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April 7, 2003
L-03-065

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555-0001

Subject: Beaver Valley Power Station, Unit No. 1 and No. 2
BV-1 Docket No. 50-334, License No. DPR-66
BV-2 Docket No. 50-412, License No. NPF-73
Revision 1 to Reply to Request for Additional Information Regarding Proposed Alternative Repair Methods for Reactor Vessel Head Penetrations (Relief Request No. BV3-RV-04)

On March 28, 2003, the FirstEnergy Nuclear Operating Company (FENOC) submitted a relief request for approval of a reactor vessel head penetration alternative repair method (embedded flaw repair). In the submittal, FENOC submitted Relief Request BV3-RV-04 to the requirements of Section XI of the ASME Code requesting authorization to use the embedded flaw repair technique. Following an initial review of the FENOC March 28, 2003 submittal (Ref. L-03-056), the NRC provided six questions regarding the FENOC relief request. Responses were provided in our response submittal (Ref. L-03-058, dated April 3, 2003).

During the NRC's review of the subject relief request, the staff identified a need for additional information to facilitate the review. Enclosed is a revised response to the questions which includes the additional information requested. Revision bars in the right hand column have been added to identify the changes.

BVPS has identified the need to perform repairs using the embedded flaw repair technique during the current 1R15 refueling outage. Therefore, expedited approval of this Code alternative is requested.

A047

No new commitments are contained in this submittal. If there are any questions regarding this matter, please contact Mr. Larry R. Freeland, Manager, Regulatory Affairs/Performance Improvement at 724-682-5284.

Sincerely,

Mark B. Bezilla

Enclosure

c: Mr. T. G. Colburn, NRR Senior Project Manager
Mr. D. M. Kern, NRC Sr. Resident Inspector
Mr. H. J. Miller, NRC Region I Administrator

Enclosure to L-03-065

Beaver Valley Power Station (BVPS) Unit 1 & 2
Rev. 1 to Responses NRC RAI Questions (Relief Request No. BV3-RV-04)

The responses that follow make use of comparisons with other Westinghouse 3-loop plants. The table below provides a geometric comparison that shows that Beaver Valley is comparable to these plants.

	Reference Plant	Beaver Valley Unit 1 & 2	North Anna Units 1&2
RPV Head Inner Radius	79.094 inches	79.094 inches	79.094 inch
RPV Head Thickness	6.188* inches	6.188 inches*	6.299 inch**
CRDM Nozzle OD	4.000 inches	4.000 inches	4.024 inch
CRDM Nozzle ID	2.750 inches	2.750 inches	2.748 inch
RPV Head Op. Temp.	597°F	595°F	600.1 °F

*minimum wall thickness **nominal wall thickness

The questions below refer to the licensee's request for relief dated March 28, 2003, for BVPS 1 and 2 (Relief Request No. BV3-RV-04; Ref. L-03-056).
(Note: Revision bars in the right hand column have been added to identify the changes from our previous RAI response L-03-058.)

Question 1. ***Page 2 of 4, item 2 states that unacceptable radial flaws will be sealed off with a 360 degree overlay of Alloy 52 covering the entire weld. Please discuss the pre-weld nondestructive examination (NDE) that will be performed to assure the entire location of the J-groove weld is identified to assure Alloy 52 extends past the weld into the butter. This is in reference to North Anna lessons learned.***

Response to Question 1:

WCAP-15986, dated March 2003, titled "The Embedded Flaw Process for Repair of Reactor Vessel Head Penetrations and Its Application at North Anna Unit 2" has recently been issued. This report is the final signed version of a draft report provided to NRC staff in October 2002 under Westinghouse letter LTR-SMT-02-81. Supporting information from this report is included in Appendix A. The WCAP was submitted via letter L-03-064 and does not contain proprietary information. An evaluation of the repairs at North Anna 2 was performed and corrective actions have been taken to address the issue of complete weld coverage. A brief summary of the BVPS actions is provided below. These actions have been integrated into the repair procedures to be applied at Beaver Valley.

The Westinghouse repair procedure includes a pre-welding step to positively identify the interface boundary between the J-groove weld material of 82/182 weld and the stainless steel cladding. This interface boundary is located with a ferrite meter hand held instrument that identifies this interface boundary. This technique was recently used successfully at the ANO Unit 1 head repair project, and has also been verified on Westinghouse mockups and a cancelled Westinghouse plant reactor vessel head.

The use of the ferrite tool to identify the boundary of the J-groove attachment weld was discussed and demonstrated at a meeting between the NRC and Entergy Operations, Inc. on October 16, 2002 (as docketed by the NRC on November 7, 2002; Reference Ascension Nos. ML 023120269 and ML 023170270). The purpose of that meeting was to discuss the planned ANO-1 reactor vessel head weld repair technique. The identification of the 82/182 material boundary portion of the weld repair process was described in slide 19 of the presentation and is comparable with that which will be implemented at Beaver Valley Unit 1. Slide 19 states that:

1) the boundary existing between 082 material and Stainless Steel clad will be identified using "ferrite" tool;
2) marks will be applied to the location of 082/182 Stainless Steel clad interface to identify the boundary;
3) personnel will be trained and qualified;
4) independent verification will be performed;
5) welds will overlap Stainless Steel clad by a minimum of one half inch;
6) written instructions will control the process.

At Beaver Valley Unit 1, the ferrite instrument model (FERITESCOPE MP30), supplied by Fischer Technology, Inc. will be used to perform the identification. The ferrite tool is being used as a "go/no go" gauge to identify the boundary. The ferrite meter is calibrated to be within a maximum of $\pm$ 1% Fe (iron) based on the known percentage of Fe. Markings will be applied to the location of the interface. Markings are made so as to allow the interface to be located as well as a boundary at least one half inch outboard of the stainless steel clad/82 interface. The repair weld is required, by procedure, to be a minimum of one half inch beyond the interface boundary. This Westinghouse repair procedure assures that the Alloy 52 repair weld material extends past the weld and onto the stainless steel clad. Personnel using the tool were recently trained on a cancelled Westinghouse plant reactor vessel head. Written instructions on the use of the ferrite tool are included in the Westinghouse repair procedure to be utilized at Beaver Valley.

Question 2. ***Page 2 of 4, item 4 states that the finished weld will be examined by dye penetrant, ultrasonic, or eddy current testing to ensure acceptability. Please be more specific as to what method will be applied by location.***

Response to Question 2:

The weld repair will be applied to the J-groove weld and the penetration tube outside surface below the weld. These post repair wetted surfaces will be examined by dye penetrant exam, using standard, visible dye, solvent removable, dye penetrant techniques. In addition, the penetration tube below the weld will also be examined from the inside tube surface using both Eddy Current (ECT) and Ultrasonic (UT) techniques. The ECT exam provides near surface data on the condition of the ID surface, while the UT exam provides data on the through wall tube condition. Both the ECT and UT techniques were successfully demonstrated during the latest EPRI/MRP blind mock-up tests.

Question 3. ***On page 4 of 4, under Precedent, the licensee states that the Nuclear Regulatory Commission had approved a similar alternative for North Anna Power Station, Unit 2 on January 23, 2003. This relief was granted based on the North Anna licensee providing information specific to its plant as its basis for justification of the relief request. Please provide the basis for items 1, 2, and 3 on page 3 of 4 under "Basis for Alternative Requirements." Basis should discuss stresses, cyclic fatigue, etc., as it pertains to BVPS Units 1 and 2.***

Response to Question 3:

The original wording of the relief request has been repeated below for items 1, 2, and 3 along with the basis, which appears below each item.

The embedded flaw repair technique is considered a permanent repair for the following reasons:

Item 1. As long as a Primary Water Stress Corrosion Cracking (PWSCC) flaw remains isolated from the primary water (PW) environment, it cannot propagate. Since Alloy 52 weldment is considered highly resistant to PWSCC, a new PWSCC flaw cannot initiate and grow through the Alloy 52 overlay to reconnect the PW environment with the embedded flaw. Structural integrity of the affected VHP J-groove attachment weld will be maintained by the remaining unflawed portion of the weld.

Basis

Alloy 690 and Alloy 52 are highly resistant to stress corrosion cracking, as demonstrated by multiple tests, as well as over ten years of service experience in replacement steam generators. Excerpts from WCAP-15986, referred to in response to Question 1, are provided as further background and information in Appendix A.

Item 2. The residual stresses produced by the embedded flaw technique have been measured and found to be relatively low. This was documented in the attachment to a letter from E. E. Fitzpatrick, Indiana Michigan Power Company (I&M), to the Nuclear Regulatory Commission, "Reactor-Vessel Head Penetration Alternate Repair Techniques" (letter AEP:NRC:1218A, dated March 12, 1996). The low residual stresses indicate that no new flaws will initiate and grow in the area adjacent to the repair weld.

Basis

The basis for this statement has been provided in both the D.C. Cook and North Anna Unit 2 relief requests. We note that this information is applicable to Beaver Valley because the penetration tubes for D.C. Cook are of the identical size as those of Beaver Valley. The measured data as submitted in WCAP 13998 and reviewed by the staff for D.C. Cook is applicable to the proposed Beaver Valley repair, and the resulting residual stresses are bounded by the D.C. Cook submittal.

It is also important to note that the thermal expansion properties of Alloy 52 weld metal are not specified in the ASME Code, as is the case for other weld metals. In this case, the properties of the equivalent base metal (Alloy 690) should be used. For that material, the thermal expansion coefficient at 600 degrees F is 8.2 E-6 in/in/degree F as found in Section II part D of the Code. The Alloy 600 base metal has a coefficient of thermal expansion of 7.8 E-6 in/in/degree F.

The effect of this small difference in thermal expansion is that the weld metal will contract more than the base metal when it cools, thus producing a compressive stress on the Alloy 600 tube. This beneficial effect has already been accounted for in the residual stress measurements reported in the technical basis for the embedded flaw repair, as noted in the references provided above.

Item 3. There are no other known mechanisms for significant flaw propagation in this region since cyclic fatigue loading is negligible.

Basis

The Fatigue Usage Factor for the CRDM region for the Beaver Valley Unit 1 CRDM Housings was determined to be 0.0972, which is negligible compared to the ASME Code allowable value of 1.0. The comparable fatigue usage for Unit 2 is 0.138. Therefore fatigue driven crack growth is not a mechanism for further crack growth after the embedded flaw repair process is implemented.

The small residual stresses produced by the embedded flaw weld will act constantly, and, therefore, will have no impact on the fatigue effects in this region. Since the stress would be additive to the maximum and minimum stress, the stress range will not change. The small usage factors noted above will not be affected.

The following questions/comments (Questions 4, 5 & 6) address the issue of residual stresses that may be induced on the nozzle inner diameter (ID) by the outer diameter (OD) weld overlay method. In particular, as related to possible extension of the embedded flaws and subsequent growth of ID surface flaws that could exceed American Society for Mechanical Engineers Boiler and Pressure Vessel Code flaw acceptance criteria:

Question 4. ***For the overlay weld repair approach, application of this repair on the nozzle outside surface will tend to cause a flaring of the nozzle open end and may induce tensile stresses on the inside surface of the nozzle. The request should describe the residual stress state on the inside surface post-repair and compare this state to that for the original as-fabricated condition, for the repair configuration that will be applied.***

Response to Question 4:

The application of the weld metal on the OD of the tube will have no tensile impact on the stresses on the ID of the tube, because the thickness of the weld metal is small compared to the overall thickness of the tube. If there is any impact at all, it will induce a compressive residual stress at the ID of the tube, just as the BWR weld overlay repairs do. The information provided in WCAP-15986 (excerpts included in Appendix A) and its references (WCAP-13998, which was part of the DC Cook information referenced in Question 3) also support these conclusions.

Question 5. ***Because the repair welding may induce tensile stresses on the nozzle inside surface and at mid-wall locations within the nozzle thickness, post-repair volumetric examinations may be necessary to demonstrate that the embedded flaw has not extended and to provide assurance that no cracks have been initiated on the nozzle inside surface. The request should discuss this issue, and if no post-repair NDE of the penetration ID will be performed, a justification for not performing such post-repair examinations should be provided.***

Response to Question 5:

As described in the response to Question 2, Beaver Valley plans to do a post repair volumetric NDE. Both ECT and UT methods will be used to assess both the surface conditions for incipient flaw growth on the ID surface and potential flaw extension resulting from the welding. Both the ECT and UT techniques have been successfully demonstrated during the latest EPRI/MRP blind mock-up tests. Note that residual stress measurements and analyses described in response to Question 3 indicate that crack growth, after the embedded flaw repair process is applied, should not occur. The post repair NDE examinations will confirm these conclusions.

Question 6. Considering residual, thermal and operating stresses, and the largest flaw that may be left on the nozzle inside surface post-repair, an analysis that demonstrates that this assumed flaw will not exceed the ASME Code flaw acceptance criteria of 0.75% through-wall prior to re-inspection should be provided.

Response to Question 6:

As stated above, the tensile stresses on the inside of the tube will be reduced based upon the compressive stresses from the OD imbedded flaw repair. As noted in the response to Question 3, item 2; the small difference in thermal expansion properties between Alloy 52 weld metal and Alloy 600 base metal results in a compressive stress adder on the penetration tube wall. This same conclusion was identified by the staff in the January 2003 letter to North Anna Unit 2 granting relief for application of an embedded flaw repair. Taking a conservative approach to this question, it was assumed that a flaw existed on the inside of the tube in the presence of the operational and residual stresses which exist before the repair occurs, and the analytical results are provided in Figures 1 and 2 (attached).

As noted in the response to Question 5, post repair NDE of the penetration tube base material will be performed. The NDE methods used for the detection of inner surface flaws have been demonstrated through the EPRI/ MRP inspection protocol to detect ID axial flaws which are 5% of the wall thickness (approximately 0.032 inches). (Reference EPRI MRP Inspection Demonstration Report, dated December 2, 2002).

As noted in the response to Question #3, the fatigue usage factor in this region is quite low, and fatigue crack growth is therefore not a concern.

To further support the conservatism of this assessment, flaws were postulated at a location 0.5 inch below the attachment weld, and at either the uphill or downhill location on the tube. The results are shown in the attached Figures 1 and 2, which were prepared from an existing analysis of a Westinghouse 3-loop plant of similar design and construction to BVPS Unit 1. The specific results that apply to the BVPS Unit 1 penetrations being repaired (numbers 50, 51, 52, and 53) are for angles of 38.6 degrees. The angle mentioned is the angle of intersection between the tube and the head.

The crack growth calculations shown here used a methodology consistent with the recently approved Section XI flaw evaluation approach, with a PWSCC crack growth law that is consistent with the MRP-55 report. Figure 1 shows the results for an axial flaw on the uphill side of the nozzle. Curves were developed for a range of nozzle angles, but the governing case for Unit 1 is for an angle of 38.6 degrees, which corresponds to the angle of the tubes in which indications were found. It can be seen that at least 4.25 years are required to grow a flaw from the threshold for initiation at 9MPA sq-rt-m to a depth of 75 percent of the wall thickness. This is a very conservative calculation because the inspection has shown that there are no flaws of any depth on the inside surface of the penetration, and because no benefit was taken for the compressive residual stresses induced by the weld repair.

Another measure of the conservatism is to look at the size flaw that would grow to the ASME limit of 75% of the wall thickness in one fuel cycle. From Figure 1, it can be seen that a flaw depth of over 30% of the wall would be required to have such growth.

A more general approach would be to consider all the tubes, regardless of where indications might be found. The most limiting penetration in Figure 1 is the 42.6 degree penetration, and for this case at least 4.2 years would be required to grow a flaw to the allowable depth of 75 percent of the wall thickness.

Figure 2 shows similar results for the downhill side of the nozzle, where the stresses are lower. Again, the governing case is for a 38.6 degree angle, and the time required to grow a flaw from the threshold for crack growth to a depth of 75% of the wall thickness is shown to be approximately 7.2 years. Note that the initial flaw size for this case is rather large, because the stresses are low in this region, and a large flaw must be postulated to reach the threshold for crack growth.

Again, a more general approach would be to consider all the tubes, regardless of where indications might be found. The most limiting penetration in Figure 2 is the zero degree penetration, and for this case at least 5.8 years would be required to grow a flaw to the allowable depth of 75 percent of the wall thickness.

In all the cases discussed here, the time for a flaw to grow to the allowable depth far exceeds one fuel cycle, and therefore should not be a concern.

Figure 1
Beaver Valley Unit 1 Stress Corrosion Crack Prediction for 0.5" Below Weld (Nozzle Uphill)
Longitudinal Inside Surface (Aspect Ratio = 6:1)

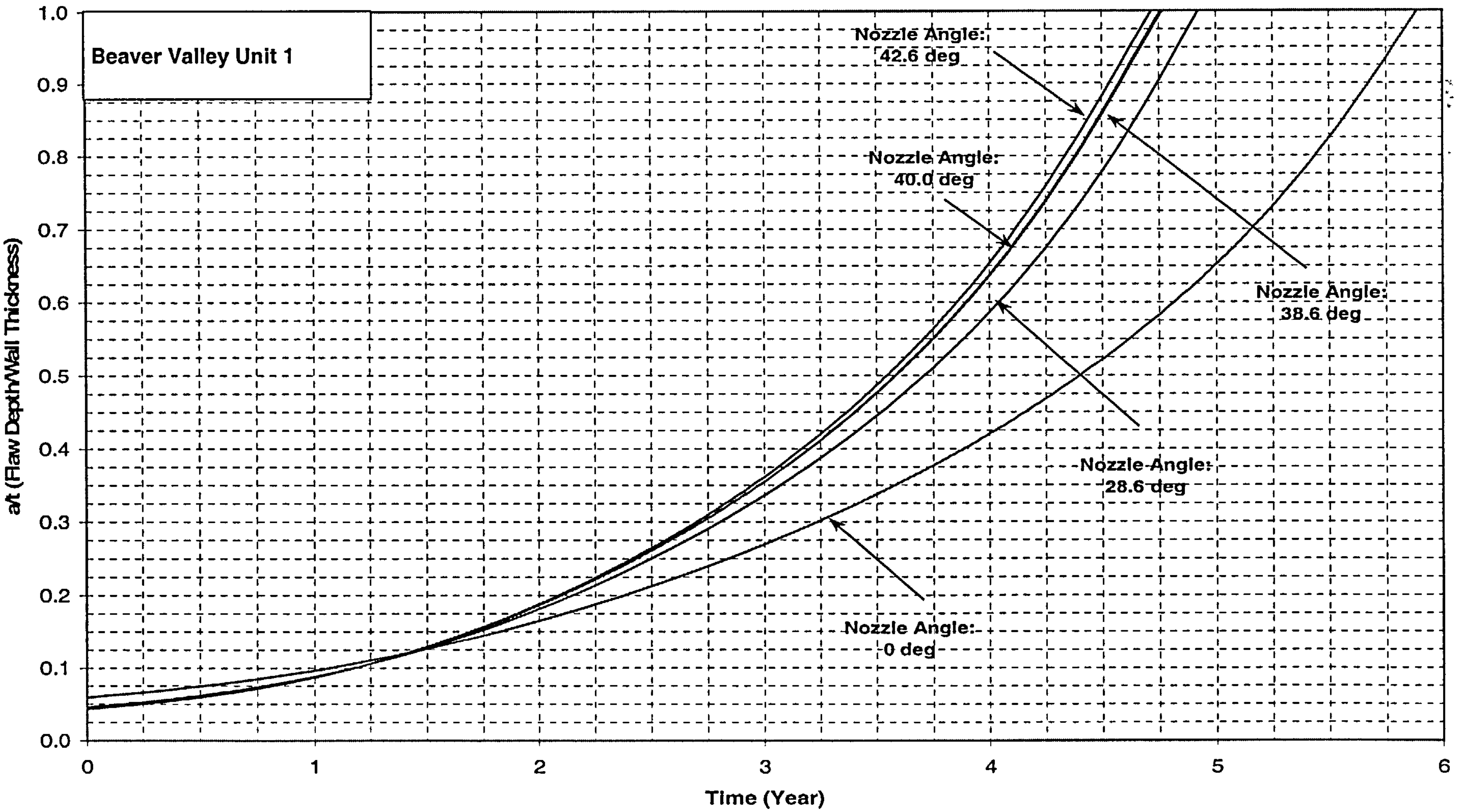
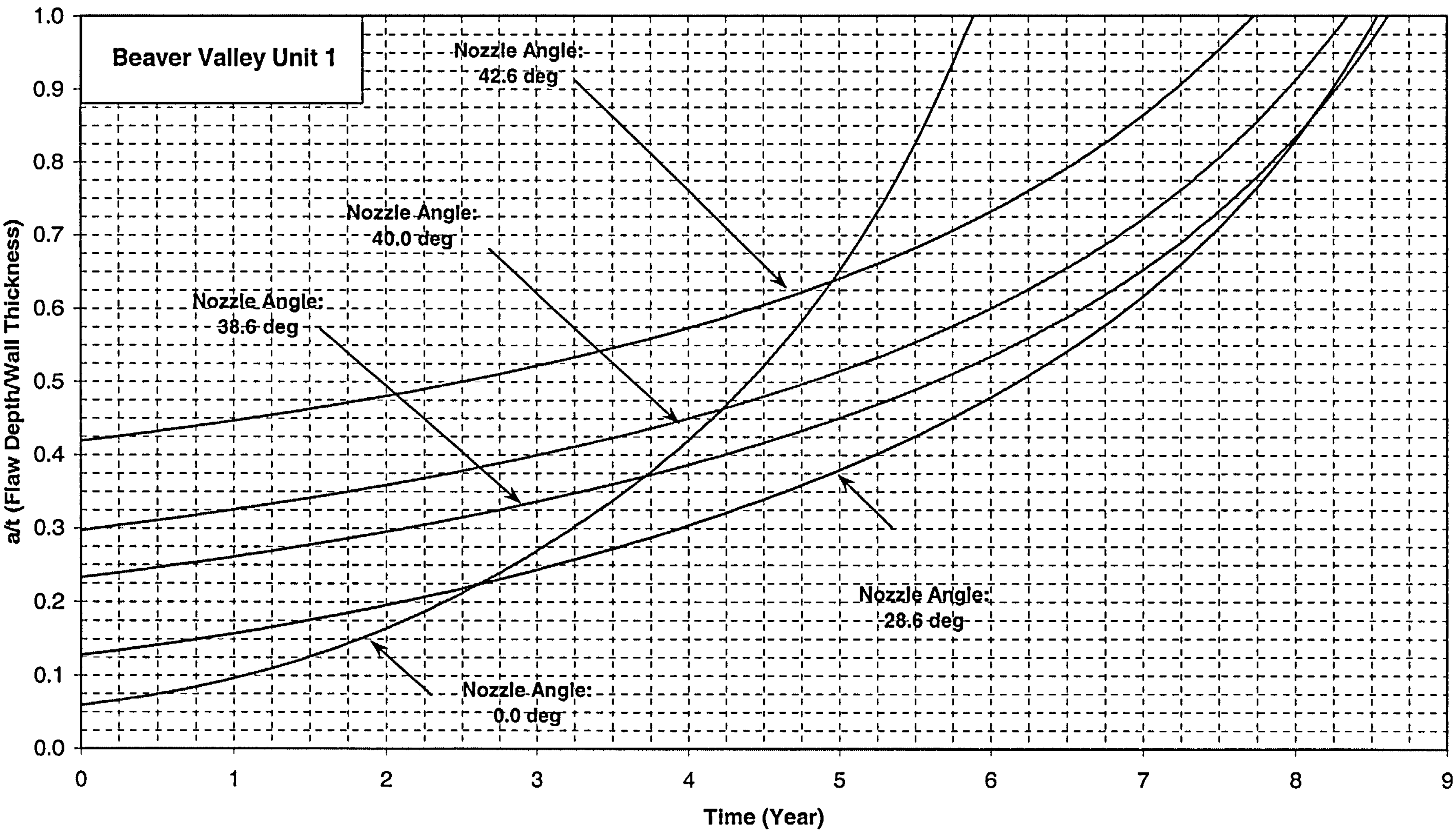


Figure 2
Beaver Valley Unit 1 Stress Corrosion Crack Prediction for 0.5" Below Weld (Nozzle Downhill)
Longitudinal Inside Surface (Aspect Ratio = 6:1)



Appendix A

Information from WCAP-15986 to Support Beaver Valley Response

"The Embedded Flaw Process for Repair of Reactor Vessel Head Penetrations and Its Application at North Anna Unit 2"

1.1 SUMMARY OF TECHNICAL BASIS FOR THE EMBEDDED FLAW REPAIR

The embedded flaw repair technique was developed by Westinghouse in 1994, and involves the deposition of at least two layers of Alloy 52 weld metal to isolate existing flaws and susceptible material from the primary water environment.

The embedded flaw repair technique is considered a permanent repair for the following reasons: first, as long as a Primary Water Stress Corrosion Crack (PWSCC) remains isolated from the primary water (PW) environment, it cannot propagate. Since Alloy 52 weldment is highly resistant to PWSCC, a new PWSCC crack will not initiate and grow through the Alloy 52 overlay to permit the PW environment to contact the susceptible material. The resistance of Alloy 690 and its associated welds, Alloys 52 and 152, has been demonstrated by laboratory testing in which no cracking has been observed in simulated PWR environments, and by approximately 10 years of operational service in steam generator tubes, where no PWSCC has occurred. The crack growth resistance of this material has been documented in EPRI Report TR-109136, "Crack Growth and Microstructural Characterization of Alloy 600 PWR Vessel Head Penetration Materials," [1] and other papers. The service experience will be further discussed in Section 4.

The residual stresses produced by the embedded flaw technique have been measured and found to be relatively low [2] because of the small thickness of the weld. This implies that no new cracks will initiate and grow in the area adjacent to the repair weld. There are no other known mechanisms for significant crack propagation in this region because the cyclic fatigue loading is considered negligible. Cumulative Usage Factor (CUF) in the upper head region was calculated to be less than 0.2 [3] in the reactor vessel design report, as well as in various aging management review reports.

The thermal expansion properties of Alloy 52 weld metal are not specified in the ASME code, as is the case for other weld metals. In this case, the properties of the equivalent base metal (Alloy 690) should be used. For that material, the thermal expansion coefficient at 600°F is 8.2 E-6 in/in/degree F as found in Section II Part D. The Alloy 600 base metal has a coefficient of thermal expansion of 7.8 E-6 in/in/degree F, a difference of about 5 percent.

The effect of this small difference in thermal expansion is that the weld metal will contract more than the base metal when it cools, thus producing a compressive stress on the Alloy 600 tube or the attachment weld, where the crack may be located. This beneficial effect has already been accounted for in the residual stress measurements reported in the technical basis for the embedded flaw repair.

The small residual stress produced by the embedded flaw weld will act constantly, and therefore, will have no impact on the fatigue effects in the CRDM region. Since the stress would be additive to the maximum as well as the minimum stress, the stress range would not change, and the already negligible usage factor, noted above, for the region would not change at all.

4 Background and Experience – SCC Resistance of Alloy 52

4.1 INTRODUCTION

Alloy 52 is the filler metal used for the joining of Alloy 690 components by either the gas-tungsten arc welding (GTAW) or gas metal arc welding (GMAW) processes. The welding electrode used for the shielded metal arc welding (SMAW) process is Alloy 152. Both of these materials have compositions not differing greatly from the parent Alloy 690 material. Nominal compositions are provided in the following table.

Element	Alloy 690 Base Metal SB-167	Alloy 152 E-NiCrFe-7 SMAW	Alloy 52 ER-NiCrFe-7 GTAW/GMAW
C	0.05 max	0.05 max	0.04 max
Mn	0.5 max	5.00 max	1.00 max
Fe	7 to 11	7 to 12	7 to 11
P	-	0.03 max	0.02 max
S	0.015 max	0.015 max	0.015 max
Si	0.5 max	0.75 max	0.5 max
Cu	0.5 max	-	0.3 max
Ni	58 min	Bal	Bal
Co	-	-	-
Al	-	0.50 max combined	1.10 max Al or 1.50 max combined
Ti	-		
Cr	27 to 31	28.0 to 31.5	28 0 to 31.5
Nb + Ta	-	1 to 2.5	0.10 max
Mo	-	0.50 max	0.50 max
Other elements	-	0.50 max	0.50 max

Essentially coincident with the introduction of Alloy 690 as the material of choice for nuclear applications, Alloys 52 and 152 were introduced for fusion welding applications with 690.

The following paragraphs provide a summary of the experience with respect to these filler metals in service and in laboratory testing. As a point of interest, a summary of the background and corrosion resistance of Alloy 690 is provided in Appendix A. This summary was prepared to endorse the selection of Alloy 690 for SG tubing applications. It will be noted that, in view of the apparent immunity of Alloy 690 to PWSCC, nearly all of the testing reported in the literature cited has been in faulted secondary side chemical environments.

4.2 SERVICE EXPERIENCE

Steam Generators. The majority of the operating plant experience with Alloy 690 and the weld metals Alloys 52 and 152 is associated with replacement steam generator (SG) programs beginning in approximately 1994 with the Delta 75 replacements for V. C. Summer. In addition to the exclusive use of Alloy 690 for the SG heat transfer tubing applications, the weld metals were used for a range of applications in which contact with primary reactor coolant was required. A brief summary of the weld metal applications, primarily for Westinghouse-designed components, follows.

Plant	efpy	Component	Material	Application
New and Replacement Steam Generators				
V. C. Summer	7 +	SG nozzle welds	Alloy 52 and/or Alloy 152	Buttering over Alloy 82/Alloy 182 welds
		Safe end-nozzle welds		
		Divider plate-channel head & stub runner		Final weld layer (in contact with RCS)
N. Anna 1	7 +	Tubesheet cladding	Alloy 52 and/or Alloy 152	All buttering, cladding and welding operations
N. Anna 2	5 +	SG nozzle welds		
Kori 1	5 +	Safe end-nozzle welds		
Shearon Harris	3 +	Divider plate-tubesheet welds		
S. Texas 1	3			
S. Texas 2	1 +			
ANO-2	2			
Farley 1	2			
Farley 2	1 +			
Kewaunee	3			
Sequoyah 1	In mfgrg	Tubesheet cladding	A52/A152	
Ulchin 5 and 6	In mfgrg	Tubesheet cladding, nozzles, partial penetration welds	A52/A152	All buttering, cladding and welding operations
Other Components				
Sequoyah 1; N. Anna		Canopy seal overlays	A52/A152	
Mihama 1		CRDM replacements	A52/A152	Full penetration weld
Calvert Cliffs 1	2000	Quick-Lok repairs	A52/A152	Full penetration weld
Fort Calhoun, Waterford 3	1999, 2000	PZR nozzle repairs	A52/A152	Partial penetration welds
ANO 2; Palo Verde 2	2000	PZR heater sleeve repairs	A52/A152	Partial penetration welds
SONGS 2 & 3	1997-1998	PZR steam space and side shell nozzles; HL and CL A600 nozzle repairs	A52/A152	Partial penetration welds
D. C. Cook 2	~ 5 (1996)	CRDM nozzle repair	A52/A152	Overlay repair

In addition to these Westinghouse units, similar experience has been accrued with replacement SGs in Europe and in Japan, and in B&W replacement units for domestic PWRs.

There have been no reported instances of environmental degradation of any kind for any of these applications; this includes both the Alloy 690 base metal and the Alloy 52 or Alloy 152 weld metals.

This experience is fully consistent with expectations from laboratory testing performed to support the qualification of these materials. This class of austenitic nickel-base alloys, containing greater than 27 wt. pct. chromium, has exhibited full resistance to primary water stress corrosion cracking (PWSCC), to the extent that they are generally regarded as immune to this form of environmental degradation.

This experience, combined with the growing operating plant experience, also provided the basis for the use of Alloys 52 and 152 for the recent primary loop nozzle repairs at V. C. Summer.

Head Penetrations. The best example of service experience of an Alloy 52 weld repair is provided by the experience of the D. C. Cook Unit 2 embedded flaw repair. Penetration number 75 at this plant was found to have an inside surface flaw with a depth of approximately 40 percent of the tube wall thickness. This penetration was repaired with the embedded flaw repair process in 1996, and the repair was re-inspected in January of 2002.

The inspection of January 2002 was carried out with both dye penetrant and eddy current testing. The penetrant examination showed no indications, as did the eddy current testing. The eddy current results are more quantitative, and will be discussed here in some detail. The method was demonstrated and qualified under a program in response to the NRC Generic Letter 97-01. The process uses an eddy current coil with high-resolution gray scale imaging, with a magenta response at 50 percent of the amplitude of the calibration notch (0.004 inch long and 0.040 inch deep). This was shown empirically to correspond to the response to actual PWSCC. An example of such a response is shown in Figure 4-1, which shows actual clustered axial flaws in a penetration tube. The coil design is optimized for high spatial resolution, in order to distinguish individual responses among clusters of cracks, such as those shown in Figure 4-1.

This eddy current testing and display process was applied to the D.C. Cook penetration 75 in January 2002, and the results are shown in Figure 4-2. The results show no evidence of cracking after six years of service.

4.3 LABORATORY EXPERIENCE

For the reasons stated above, i.e., the fact that thorough laboratory testing and field experience to date have indicated no basis for concern over PWSCC with Alloy 690, relatively little testing for either crack initiation or crack propagation has been performed for either the base metal or the weld metals over the last ten or more years. The only research with which Westinghouse is familiar is cited below.

Psaila-Dombrowski et al. [10] evaluated the SCC resistance of Alloy 152 welds in primary water environments using constant extension rate tests (CERT) at 343°C (650°F). Examination of the fracture surfaces indicated no environmentally-related degradation. All fracture occurred by ductile rupture.

Psaila-Dombrowski et al. [11] performed a series of CERT tests on Alloys 52 and 152 weldments in simulated primary water at 343°C (650°F). After testing for periods up to 4122 hours, environmentally-related crack propagation was not observed.

These are the only published test results with which Westinghouse is familiar.

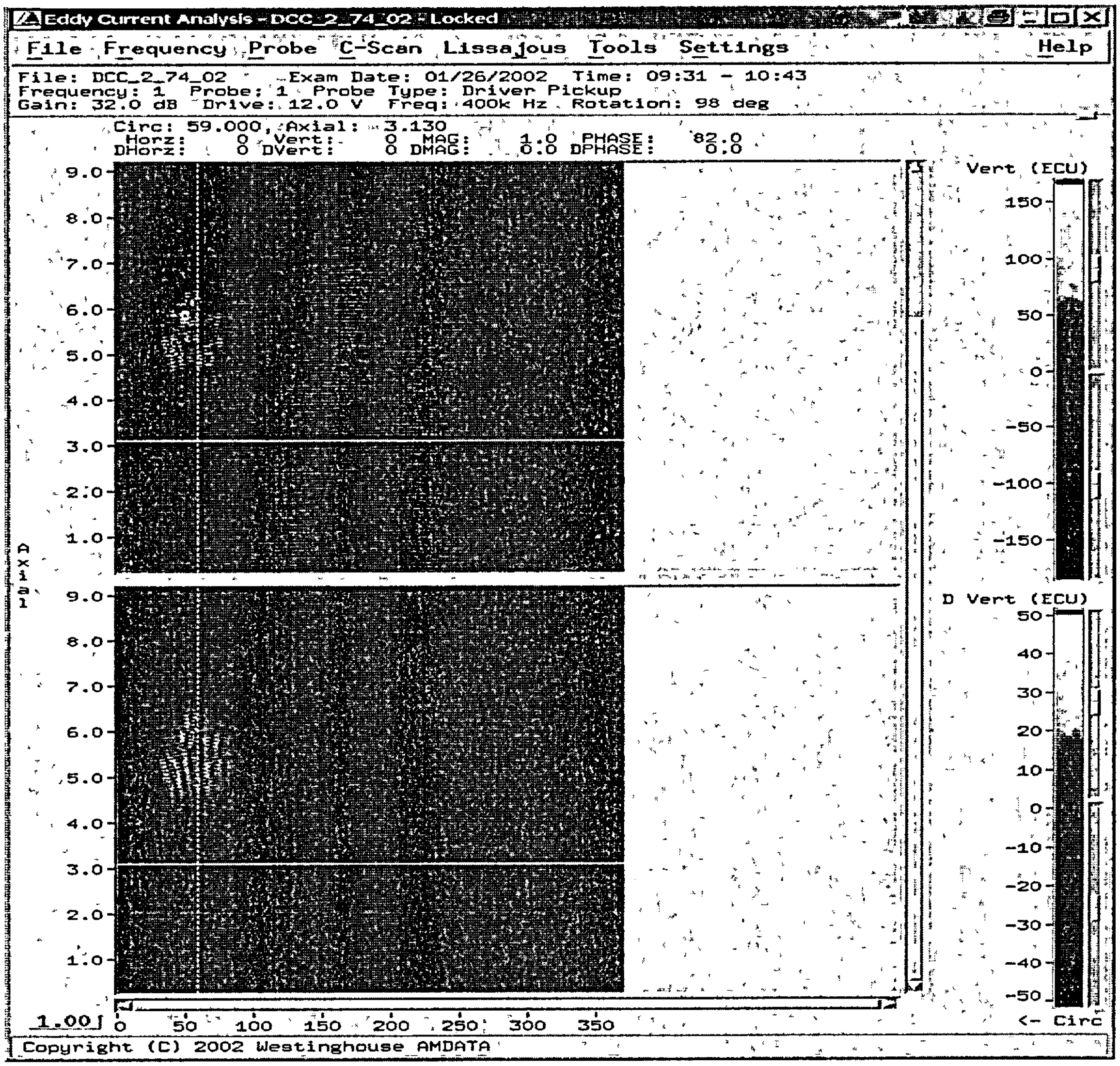


Figure 4-1 ECT View of Craze Cracking

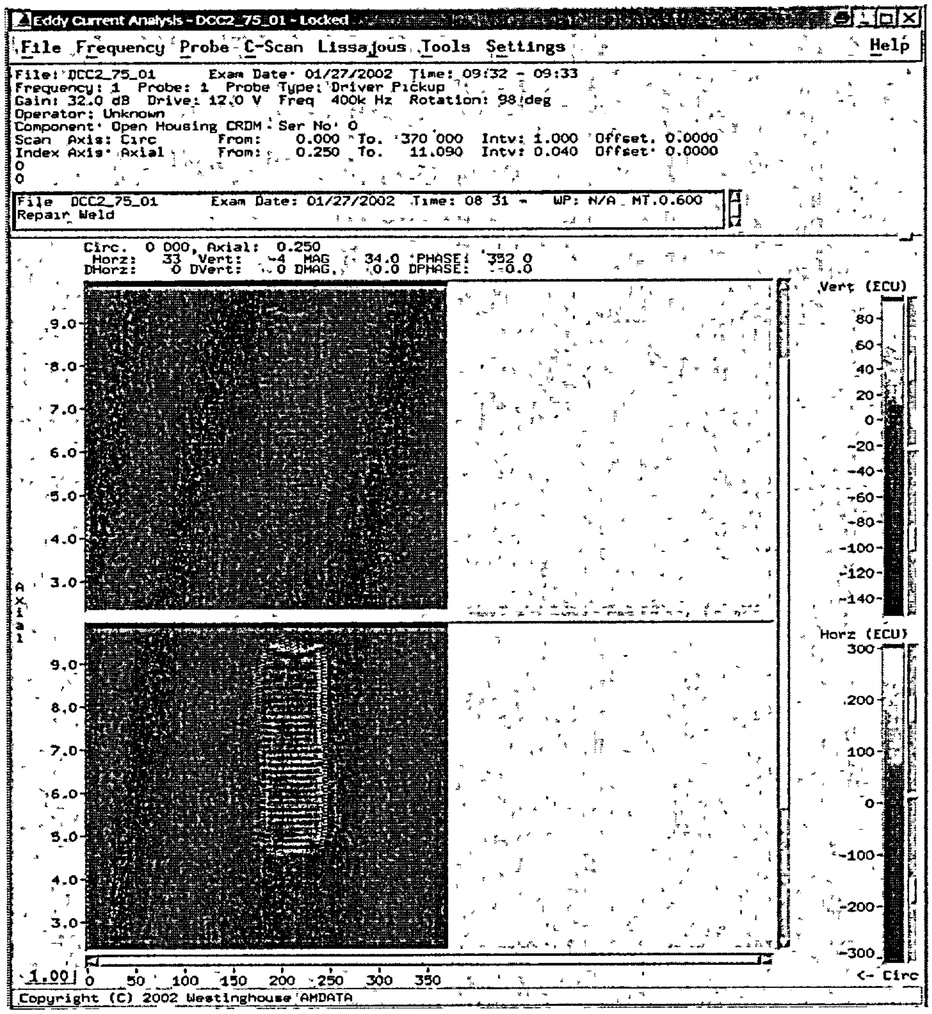


Figure 4-2 ECT View of 1996 Repair, Taken in 2002

7 References

1. TR-109136, "Crack Growth and Microstructural Characterization of Alloy 600 PWR Vessel Head Penetration Materials," EPRI, December 1997.

2. WCAP-13998, "RV Closure Head Penetration Tube ID Weld Overlay Repair," March 1994. [Westinghouse Proprietary].

3. WCAP-15269, Rev. 1, "Aging Management Review and Time Limited Aging Analysis for the North Anna Units 1 and 2 Reactor Pressure Vessels," September 2001.

4. Rotterdam Welding Procedure 34.08, "Procedure for a combination of manual gas tungsten arc welding and manual gas metal arc welding of solid Inconel (P-Number 43) to solid Inconel (P-Number 43) or to Inconel weld overlay cladding."

5. Rotterdam Welding Procedure 37.02, "Procedure for manual shielded metal arc overlay cladding with Inconel (P-Number 43) of low alloy steel (P-Number 12B)."

6. Rotterdam Drawing 30660-1088, "Top Head Cap."

7. Rotterdam Drawing 30660-1097, "Top Head Cap (Pre Machined)"

8. Rotterdam Drawing 30660-1103, Sheet 1, "Closure Head Assembly C.R.D. Housing Assy."

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