while they were being lifted into place, abrasion from tools, lifting hardware, and concrete placement operations. Any of these actions could result in surface gouges and/or the removal of the oxide coating adhering to the liner plate at the point of impact, inducing additional corrosion at that location.

As part of the construction of the temporary opening, Bechtel issued NCR 040, which describes a liner condition indicative of fabrication and/or construction induced surface irregularities. During construction of the containment liner wind bracing and stiffeners were provided until the containment shell concrete was placed. Typically the wind bracing was constructed on each ring, approximately 4 ft below a weld seam. The wind bracing also provided a work platform that supported construction activities such as fit-up, welding, NDE, etc. The locations of the defects described in NCR 040 are in this general area. The removal of the wind bracing by arc gouging, grinding, etc. could have resulted in these types of defects.

Once the concrete placed against the exterior surface of the liner has cured, an alkali environment having a pH, typically greater than 12, is formed, significantly reducing the corrosion rate of carbon steel. NRC Information Notice 2004-09: "Corrosion of Steel Containment and Containment Liner" states that "in some instances, corrosion has been found at higher elevations of the liner plates. Generally, the instances of such corrosion have been associated with foreign objects (wooden pieces, workers' gloves, wire brush handles, etc.) lodged between the liner plate and the concrete. As the corrosion is initiated in the areas not visible during visual examinations, such instances of corrosion were found when corrosion had penetrated through the liner thickness. Some licensees have performed ultrasonic examination of the suspect areas (area of obvious bulging, hollow sound, etc.) to detect such corroded areas."

During placement, the concrete was vibrated to consolidate it to eliminate voids and provide immediate contact and subsequent bond after curing, with the reinforcement, liner stud anchors, and liner. Should concrete voids remain adjacent to a metallic surface following placement, corrosion may have occurred due to the presence of moisture and oxygen. The long term presence in a void of residual water from the concrete paste is

unlikely since it is will be absorbed by the porous concrete and contribute to continued hydration of the concrete.

The bond immediate contact or bond between the liner plate and the concrete may be broken during the cyclic heating and cooling of the liner plate prior to placement of the concrete dome. This loss of bond immediate contact or during construction may have provided a source of moisture resulting from continued concrete placement activities as well as normal precipitation which could have accessed the back of the liner prior to completion of the dome.

Measurements taken during the original construction Structural Integrity Test (SIT) document that the concrete was cracked due to the strain induced during the pressurization. The concrete cracks open up to 0.01 to 0.02 inches at test pressure and has a minor residual crack width upon depressurization. Subsequent Integrated Leak Rate Tests (ILRTs) result in the reopening and closing of these cracks. The cracked concrete provides a hypothetical route for moisture making its way through the concrete cracks to the liner surface, but such moisture would be absorbed by the concrete before it made its way through 4½ ft wall thickness, or 2½ ft dome thickness. During normal plant operation the liner temperature may rise to between 90 ^{o}F and 100^{o}F, according to the Unit 1 Technical Specifications. This higher temperature has the effect of driving the water in the concrete pores away from the heated liner surface to the cooler exterior concrete surface, reducing the supply of moisture required for corrosion. This process would likely be accelerated in winter when the cooler outside temperature and lower vapor pressure (humidity) creates a higher stimulus for moisture migration.

In summary, there were many opportunities for liner corrosion to occur during fabrication and construction of the containment, but relatively few possibilities for corrosion to proceed during normal plant operation. The development of the alkali environment and absence of moisture source is demonstrated by the general condition of the containment liner plate and reinforcing steel. With the exception of the three areas of liner degradation the liner and reinforcing steel were found free of degradation.

Observed Degraded Conditions

FENOC Condition report CR-06-01122 described the liner corrosion as follows:

> "Observation of the exposed backside of the containment liner plate following hydrolasing revealed two areas of degradation. (See Figures 1, 2 and 4). The degradation comprised general surface pitting that varied in depth and diameter over each of the areas (approximately 16 inches by 18 inches each). Additionally, one area (Area 2) exhibited a continuous depression of 7 to 9 inches in length and ½ to ¾ inches in width. The areas were approximately 15 feet distant from one another, and approximately 10 feet above the work platform surface (EL. 765+)."
>
> "The cause mechanism is not known, but it is concluded that the condition was pre-existent and did not result from concrete removal. It is also concluded that the

pitting is not thru-wall since no seepage on the inside surface of the liner was reported during the hydrolasing. Seepage would almost certainly have occurred due to the high pressure water stream. Consequently, the liner is considered to remain leaktight and structurally sound for both fuel movement and completion of liner removal."

Figures 5, 6 and 7 and FENOC UT Erosion/Corrosion Examination reports, BOP-UT-06-025 and 026, document the results of UT scanning of the two areas of interest. The reports show the deepest pit in Area 2 resulting in a liner thickness of 0.151 inches where the surrounding plate thickness is 0.376 inches. The deepest pit in Area 1 results in a liner thickness of 0.225 inches. Both pits are on the order of $^{1}/_{4}$" to $^{3}/_{8}$" inches in diameter as described in the two Examination Reports. The extent of the general thinning in Area 1 has bounding dimensions of 10" x 2" with a liner thickness of 0.30 inches and the continuous depression in Area 2, described in CR-06-01122 above, has a liner thickness of 0.30 inches with isolated pits having a reduced liner thickness of 0.25 inches. In general, the liner plate was essentially free of degradation as seen in Figures 1, 2, and 4, indicating that the concrete acts to mitigate corrosion of the carbon steel liner, and the corrosion processes are isolated.

Bechtel NCR 040 identifies 20 liner surface depressions with the largest having the dimensions 1½ " x ¼" x $^{1}/_{16}$" deep.

The observed corrosion conditions described in the NCR and in this subsection are addressed by referencing the liner design analyses for Unit 1 and supplemental evaluations.

Stress and ASME IWE Acceptance Criteria

The objective of this report is to evaluate the effects of the observed liner plate degradation, consisting of pitting and general area plate thickness loss, on the containment liner structural performance as a leaktight membrane. The containment liner is subjected to pressure and temperature loads associated with the SIT and ILRT, normal operation at sub-atmospheric pressure, and normal operation at atmospheric pressure, and the hypothetical Design Basis Accident. For each of these loading conditions the acceptance criteria are provided in UFSAR Table 5.2-13 and the pressure and temperature loadings are summarized below.

Load Case	Pressure	Temperature
Accident	45 psig	280 °F (UFSAR Fig. 14-2.36)
Test (SIT)	52 psig	75 °F to 105 °F
Test (ILRT)	43.3 psig	75 °F to 105 °F
Sub-atmospheric Operation	-6.7 psig	75 °F to 105 °F
Atmospheric Operation	12.8 psia to 14.2 psia (New Tech Spec Limit)	70 °F to 105 °F (New Tech Spec Limit)

In addition to these mechanical loadings, the requirements for in-service visual inspections of the liner condition as reflected on the surface areas, including welds and base metals, as defined in ASME XI, Subsection IWE, must be met.

Article IWE-3000 Acceptance standards state that examination results revealing flaws or areas of degradation not meeting "the acceptance standards listed in Table IWE-3410-1 shall be acceptable for continued service without the removal or repair of the flaw or area of degradation or replacement if an engineering evaluation indicates the that flaw or area of degradation is nonstructural in nature or has no unacceptable effect on the structural integrity of the containment." It further states that if supplemental examinations determine that "the thickness of the base metal in local areas is reduced by no more than 10% of the nominal plate thickness or the reduced thickness can be shown by analysis to satisfy the requirements of the Design Specification, the component is acceptable by engineering evaluation."

The following calculations, which define the liner design basis, are used for the required engineering evaluation, cited by IWE, to assess the impact of the liner degradation on the liner structural performance as a leaktight membrane. These are:

- Calculation 11700-EA-41 BV-1 Reactor Containment Liner Stress Analysis
- Calculation 8700-DSC-156W Liner Minimum Wall Thickness

Two degraded conditions are evaluated, general thinning associated with the areas described previously and the pitting corrosion. They are evaluated for the loading conditions previously tabulated for the DBA and ILRT. Note that normal operation at sub-atmospheric and atmospheric pressure are enveloped by the ILRT for establishing the maximum liner in-plane tension load and the transverse loading on the remaining liner over the pitted areas. The postulated accident condition places the liner in compression along with the transverse loading on the remaining liner over the pitted areas.

General Area Thinning: Area 1 and Area 2 each have an extended trough each with reduced liner thicknesses of 0.30 inches. As shown in the referenced calculation 8700-DSC-156W, the minimum liner thickness for the general liner at the mid-height of the containment shell is 0.278 inches for the ILRT pressure and for the accident thermal and pressure loading. This thickness for the accident case is defined at the base of the cylindrical liner where it is completely constrained by the concrete shell.

The maximum accident case compressive stress is developed at the base-mat junction where the liner is essentially fully restrained for thermal loads due to the configuration of the containment wall with the containment mat. At the containment cylinder mid-height the compressive stresses are relaxed due to containment pressure expansion. Calculation 11700-EA-41 shows a maximum stress intensity of approximately -22 ksi at elevation 1465 inches which is at the dome cylinder intersection of the cylinder and a similar stress of -19.83 ksi at the cylinder mid-height. Using this stress and the equation for liner buckling on page 12 of calculation 8700-DSC-156W the thickness required to prevent

buckling of a 12” x 12” (the area bounded by the liner anchor studs) square liner plate would be 0.147 inches in the membrane zone of the containment, away from the restraint at the base.

Liner pitting is addressed by treating the liner over the pitted areas to be a circular plate clamped at the edges and subjected to transverse pressure, due to the ILRT or to the Accident condition, and to an in-plane compression due to the thermal expansion of the liner during the postulated accident. The results are summarized in the following table for a range of pit diameters and corresponding liner thicknesses and are additive to the other stresses in the liner, which is the membrane compression for accident conditions. These results have been prepared for this evaluation assuming full restraint of the liner due to thermal expansion which is shown in Attachment 1 to be the most severe condition. Thermal compressive stresses for the DBA loading are extracted for use in the evaluation described in the following table.

Pit Radius	Remaining Plate Thickness	Radial Bending Stress ILRT, 43.3 psi	Amplified Stress for Accident Case 45 psi
0.15 inch	0.0277 inch	1,009 psi	30,864 psi
0.15 inch	0.0478 inch	373 psi	436 psi
0.19 inch	0.0321 inch	1,160 psi	30,454 psi
0.19 inch	0.0478 inch	553 psi	703 psi
0.19 inch	0.151 inch	104 psi	108 psi
0.25 inch	0.039 inch	1,388 psi	28,779 psi
0.25 inch	0.0478 inch	942 psi	1,557 psi
0.3 inch	0.0441 inch	1,558 psi	30,188 psi
0.3 inch	0.0478 inch	1,335 psi	3,747 psi
0.35 inch	0.0489 inch	1,719 psi	30,820 psi
0.35 inch	0.054 inch	1,418 psi	3,454 psi
0.4 inch	0.054 inch	1,869 psi	30,039 psi
0.4 inch	0.0598 inch	1,507 psi	3,410 psi
0.45 inch	0.058 inch	2,015 psi	30,702 psi
0.45 inch	0.066 inch	1,563 psi	3,351 psi
0.5 inch	0.063 inch	2,115 psi	30,211 psi
0.5 inch	0.067 inch	1,846 psi	5,470 psi
0.75 inch	0.083 inch	2,733 psi	30,307 psi
0.75 inch	0.095 inch	2,078 psi	4,037 psi
0.75 inch	0.313 inch	241 psi	252 psi

These stresses apply to the lower section of the containment where the concrete cylinder constrains the liner when it is subjected to thermal expansion during the postulated accident. The steel plate is ASME SA 537 Gr B, with a value of Sm = 22,000 psi. For the accident loading condition of Dead Load and Concrete Constraint + Pressure + Temperature + DBE the allowable stress in the liner plate for combined membrane and bending is: 3 Sm = 66,000 psi. The maximum incremental bending stresses calculated must be added to the in-plane membrane stress equal to 36,000 psi, resulting in maximum combined stresses of approximately 66,000 psi. As shown in Attachment 1, the stresses in the containment membrane zone, where the concrete does not provide as much

constraint to the thermal expansion of the liner, are substantially less. The steel plate in this zone is ASME SA 516 Gr 60, with a value of S_m = 15,000 psi. For the accident loading condition, the maximum stress is approximately 20,000 psi, substantially below the allowable value of 3 S_m = 45,000 psi.

The current acceptance criteria in the 1998 edition of ASME III - Division 2, Table CC 3720-1 are limits on strain, not stresses, and the maximum allowable compressive strain for combined membrane and bending is 0.014 in./in. This strain is nearly 7 to 12 times the yield strain of SA 516 Grade 60 which as a yield stress of 32,000 psi or ASME SA 537 Gr B plate which has a 60,000 psi yield stress, respectively. Therefore, if the analysis were to be redone to current ASME criteria, plate sections thinner than those tabulated above would meet these acceptance criteria and be acceptable.

As this discussion has shown, the stresses in the liner at a hypothetical pit having a liner thickness on the order of 1/5 the minimum thickness identified in the surveys of the Beaver Valley Unit 1 liner, 0.151 inches, would be expected to meet the UFSAR acceptance criteria. Consequently, neither the structural integrity or pressure retaining capacity of the liner is challenged by the observed areas of degradation and no loss of liner function will occur.

Should adjacent pits merge to form larger pits, the liner thickness spanning the resulting pit would be limited to the smallest dimension tabulated above. If this process were to proceed to the extreme, covering a more extensive area, the limiting liner thickness would be 0.147 inches, as previously defined for a 12” x 12” area bounded by the anchor studs.

The additional ILRT loads to be applied to the liner, during the 20 year period of the license extension, do not adversely affect its fatigue capacity since these incremental stresses are very low for the actual liner thickness where pitting corrosion was observed. The slight variations in the future operating pressure from atmospheric pressure will produce stresses bounded by the ILRT pressure increment. In the absence of compressive stresses due to the accident thermal loading conditions, these stresses, which are less than 5 percent of the ILRT pressure, do not adversely affect the fatigue capacity.

The minimum liner as-found thickness was identified by the UT surveys as 0.151 inches for a pit with an approximate diameter of $^3/_8$ inches. For this case, the tabulated plate thickness for the pit with a 0.19 inch radius has been assigned the remaining as-found liner thickness of 0.151 inches, which is more than 3 times greater than the value of the thickness of 0.0478 inches, used to estimate an incremental stress of 703 psi due to the accident loading conditions. For a 3/8 inch diameter pit and thickness of 0.151 inches, the incremental stresses are less than 200 psi. Similarly, for the pits identified in Bechtel NCR 040, the limiting pit is taken as a circular pit with diameter of 1 ½ inches and liner thickness of 0.313 inches. There is no adverse effect on the containment liner’s structural integrity and function as a leaktight membrane as a result of the degradation identified.

Liner Examinations

ASME XI IWE-3122.4(b) states when flaws or areas of degradation are accepted by engineering evaluation the area containing the flaw or degradation shall reexamined in accordance with IWE-2420(b) or (c). IWE-2420(b) states when component examination results require evaluation of flaws, areas of degradation, of repairs in accordance with IWE-3000, and the component is found to be acceptable for continued service, the areas containing such flaws, degradation , or repairs shall be reexamined during the next inspection period listed in the schedule of inspection program of IWE-2411 or IWE-2412, in accordance with Table IWE-2500-1, Examination Category E-C. IWE-2420(c) states when the reexaminations required by IWE-2420(b) reveal that the flaws, areas of degradation, or repairs remain essentially unchanged for three consecutive inspection periods, the areas containing such flaws, degradation, or repairs no longer require augmented examination in accordance with Table IWE-2500-1, Examination Category E-C.

Table IWE-2500-1 for Examination Category E-C, E4.12 Surface Area Grid, Minimum Wall Thickness Location lists that 100% of the minimum wall thickness locations shall be examined during the first and each successive inspection period. The examination methods for the augmented examination areas shall comply with the following criteria.

The ultrasonic thickness measurements are to be performed using one foot square grids. The number and location are to be determined by the Owner. The location of the minimum wall thickness shall be marked such that periodic reexamination of that location can be performed in accordance with the requirements of Table IWE-2500-1, Examination Category E-C, which is stated above.

Since observed areas 1 and 2 have been repaired by replacement, only degraded Area 3 should be mapped on the inside of the containment liner. As discussed above, this area is to be UT examined with the area of minimum thickness clearly marked for future examinations. The area is to be examined the next 3 inspection periods. If no change the area will require no additional inspections. If a change is noted another engineering evaluation shall be performed.

FENOC ASME XI program should also include the requirement to perform UT examination on any suspected areas such as where paint is blistering and demonstrated to be related to liner degradation mechanisms.

References:

1. FENOC letter ND1MDE:0338 dated March 2, 2006 DIT-Cont Liner Evaluation, Beaver Valley Unit 1
2. 11700-EA-41, Rev. 0, dated November, 1971, "Reactor Containment Liner Stress Analysis"
3. 11700-EA-49, Rev. 0, dated November, 1971, "Stress and Buckling Analysis of the Liner Wall-Mat Junction and the Liner Skirt"
4. 11700-EA-50, Rev. 0, dated November, 1971, "Reactor Containment Liner Buckling Analysis"
5. 8700-DCS-156W, Rev. 0, dated February 26, 1991, "Liner Minimum Wall Thickness"
6. Inspection Report: BOP-UT-06-025, dated February 27, 2006
7. Inspection Report: BOP-UT-06-026, dated February 27, 2006
8. CR 06-01122 "Degraded Liner Plate Surface in Area of SGRO Access Opening"
9. BOP-VT-05-040, "Visual Examination of Removed Reinforcing Bar"
10. NCR-040, Bechtel Nonconformance Report "U1 Exterior Liner Plate"
11. Stone & Webster Inc. letter SW-BV-0731, "Verification of Corrosion Allowances"
12. ASME XI, Subsections IWE and IWL latest editions and addenda
13. NRC Information Notice 2004-09 "Corrosion of Steel Containment and Containment Liner"
14. "Detection of Aging of Nuclear Power Plant Structures" Draft, by D. J. Naus of the Oak Ridge National Laboratory and H. L. Graves, III of the U. S. N. R. C

CONTAINMENT LINER DEGRADATION
ATTACHMENT 1

Reference: Theory of Plates & Shells by S.P. Timoshenko, 2nd Edition
Articles 16 + 94

OBJECTIVE

Determine the effect of pitting corrosion on the incremental stresses in the remaining liner plate spanning over the pit. The pit is assumed to be circular and the liner plate spanning the pit is taken to be a circular plate fixed at the perimeter and loaded by an out-of-plane pressure, the SIT or Accident pressure. For the accident case, the there is an in-plane compression stress which acts to amplify the bending stresses in the circular plate.
The approach used in this evaluation is to determine the radial bending stresses in the periphery of the plate for the pressure load using the results in Article 16 of the Reference.

$(\sigma_{Radial})_{max} = 3 \times (3 + \nu)\, p\, a^2 / 8\, t^2$ where: ν is poisson's ratio, 0.30
p is the pressure load
a is the pit radius
t is the liner thickness over the pit

For the plate with a fixed perimeter, an additional stress equal to: $6\, p\, a^2 \div 8\, t^2$
is added to the maximum radial stress described above.
Note that the bending stress is proportional to the bending moment which is proportional to the curvature, or the second derivative of the deflection with respect to the radius.

The amplification factor to determine the effects of the in-plane compression due to the temperature rise in the liner during the accident is determined using Article 94 of the Reference. An approximation of the effects of the in-plane compression
The curvature for a transversely loaded circular plate with no in-plane compression is multiplied by the Stress Multiplier to account for in-plane tension. The curvature, and therefore the bending moment stress is multiplied by the factor identified below:

Art 94, eqn I $[1 + c''\alpha] / [1 - \alpha]$ is the SM. $c'' = -0.473$ From Table 81 for Uniform Load and clamped edges

and $\alpha = N a^2/14.68D$ N is assumed to be a membrane compression stress of **36,000 psi**, associated with the full restraint of the liner subjected to a 200 ^{o}F temperature increase.
This is typical of the condition of the liner at the base of the cylinder and is the governing condition.

$D = E\, t^3 \div 12\, (1 - \nu^2)$

Using the clamped edge boundary condition and the assumption of a transverse pressure equal to 45 psi, in combination with the compression stress and 43.3 psi with no compression for Test (ILRT) Condition.

The maximum stress due to the radial bending moment is determined from equation 71 in Article 16 and amplified by the factor in article 94. which accounts for the in-plane compression stresses.

Pit Radius	Plate Thickness	Plate Stiffness, D	45 psi Radial Bending Stress Accident Case	43.3 psi Radial Bending Stress ILRT	α	Amplified Stress for Accident Case
0.15 inch	0.0277 inch	56.20	1,048 psi	1,009 psi	0.9818	30,864 psi
0.15 inch	0.0478 inch	290.04	388 psi	373 psi	0.1902	436 psi
0.19 inch	0.0321 inch	88.09	1,205 psi	1,160 psi	0.9787	30,454 psi
0.19 inch	0.0478 inch	290.04	575 psi	553 psi	0.2972	703 psi
0.19 inch	0.151 inch	9143.37	108 psi	104 psi	0.0094	108 psi
0.25 inch	0.039 inch	157.53	1,443 psi	1,388 psi	0.9729	28,779 psi
0.25 inch	0.0478 inch	290.04	979 psi	942 psi	0.5284	1,557 psi
0.3 inch	0.0441 inch	227.30	1,620 psi	1,558 psi	0.9710	30,188 psi
0.3 inch	0.0478 inch	289.13	1,388 psi	1,335 psi	0.7633	3,747 psi
0.35 inch	0.0489 inch	310.15	1,786 psi	1,719 psi	0.9686	30,820 psi
0.35 inch	0.054 inch	418.17	1,474 psi	1,418 psi	0.7184	3,454 psi
0.4 inch	0.054 inch	406.66	1,942 psi	1,869 psi	0.9648	30,039 psi
0.4 inch	0.0598 inch	567.91	1,566 psi	1,507 psi	0.6909	3,410 psi
0.45 inch	0.058 inch	515.75	2,094 psi	2,015 psi	0.9629	30,702 psi
0.45 inch	0.066 inch	763.50	1,625 psi	1,563 psi	0.6685	3,351 psi
0.5 inch	0.063 inch	656.17	2,199 psi	2,115 psi	0.9603	30,211 psi
0.5 inch	0.067 inch	809.51	1,919 psi	1,846 psi	0.7784	5,470 psi
0.75 inch	0.083 inch	1495.00	2,840 psi	2,733 psi	0.9483	30,307 psi
0.75 inch	0.095 inch	2276.91	2,159 psi	2,078 psi	0.6227	4,037 psi
0.75 inch	0.313 inch	81044.85	250 psi	241 psi	0.0175	252 psi

Note that the thickness to diameter ratios exceed the limits for a thin plate, approximately 1:10, for the cases of the pit with 0.19" radius and for the pit with a 0.75" radius and 0.313 plate thickness. The approximation is valid for the other cases, which provide some perspective of the magnitude of the incremental stresses.

These stresses apply to the lower section of the containment where the concrete cylinder constrains the liner when it is subjected to thermal expansion during the postulated accident. The steel plate is ASME SA 537 Gr B, with a value of S_m = 22,000 psi.
For the accident loading condition of Dead Load and concrete constraint + Pressure + Temperature + DBE the allowable stress in the liner plate for combined membrane and bending is: $3 S_m$ = 66,000 psi The maximum incremental bending stresses calculated must be added to the in-plane membrane stress equal to 36,000 psi, resulting in maximum combined stresses of approximately 66,000 psi.

CONTAINMENT LINER DEGRADATION
ATTACHMENT 1

Consideration of the liner in the zone of the containment away from the constraint of the concrete cylinder at the base is a much less severe condition since the in-plane stress of 20,000 psi results in a lower bending stress amplification factor.

A few of the cases tabulated above are re-evaluated using an in-plane compressive stress of 20,000 psi instead of 36,000 psi.

			45 psi	43.3 psi		
Pit Radius	**Plate Thickness**	**Plate Stiffness, D**	**Radial Bending Stress Accident Case**	**Radial Bending Stress ILRT**	α	**Amplified Stress for Accident Case**
0.15 inch	0.0277 inch	56.20	1,048 psi	1,009 psi	0.5454	1,711 psi
0.19 inch	0.0321 inch	88.09	1,205 psi	1,160 psi	0.5437	1,962 psi
0.25 inch	0.039 inch	157.53	1,443 psi	1,388 psi	0.5405	2,337 psi
0.3 inch	0.0441 inch	227.30	1,620 psi	1,558 psi	0.5394	2,619 psi
0.35 inch	0.0489 inch	310.15	1,786 psi	1,719 psi	0.5381	2,883 psi
0.4 inch	0.054 inch	406.66	1,942 psi	1,869 psi	0.5360	3,125 psi
0.45 inch	0.058 inch	515.75	2,094 psi	2,015 psi	0.5349	3,363 psi
0.5 inch	0.063 inch	656.17	2,199 psi	2,115 psi	0.5191	3,449 psi
0.75 inch	0.083 inch	1495.00	2,840 psi	2,733 psi	0.5126	4,414 psi

The steel plate in this zone is is ASME SA 516 Gr 60, with a value of Sm = 15,000 psi.
For the accident loading condition, the maximum stress is approximately 20,000 psi, substantially below the allowable value of 3 S_m = 45,000 psi.

Attachment 12

MPR Associates Report

(6 pages)

MPR
ASSOCIATES INC.
ENGINEERS

March 13, 2006

QUALITY ASSURANCE DOCUMENT
This document has been prepared, reviewed, and approved in accordance with the Quality Assurance requirements of 10CFR50 Appendix B, as specified in the MPR Quality Assurance Manual.
Prepared by [signature]
Reviewed by [signature]
Approved by [signature]

Mr. Mark Manoleras
Design Engineering Manager
Beaver Valley Power Station
P.O. Box 4
Shippingport, PA 15077

Subject: Technical Review of Beaver Valley Containment Liner Corrosion

References:

1. BVPS Condition Report 06-01122, "Degraded Liner Plate Surface in Area of SGRO Access Opening," 2/20/2006.
2. Eldon R. Dille, "Beaver Valley Unit 1 Engineering Assessment Report 1R17 Exterior Containment Liner Corrosion," March 2006, DRAFT.
3. BETA Laboratory Report, Tracking No.: 14878, Plant & Unit: Beaver Valley Unit #1, Part: Containment Materials, 3/7/2006, DRAFT.
4. BVPS Technical Review, "Containment Liner Corrosion," 3/8/2006, DRAFT Rev. 4.

Dear Mr. Manoleras:

This letter documents the results of MPR's independent technical review of the containment liner corrosion at Beaver Valley Power Station. The BVPS containment is constructed from steel reinforced concrete with a 3/8-inch steel liner to provide a vapor barrier. Three areas of localized corrosion were found on the concrete side of the containment liner while removing an approximately 20-ft by 20-ft hatch section to create a temporary construction opening.

The specific cause of the corrosion has not been identified. Therefore, no definitive conclusion can be made as to whether the corrosion was active or passive at the time of the hatch removal. However, evidence exists to conclude the corrosion was most likely due to an initial construction defect such as a void adjacent to the liner. No evidence exists to suggest the corroded areas were supplied with the oxygen and water required to maintain activity over a long period of time. The corrosion was most likely inactive since the thickness of the concrete shell precludes any significant amount of air and/or water ingress.

The area with the greatest corrosion had a minimum measured thickness of approximately 0.150 inches. The liner requires a thickness of only 10-15 mils to maintain leak-tightness, and it has

been shown that the liner has significant leak area tolerance for through-wall holes. The structural integrity of the liner is not of concern. The concrete reinforcing steel carries the structural load of containment and was not affected by the liner corrosion. The vapor barrier function of the liner remained intact and has significant margin for any similar undiscovered liner corrosion. Therefore, the containment concrete, reinforcing steel, and liner design functions are not compromised by the liner corrosion.

MPR recommends that the BVPS technical review should focus on the fact that the structural integrity of the containment reinforcing steel was not affected by the liner corrosion. MPR concludes that BVPS's path forward (i.e., repair the corroded sections) and the current visual inspection procedures of the containment liner interior are sufficient to monitor and maintain the design function of the containment liner.

Please call Jim Nestell or me with any comments or questions regarding this letter.

Sincerely,

Scott Kiffer

Messrs. Manoleras and Ebeck:

Our official preliminary response will be sent in writing on Monday. This e-mail is to summarize our conversation this afternoon and provide a draft outline of our initial response, for informational purposes.

The specific cause of the corrosion has not been identified. As such, no definitive conclusion can be made as to whether the corrosion cells were active or passive. However, sufficient evidence exists to conclude the corrosion was most likely due to an initial construction defect and is no longer active. The laboratory analysis indicates the corrosion was due to general corrosion in a water and oxygen environment. Trace amounts of chlorides were found in the pits of one corroded area, but not in sufficient quantities to cause concern. Therefore, continued activity of the corrosion requires a renewable supply of water and oxygen.

However, the corroded areas are not considered to be subject to a renewable supply of reactants due to the following reasons:

- The corroded areas were not near the floor. Therefore, the initial source of water is considered to not have been due to defects in (or lack of) a moisture barrier, floor drains, or other equipment. Investigation of the debris pile did not indicate any foreign matter contamination.
- Periodic wetting of the liner due to water ingress from the concrete exterior is considered unlikely. As mentioned in the BVPS technical review, no significant driving head exists to cause water ingress. However, capillary action is not addressed in the current technical report. MPR considers water transport due to capillary action to be unlikely due to the random crack geometry, the thickness of the concrete, and the original water sealant applied during construction. Similarly, the concrete liner is not considered to be in contact with external air, which eliminates relative humidity and dew point condensation as a potential source of water.
- Embedded foreign material does not appear to be a likely source of moisture, based on examination of the concrete debris pile performed by BVPS and the separate incidences of corrosion exhibited by the three distinct regions.

It is MPR's opinion that the corrosion was most likely due to an initial construction defect and is no longer active. The laboratory analysis documented spherical voids about 1/16 – 1/8 inch in diameter in the concrete sample which was in contact with the liner. The voids are most likely due to defects during the original concrete pour. These voids provided an initial water and oxygen environment in the vicinity of the liner. Moreover, the steel liner was installed without removing the mill scale after fabrication. The mill scale combined with the oxygen and moisture from the voids, resulting in pitting corrosion initiating at local defects in the mill scale. It is MPR's belief that the corrosion was halted once the initial oxygen from the voids had been consumed and the concrete had fully cured.

Furthermore, the potential occurrence of additional similar corrosion cells at other locations cannot be eliminated. However, MPR believes that the identified corrosion (or similar undiscovered corrosion) does not compromise the design function of the containment liner due to the following reasons:

- The containment liner provides a leak-tight membrane but is not a structural member of containment.
- Although the structural integrity of the liner should be maintained, its structural integrity is not necessary for the containment structure concrete to fulfill its licensing basis. No corrosion of the concrete reinforcing steel was found in the vicinity of the liner

corrosion. Therefore, the containment concrete is not compromised by this method of liner corrosion, a fact which should be emphasized in the technical review.

- It has also been shown that only a negligible liner thickness is required for leak-tightness and that the liner may tolerate through-wall holes without significant radiological release.

Therefore, MPR concludes that BVPS's path forward (i.e., repair the corroded sections) and the current visual inspection procedures of the containment liner interior are sufficient to address the current corrosion and any similar, as yet undiscovered, corrosion.

Please feel free to call me on my mobile phone (given below) should you have any further questions this weekend.

Regards,

Scott D. Kiffer
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MPR
ASSOCIATES INC.
ENGINEERS

March 8, 2006
0321-0602-P001-00

Mr. Mark Manoleras
Design Engineering Manager
Beaver Valley Power Station
P.O. Box 4
Shippingport, PA 15077

Subject: Technical Review of Beaver Valley Containment Liner Corrosion

Dear Mr. Manoleras:

As discussed between you and Mr. Alex Zarechnak of MPR Associates, this letter describes a proposed scope of work for MPR to provide independent technical review of FENOC findings and conclusions concerning recently discovered containment liner corrosion at the Beaver Valley Power Station (BVPS).

Scope of Work

MPR engineers will provide independent technical review of inspection results, design analyses and structural evaluations, and probable root causes provided by FENOC related to the containment liner corrosion. The specific documents to be reviewed will be determined by FENOC but are expected to include the following:

- BVPS CR and its corrective actions that identify the as-found condition of the liner
- Eldon R. Dille and BETA Laboratory reports that characterize the type and extent of corrosion found on the liner samples
- BVPS containment liner technical report that performs a structural evaluation of the containment liner in the corroded condition and identifies the probable cause and extent of the corrosion

The purpose of the review will be to independently assess the procedures, methods, and approaches utilized and to identify recommendations for supporting the final conclusions.

Schedule

The proposed scope of work will commence immediately. A preliminary review response shall be provided by MPR on March 13, 2006; an initial reaction will be provided in a telephone conversation on March 11, 2006. The final review shall be completed by March 20, 2006.

Cost Estimate

This scope of work will be performed on a time-and-material basis using MPR standard rates, which are on file with FENOC. The actual cost will depend on the specific scope of review as assigned by FENOC. Direct costs and expenses such as travel, lodging, etc. will be billed at cost.

For budgeting purposes the estimated cost for the proposed scope of work is $12,000 including work at MPR offices and plant site. This budget will be reviewed and revised as needed at FENOC direction as the actual scope of the review effort becomes better defined.

Quality Assurance

The proposed scope of work will be performed per the requirements of 10CFR50 Appendix B, as contained in MPR's Quality Assurance Manual.

Please feel free to call Alex Zarechnak or me if you have any questions regarding this letter. MPR would be happy to discuss any issues covered in this proposal in order to better meet BVPS's needs.

Sincerely,

Scott Kiffer