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1448 S.R. 333
Russellville, AR 72801
Tel 501 858-5000

February 25, 2000

1CAN020007

U. S. Nuclear Regulatory Commission
Document Control Desk
Mail Station OP1-17
Washington, DC 20555

Subject: Arkansas Nuclear One - Unit 1
Docket No. 50-313
License No. DPR-51
Supplemental Information for Alternative Code Repair of Hot Leg Nozzle RC-1071/1072

Gentlemen:

In letter dated February 24, 2000 (1CAN020006), Entergy Operations requested an alternative repair for a reactor coolant system hot leg nozzle associated with root valves RC-1071/1072 for Arkansas Nuclear One, Unit 1 (ANO-1). A conference call was conducted between the NRC Entergy Operations and Framatome Technologies on February 24, 2000 to discuss comments by the NRC Staff regarding our repair approach and the supporting analysis. As a result, the NRC requested additional information in the following areas:

1. Provide a summary of the basis for why the subject nozzle will not experience significant thermal stresses,
2. Provide summary details of the analysis performed for the vibration loads for the subject Code alternative repair,
3. Confirm the basis for the stress indices used to obtain the vibration results,
4. Provide summary details of the analysis performed for the weld pad overlay for the subject Code alternative repair, and
5. Provide sketches and qualitative discussion of the assumed flaws that were used for interaction with the base metal and for the new weld pad repair.

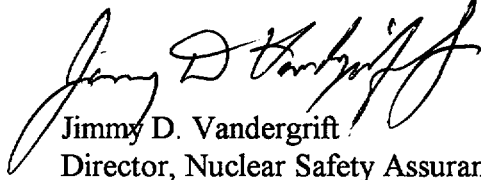
Responses to these questions are being provided in the attachment to this letter.

In addition, in our February 24, 2000 letter to the NRC we referenced that the material selected for the overlay weld was Inco-52 (UNS-N06052). This is for a TIG weld process. ANO will be applying an Inco-152 (UNS-W86152) which is a SMAW process, which has similar material properties.

A047

Please notify me if there is further information required.

Very truly yours,

A handwritten signature in black ink, appearing to read "Jimmy D. Vandergrift". The signature is fluid and cursive, with the first name "Jimmy" being particularly prominent and stylized.

Jimmy D. Vandergrift
Director, Nuclear Safety Assurance

JDV/sab
Attachments

cc: Mr. Ellis W. Merschoff
Regional Administrator
U. S. Nuclear Regulatory Commission
Region IV
611 Ryan Plaza Drive, Suite 400
Arlington, TX 76011-8064

NRC Senior Resident Inspector
Arkansas Nuclear One
P.O. Box 310
London, AR 72847

Mr. Christopher Nolan
NRR Project Manager Region IV/ANO-1
U. S. Nuclear Regulatory Commission
NRR Mail Stop 04-D-03
One White Flint North
11555 Rockville Pike
Rockville, MD 20852

NRC Question 1: Provide a summary of the basis for why the subject nozzle will not experience significant thermal stresses,

ANO Response:

Four possible sources of fatigue stresses, including both thermal and mechanical mechanisms, have been considered in the design of the weld overlay repair for this RCS nozzle. These include:

a. Low cycle thermal fatigue resulting from normal plant events such as heat up and cool down

Effects of thermal fatigue resulting from normal plant events are addressed in the FTI analyses. Since these events are well defined, a rigorous treatment is possible. One item of uncertainty is the extent to which the ANO design, which included a rolled sleeve welded at each end of the nozzle, may have played in the development of the circumferential indications seen in some of the J-welds. This investigation is still underway, but since this potential concern is a low cycle phenomenon, one can extrapolate that since the leaks did not reach detectable levels until approximately 14 years after the original installation, and since weld overlay has restored margins consistent with the original design by depositing new weld material, operation for a very limited number of cycles (until 1R16) does not pose any undue risk due to this specific potential cause.

b. Thermal fatigue resulting from system transients

The nozzle in question taps into the main RCS piping, and provides a pressure source to level instrumentation. It is not used for any other plant functions. This nozzle does not incorporate a drain or any other process piping into the design, nor is it interconnected into any other systems. Thus, this is a stagnant line, with no potential for significant temperature variations, such as could potentially be seen in sample lines, drain lines, or chemical injection lines where intermittent process flow exists. Thus, this type of transient thermal fatigue is not present in this line.

c. Thermal fatigue resulting from unidentified events such as valve in leakage or out leakage

As previously noted, this system is not interconnected into other systems. Therefore, the potential for inleakage of cool water from connected high pressure, low temperature systems is not present in this nozzle. Although inleakage cannot occur, cases of outleakage that varies from zero to some other flowrate have been reported in the industry, and must therefore be

considered. The location of the flaws is in the J-groove weld that holds the nozzle into the main RCS piping. Given that this piping is well insulated to prevent heat loss, and further given that the location of this weld is on the outside diameter of the main piping, the weld will always be at a temperature near that of the bulk RCS, as will the length of the sleeve and perhaps the first 1 inch of the nozzle. Turbulent penetration of hot RCS into the nozzle will also help to hold the temperatures stable in this region, since the nozzle inner diameter is about 0.612 inch and the thickness of the piping elbow to which the nozzle attaches is less than 3.5 inches including cladding. This is significant because turbulent penetration would be expected to keep the contained fluid at the same temperature as the bulk RCS temperature for up to 10 diameters, or about 6" into this stagnant line. Thus, even if an alternating flow rate source of outleakage did exist, the region where the flaws were observed would not change temperatures significantly as a result of this outleakage because it is already near the maximum temperature. This eliminates from concern another potential failure mechanism that has been the subject of several IE Notices and other industry events.

d. High cycle Mechanical fatigue from vibration

Mechanical vibration of small bore, cantilevered configurations are the most common cause of pressure boundary leakage events in the industry, and as such were initially suspected in this failure. However, once PT's became available, the failure mechanism seen in the nozzles was consistent among all six nozzles that had evidence of leakage, and none of the 6 exhibited the classic vibration failure mode of circumferential cracking at the toe of the weld. High cycle fatigue is also not considered a likely candidate for the root cause of the failure because these nozzles experience millions of stress cycles in the first few days of plant operation, and thus a detectable leak would be expected to occur within in a few operating cycles at most. Thus, it is highly unlikely that 6 connections of similar design would experience detectable leakage after approximately 14 years with none of the six being detected sooner. Notwithstanding the above arguments, and given that high cycle fatigue has the potential to cause another failure prior to the next refueling cycle, several additional steps have been taken to address this concern:

- 1) The level tap is being "bump" tested both before and after the repair, to determine the natural frequencies present in the configuration. This action will confirm that the tap is not in resonance with vibrations caused by the ANO-1 RCP's, which exhibit vibrations primarily at 20 hz (the motor running speed) and 100 hz (the vane pass frequency).
- 2) A vibration analysis was performed, based on measured vibration data that was obtained via consultation with the ANO Predictive Maintenance group. Historical data was not available at this specific location on the hot leg piping, but data was available for a number of points located on the cold legs. Since the RCP's are located in the cold legs, it is not unreasonable to believe that

vibrations on the cold legs would be generally higher than vibrations on the hot legs. To add additional conservatism to this assumption, a 1 mil peak to peak amplitude was assumed both at 20 hertz and again at 100 hertz, even though the highest measured value noted in the data review was less than 0.8 mils, and the vast majority of locations showed much lower values. These inputs were used in a stress analysis performed by FTI which concluded that stresses due to vibration would be on the order of 5 ksi, which is well below the endurance limit of 16.5 ksi. Stress indices of $C2 = 2.1$ and $K2 = 2.0$ were used in this analysis, consistent with Code requirements for socket welds.

- 3) The final weld configuration uses a 2 to 1 taper on the fillet weld. This geometry is believed to provide at least a 33% reduction in the stress intensity factor for all types of root defects, as compared to a standard Code configuration which allows a 1 to 1 taper (in other words, equal length legs on the fillet weld). (Reference: EPRI TR-107455, page 3-31). This change in the design would improve resistance to both known (RCP's) and unknown (flow induced) vibration sources.
- 4) Repair of the 4th RCP will return ANO to its normal operating configuration. Thus, even if an unknown vibration was present due to the recent period of 3 pump operation, those vibrations would be present for only a few hours during startup from the present outage and would then be absent until the next scheduled shutdown.

NRC Question 2: Provide summary details of the analysis performed for the vibration loads for the subject Code alternative repair

ANO Response: Enclosure 1 is a letter from Framatome Technologies dated February 24, 2000 (FTI-00-517) that provides a summary of the vibration analysis for the hot leg level nozzle

NRC Question 3: Confirm the basis for the stress indices used to obtain the vibration results

ANO Response: The stress indices ($C2=2.1$, and $K2=2.0$ for a fillet weld) and endurance limit (16.5 ksi) values were taken from the 1989 ASME Code.

NRC Question 4: Provide summary details of the analysis performed for the weld pad overlay for the subject Code alternative repair.

ANO Response: Enclosure 2 is a letter from Framatome Technologies dated February 24, 2000 (FTI-00-512) that provides a summary of the weld pad overlay repair. This also includes two diagrams showing the mesh of the finite element model.

NRC Question 5: Provide sketches and qualitative discussion of the assumed flaws that were used for interaction with the base metal and for the new weld pad repair.

ANO Response: Enclosure 3 provides four diagrams and descriptions of the flaws assumed in the analysis for the hot leg base metal and the new weld pad overlay.

Enclosure 1

**Framatome Technologies Letter dated
February 24, 2000
(FTI-00-517)**



February 24, 2000
FTI-00-517

Mr. Charles H. Turk
Entergy Operations, Inc.
Arkansas Nuclear One
1448 S.R. 333
Russellville, AR 72802

Subject: ANO-1 Level Tap Vibration Analysis
Weld Contract Order NHC00225
(FTI Job No. 1231023)

- Reference:
- 1) General Services Agreement NHA00045 between Entergy Operations, Inc. and Framatome Technologies, Inc. effective date January 1, 1998
 - 2) FTI Letter FTI-00-440, dated 2/17/00, "FTI Proposal - ANO-1 Hot Leg Level Instrument Nozzle(s) Repair"
 - 3) FTI Letter FTI-00-470, dated 2/21/00, "FTI Proposal Update - ANO-1 Level Tap Nozzle Repair"

Dear Mr. Turk:

Attached is the calculation summary, "Vibration Analysis of Hot Leg Level Tags," FTI Document 86-5007295-00. In accordance with FTG Procedure 0402-01, "Preparing and Processing FTG Calculations," calculation summaries (ID-86) may be transmitted prior to completion and release of the calculation package (ID-32). The signature of the independent reviewer on the Calculation Summary Sheet signifies that the summary package is technically accurate and that the calculations on which the summary is based have been reviewed in accordance with the procedure for calculation packages.

Should you have any questions, please do not hesitate to call me at (804) 832-2904.

Sincerely,

A handwritten signature in black ink, appearing to read 'Frank M. Gregory', written over a horizontal line.

Frank M. Gregory
Materials & Structural Analysis

c: H.C. Chadbourn



CALCULATION SUMMARY SHEET (CSS)

Document Identifier 86 - 5007295 - 00

Title VIBRATION ANALYSIS RESULTS - ANO-1 HOT LEG LEVEL TAPS

PREPARED BY:

REVIEWED BY:

NAME FRANK M. GREGORY

NAME ROBERT J. GURDAL

SIGNATURE *Frank M. Gregory*

SIGNATURE *R. Gurdal*

TITLE SUPV. ENGR. DATE 2/24/00

TITLE PRIN. ENGR. DATE 2/24/2000

COST CENTER 41020 REF. PAGE(S) 2

TM STATEMENT: SDM
REVIEWER INDEPENDENCE

PURPOSE AND SUMMARY OF RESULTS:

Purpose:

The purpose of this document is to summarize the analysis and results from Reference 1. Reference 1 documents the analysis that was performed to determine the alternating stress at the hot leg to level tap connection based on vibration information from Entergy. The goal of that analysis was to show that the alternating stress is below the endurance limit.

Conclusion:

Based on the response of the level tap to the harmonic excitation supplied by Entergy, the stress at the level tap to hot leg connection is below the endurance limit. As such, vibration is not a concern for the old level taps, for the repaired level tap, nor for the replacement level taps.

THE FOLLOWING COMPUTER CODES HAVE BEEN USED IN THIS DOCUMENT:

CODE/VERSION/REV
NONE

CODE/VERSION/REV

THE DOCUMENT CONTAINS ASSUMPTIONS THAT MUST BE VERIFIED PRIOR TO USE ON SAFETY-RELATED WORK

YES

NO

Vibration Analysis Results – ANO Hot Leg Level Taps**Purpose:**

The purpose of this document is to summarize the analysis and results from Reference 1. Reference 1 documents the analysis that was performed to determine the alternating stress at the hot leg to level tap connection based on vibration information from Entergy. The goal of that analysis was to show that the alternating stress is below the endurance limit.

References:

- 1) FTI Document 32-5007273-00, "Hot Leg Level Taps Vibration Analysis".

Analysis & Results:

The hot leg level tap Model #3 was reconstructed from FTI document 32-1164052-01. The valve CG was modified based on Entergy input. The first frequency of the level tap assembly decreased from approximately 26 Hz to 24 Hz. No credit was taken for the weld build-up for the repaired level tap.

The following vibration data from Entergy was given to apply to the level tap model.

- (+/- 0.5 mils at 20Hz and +/- 0.5 mils at 100Hz)

This data was determined to be enveloping for the hot leg level tap locations by Entergy. Using structural amplification techniques from Clough and Penzien (Dynamics of Structures, pp 67,68), response spectra were developed at 2% damping for each harmonic excitation. The spectra were then peak broadened 10% and applied to the level tap model in all three directions.

The moments at the hot leg to level tap connection were determined for each harmonic excitation. The moments for each case were combined absolutely and then vectorily combined for the different directions of excitation. This moment represents the ½ range response due to the combination of the harmonic excitations.

The stress indices for a fillet weld (conservative) were applied to determine ½ the peak stress (alternating stress) due to the excitation. The stress indices ($C_2=2.1$ and $K_2=2.0$ for a fillet weld) and endurance limit (16.5 ksi) values were taken from the 1989 ASME Code. (The stress indices are identical to the Code of Record – Winter 1981). The alternating stress is approximately 5 ksi which is well below the endurance limit of 16.5 ksi.

Therefore it is concluded that the harmonic excitation could not have caused the failure of the level taps since the resulting stress is well below the endurance limit.

For the level tap to be repaired, the weld overlay will stiffen the nozzle and further separate the first frequency from the driving frequency. As such, vibration is not a concern for this tap.

Regarding the replacement level tap design, the new nozzle is stiffer and shorter thus increasing the frequency and driving the moments down. In addition the ratio of the OD to moment of inertia has been reduced by a factor of two. For these reasons, vibration is not a concern for the replacement level tap.

Conclusion:

Based on the response of the level tap to the harmonic excitation supplied by Entergy, the stress at the level tap to hot leg connection is below the endurance limit. As such, vibration is not a concern for the old level taps, for the repaired level tap, nor for the replacement level taps.

Enclosure 2

**Framatome Technologies Letter dated
February 24, 2000
(FTI-00-512)**



February 24, 2000
FTI-00-512

Mr. Charles H. Turk
Entergy Operations, Inc.
Arkansas Nuclear One
1448 S.R. 333
Russellville, AR 72802

Subject: ANO-1 Level Tap Nozzle Repair
Weld Pad Overlays Repair – Level Tap Assembly RC-1071/RC-1072
Weld Contract Order NHC00225
(FTI Job No. 1231023)

Reference:

- 1) General Services Agreement NHA00045 between Entergy Operations, Inc. and Framatome Technologies, Inc. effective date January 1, 1998
- 2) FTI Letter FTI-00-440, dated 2/17/00, "FTI Proposal – ANO-1 Hot Leg Level Instrument Nozzle(s) Repair"
- 3) FTI Letter FTI-00-470, dated 2/21/00, "FTI Proposal Update – ANO-1 Level Tap Nozzle Repair"

Dear Mr. Turk:

FTI has completed the sizing calculation for the weld pad overlay on Level Tap Assembly RC-1071/RC-1072. The calculations demonstrate that the repair meets the Primary Stress Criteria of NB-3200 of the ASME Code, Section III, 1989 Edition without addenda.

Attached is the calculation summary, "Analysis of ANO-1 Hot Leg Nozzle Weld Pad Buildup Repair," FTI Document 86-5007275-00. In accordance with FTG Procedure 0402-01, "Preparing and Processing FTG Calculations," calculation summaries (ID-86) may be transmitted prior to completion and release of the calculation package (ID-32). The signature of the independent reviewer on the Calculation Summary Sheet signifies that the summary package is technically accurate and that the calculations on which the summary is based have been reviewed in accordance with the procedure for calculation packages.

The sizing calculations will be contained in the calculation package, "Analysis of ANO-1 Hot Leg Nozzle Weld Pad Buildup Repair," FTI Document 32-5007262-00. This document will also include a fatigue analysis of the repaired nozzle to demonstrate adequacy for plant operation until Spring, 2001.

Should you have any questions, please do not hesitate to call me at (804) 832-2754.

Sincerely,

A handwritten signature in black ink that reads "John F. Shepard".

John F. Shepard
Materials & Structural Analysis

c: H.C. Chadbourn

3315 Old Forest Road, P.O. Box 10935, Lynchburg, VA 24506-0935
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Internet: <http://www.framatech.com>



CALCULATION SUMMARY SHEET (CSS)

Document Identifier 86 - 5007275 - 00

Title ANALYSIS OF ANO-1 HOT LEG NOZZLE WELD PAD BUILDUP REPAIR

PREPARED BY:

REVIEWED BY:

NAME HT HARRISON

NAME GL WEATHERLY

SIGNATURE *HT Harrison*

SIGNATURE *G.L. Weatherly*

TITLE PRINCIPAL ENGR. DATE 2-24-00

TITLE PRINCIPAL ENGR. DATE 2/24/00

COST CENTER 41020 REF. PAGE(S) 2

TM STATEMENT: REVIEWER INDEPENDENCE ADM

PURPOSE AND SUMMARY OF RESULTS:

Purpose:

Due to observed leakage of the Hot Leg Level Tap Nozzle connection in the Hot Leg elbow (at ANO-1; approx. elev. 368'-4 11/16"; attached to valves RC-1071 & RC-1072), a repair has been designed [see Ref. 2]. The structural adequacy of the repair configuration is demonstrated in Reference 1. Reference 1 includes the qualification of the repair for the Primary Stress criteria of sub-section NB-3200 of the ASME Code, Section III, 1989 edition w/o addendum. The document herein transmits the results of the analysis for Primary Stresses.

See following page for description of the analysis.

Conclusion:

The structural analysis of the ANO-1 Hot Leg Nozzle Weld Pad Buildup Repair (Ref. 1) demonstrates that the repair meets the Primary Stress criteria of sub-section NB-3200 of the ASME Code, Section III, 1989 edition w/o addendum.

See following page for results of the analysis.

THE FOLLOWING COMPUTER CODES HAVE BEEN USED IN THIS DOCUMENT:

CODE/VERSION/REV	CODE/VERSION/REV
_____	_____
_____	_____
_____	_____

THE DOCUMENT CONTAINS ASSUMPTIONS THAT MUST BE VERIFIED PRIOR TO USE ON SAFETY-RELATED WORK

YES

NO

ANALYSIS OF ANO-1 HOT LEG NOZZLE WELD PAD BUILDUP REPAIR

References:

- 1) FTI Document 32-5007262-00, "Analysis of ANO-1 Hot Leg Nozzle Weld Pad Buildup Repair"
- 2) FTI Drawing 02-5007223C-0, "Hot Leg Nozzle Weld Pad Buildup Repair"

Purpose:

Due to observed leakage of the Hot Leg Level Tap Nozzle connection in the Hot Leg elbow (at ANO-1; approx. elev. 368'-4 11/16"; attached to valves RC-1071 & RC-1072), a repair has been designed [see Ref. 2]. The structural adequacy of the repair configuration is demonstrated in Reference 1. Reference 1 includes the qualification of the repair for the Primary Stress criteria of sub-section NB-3200 of the ASME Code, Section III, 1989 edition w/o addendum. The document herein transmits the results of the analysis for Primary Stresses.

Analysis:

- The analysis of the repair design for Primary Stresses includes the following features –
- a) The structural analysis is performed using the finite element method (using the ANSYS FE program)
 - b) An axisymmetric analytical model is employed – including Hot Leg Pipe, cladding, nozzle, original J-groove/fillet configuration and the repair weld pad/fillet welds
 - c) The Hot Leg Pipe is modeled as a spherical segment with adjusted (increased) pressure to conservatively simulate the stress levels in the Hot Leg elbow
 - d) The pressure is applied to all internal surfaces including the perimeter of the original welds (i.e., effectively the original welds are considered as non-existent or void)
 - e) No structural strength is credited to the original J-groove/fillet welds
 - f) Both the run pipe (Hot Leg elbow) moments and branch pipe (Level Tap Nozzle) loads are conservatively applied to the FE model in conjunction with the internal pressure
 - g) The Design Condition load combination of 'Design Pressure @ Design Temperature + Deadweight + Operating Basis Earthquake' is analyzed as the limiting condition for Primary Stresses. (Consideration of the relative magnitudes of the loads associated with Emergency, Faulted and Test conditions and their respective allowable stresses verifies that they are bounded by the Design Condition.)
 - h) Computer generated stresses are post-processed to obtain 'membrane' and 'membrane+bending' stresses for direct comparison to Code allowables

Results:

The ANSYS FE analysis for the limiting Design Condition load combination yields the following key results –

Maximum Primary Membrane Stress Intensity = 16.5 ksi < 1.0 S_m = 18.4 ksi
(Hot Leg pipe -- ASME Code allowable)

Maximum Primary Local Membrane + Primary Bending Stress Intensity = 26.6 ksi < 1.5 S_m = 35 ksi
(Weld Pad -- ASME Code allowable)

Conclusion:

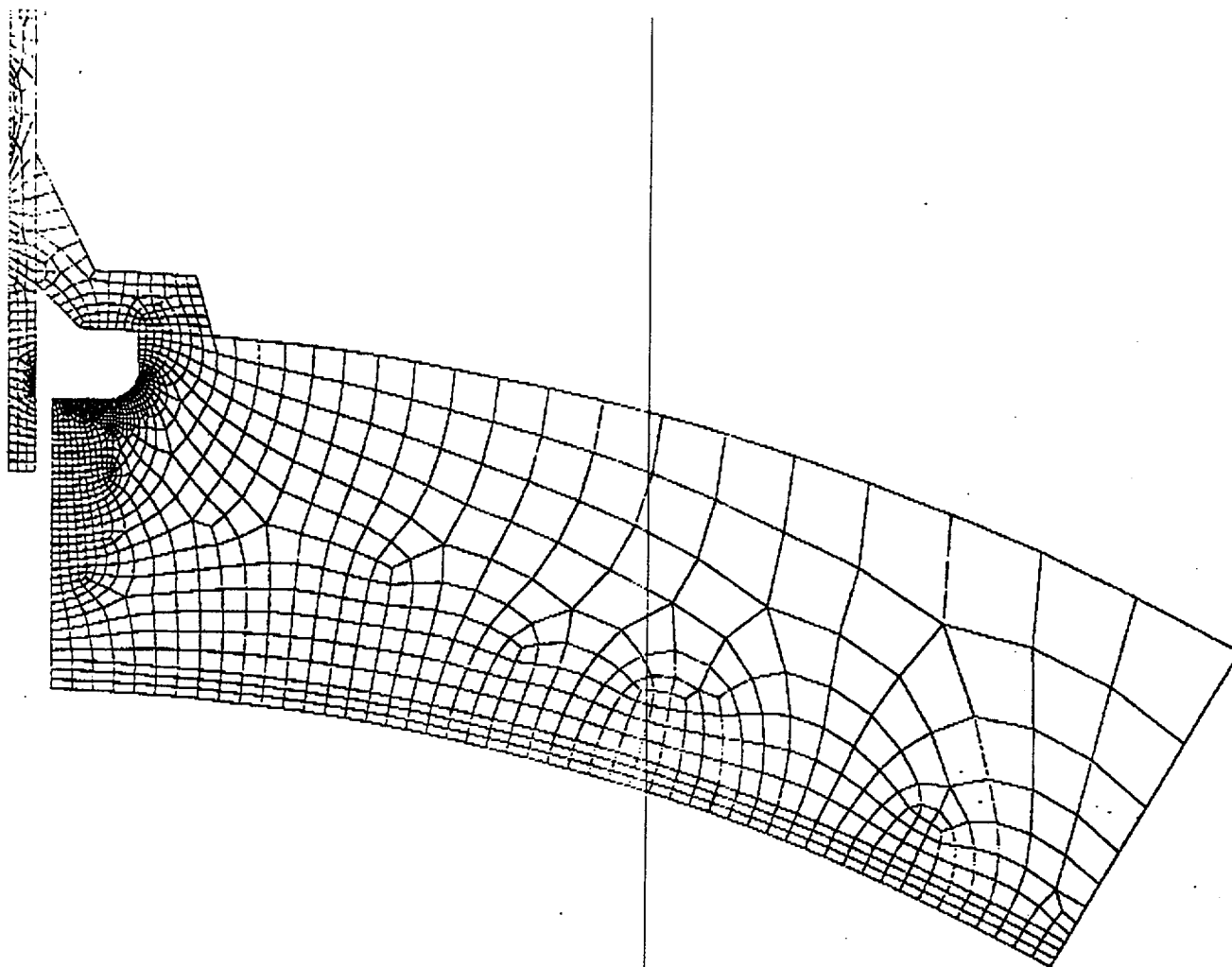
The structural analysis of the ANO-1 Hot Leg Nozzle Weld Pad Buildup Repair (Ref. 1) demonstrates that the repair meets the Primary Stress criteria of sub-section NB-3200 of the ASME Code, Section III, 1989 edition w/o addendum.

Prepared by: *SH*

Date: 2/24/00

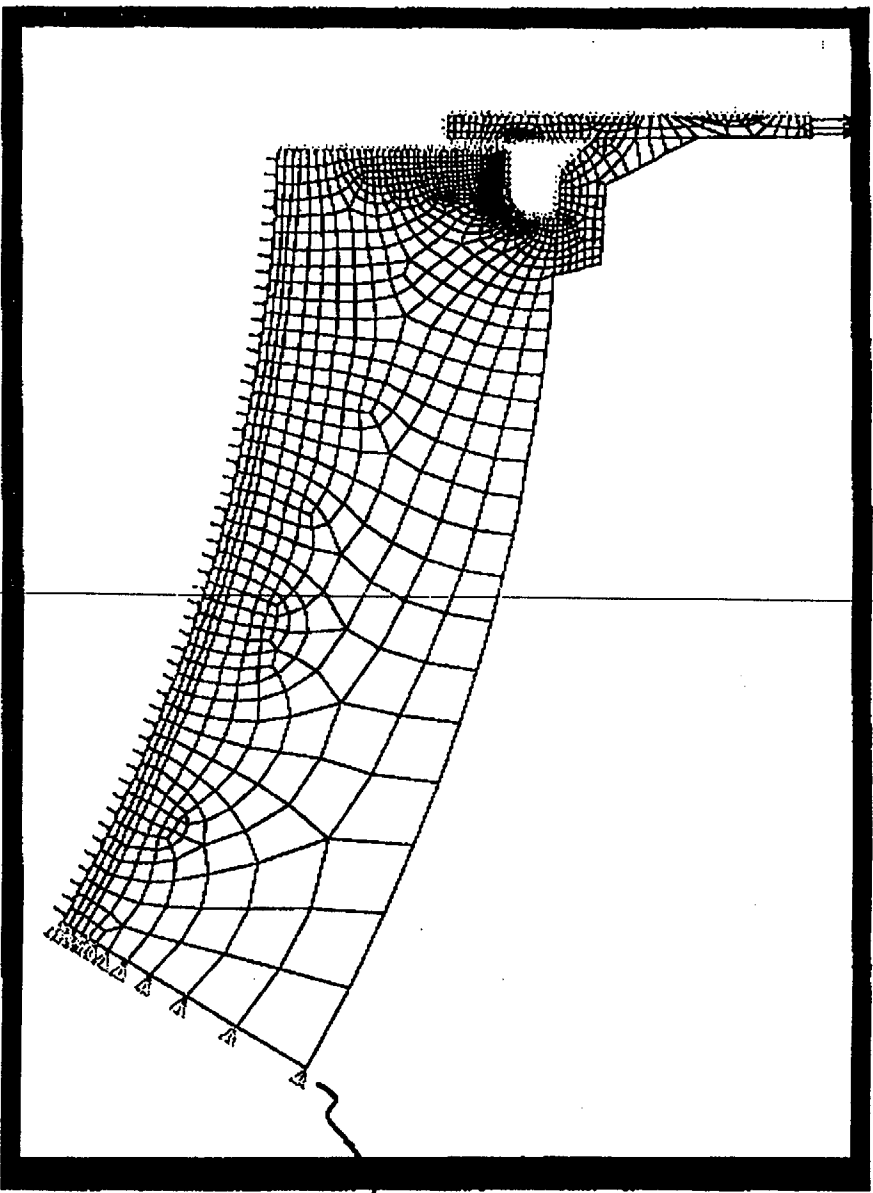
Reviewed by: *SLW*

Date: 2/24/00



ANO-1 Level Tap Repair - Design Case: no diff exp, + axial ld

FIGURE 9-1
FINITE ELEMENT MODEL OF REPAIR DESIGN

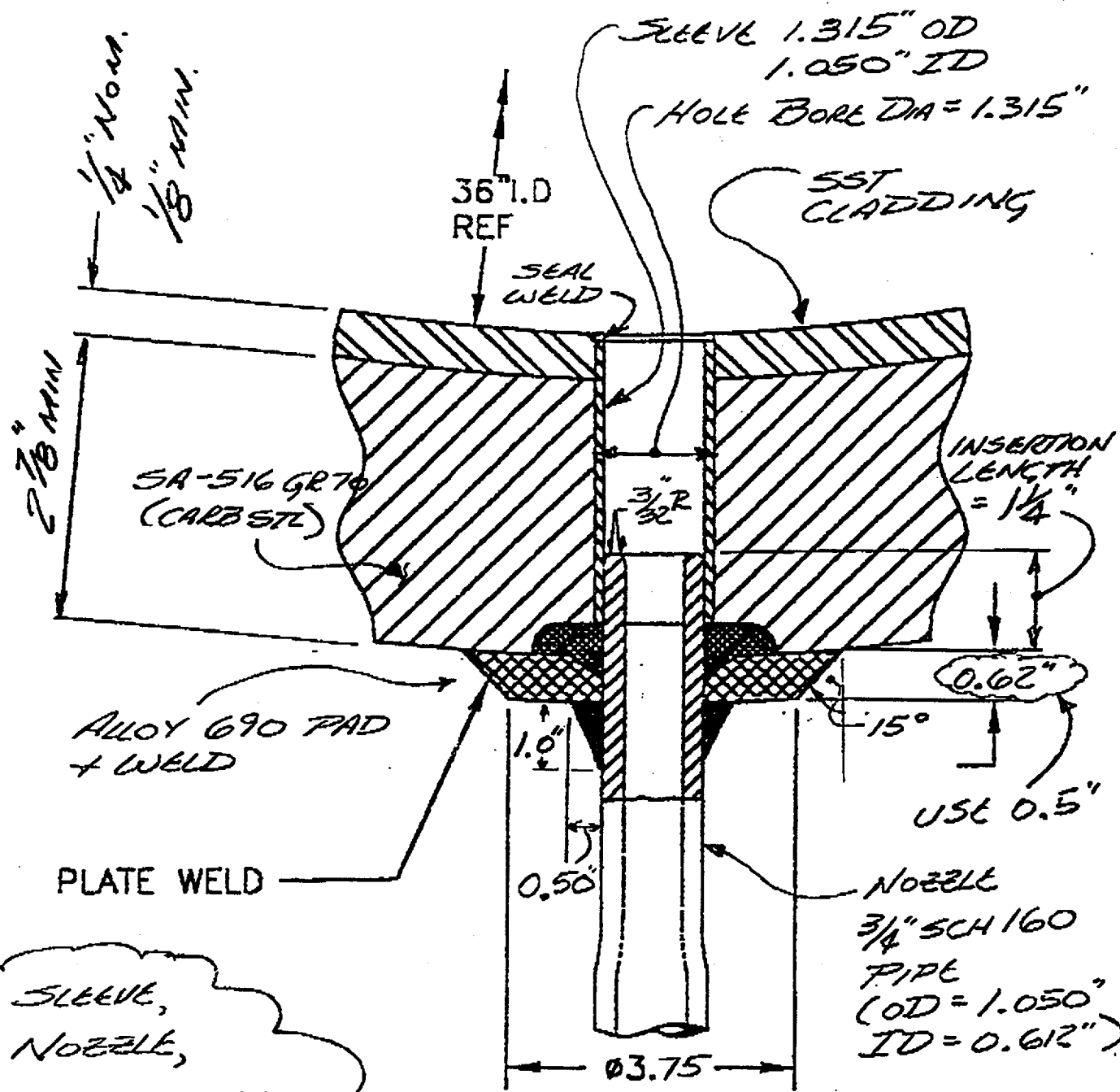


BOUNDARY CONDITIONS

DISPLACEMENT
BOUNDARY
CONDITIONS

Enclosure 3

Diagrams and Descriptions of the Flaws Assumed for the Hot Leg Base Material and Weld Pad Overlay



ALLOY 690 PAD
 + WELD
 PLATE WELD

SLEEVE,
 NOZZLE,
 ORIGINAL WELD
 ARE ALLOY 600

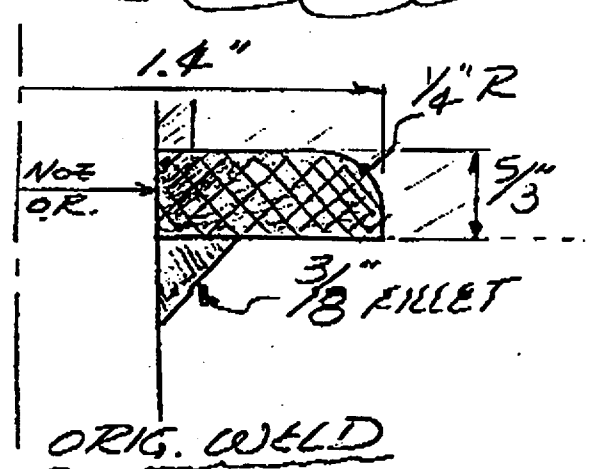
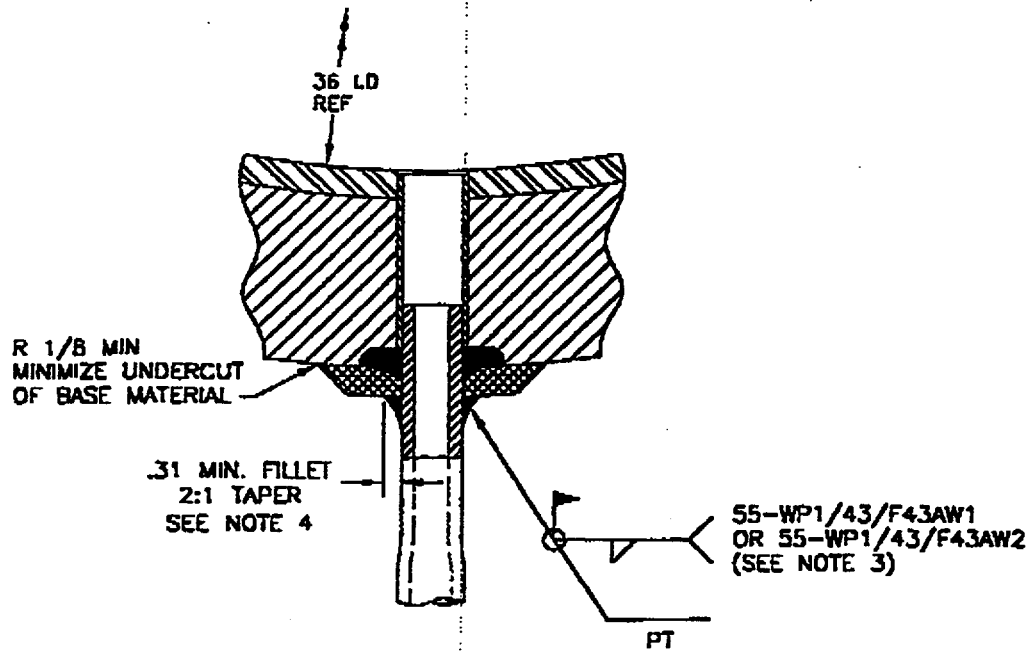


FIGURE 7-1
 GEOMETRY OF NOZZLE REPAIR

Assumed Elbow Flaw Indication at the Level Tap Nozzle

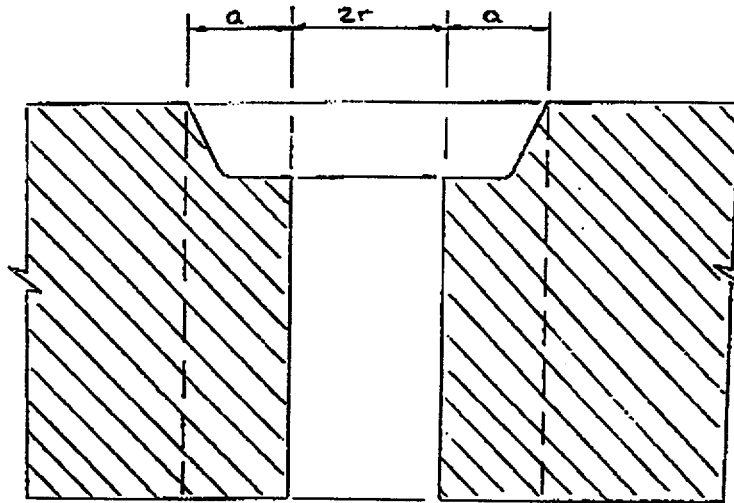
The elbow flaw is assumed to fill a 5/8" x 0.916" J-groove shaped weld prep:



Elbow Flaw Evaluation

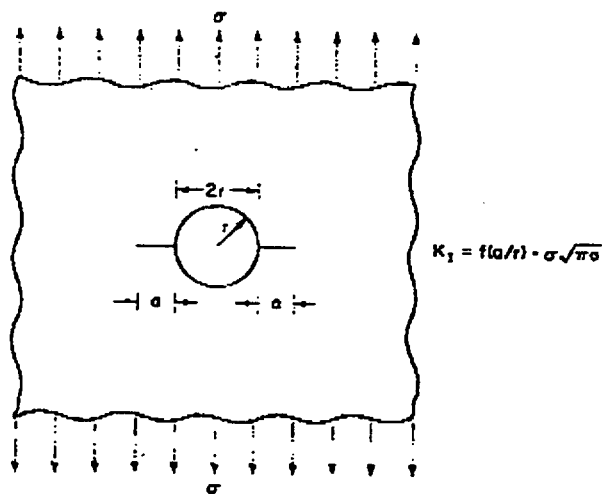
Flaw Model

For the elbow evaluation, the flaw is treated as a surface flaw, and is conservatively modeled as two symmetric cracks, radial with respect to the elbow penetration, and extending through the entire thickness of the elbow. Flaw growth is in a radial direction relative to the penetration, or parallel to the surface of the elbow:



Stress Intensity Factor Solution

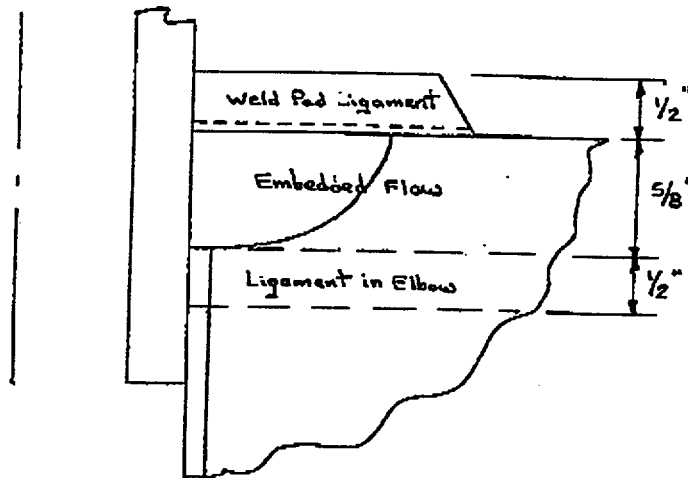
The following solution for two through-wall radial cracks at a hole under remote tension stress is used to calculate stress intensity factors:



Weld Pad Flaw Evaluation

Flaw Model

For the weld pad evaluation, the flaw is treated as an embedded flaw between the 1/2" thick weld pad and the elbow and is conservatively modeled as a center cracked panel (CCP) using only a small portion of the elbow to form one ligament of the CCP model. Flaw growth is into the weld pad perpendicular to the elbow surface:



Stress Intensity Factor Solution

The following solution for the center cracked panel is used to calculate stress intensity factors:

