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SUBJECT: Submits relief request RR2-1 to allow continued plant operation w/two pin hole leaks in 3/4 inch ASME Code Class 2 chemical injection weldment.

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NRC- 96-080

August 12, 1996

10 CFR 50.55a

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555

Ladies/Gentlemen:

Docket 50-305
Operating License DPR-43
Kewaunee Nuclear Power Plant
Relief Request No. RR2-1 to Allow Continued Plant Operation with Two
Pin Hole Leaks in a 3/4 inch ASME Code Class 2 Chemical Injection Weldment

Reference: 1) Letter from MLMarchi (WPS) to Document Control Desk (NRC) dated August 8, 1996

This letter submits relief request RR2-1 which would allow continued plant operation with two pin hole leaks in the main feedwater chemical injection line. The leak is located in the 3/4 inch chemical injection sockolet to the 16 inch A main feedwater line weldment.

The reference provided justification for the continued operation (JCO) of the Kewaunee Plant without performing a code repair of the weldment. Subsequent telephone conversations between the Nuclear Regulatory Commission (NRC) and Wisconsin Public Service (WPS) personnel on August 8, identified additional information the NRC staff needed to complete their evaluation. This information was provided to the NRC in telephone conversations on August 9. After consideration of the information, the NRC granted verbal approval for the continued operation of the Kewaunee Plant. This letter documents the additional information provided to the NRC on August 9, and provides commitments on monitoring the leak and the schedule to perform a code repair of the weld.

Attachment 1 to this letter, in conjunction with Reference 1, provides the basis for the requested relief. Attachment 1 includes: 1) the additional information provided to the NRC staff during the telephone conversations on August 9, 2) the results of a fracture mechanics evaluation to determine the safety margin for various service levels, and 3) a description of the temporary restraint placed on the chemical injection line. Although our analysis demonstrates that the chemical injection line will not fail, the restraint provides an added measure of safety.

A047

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In summary continued operation of the plant is justified based on the following:

1. Non destructive examination (NDE) results of the chemical injection sockolet to the A main feedwater line weldment and the feedwater piping in the area of the weld determined:

   a) there were no flaws in the main feedwater pipe in the area of the leak, and

   b) the root cause of the leak is associated with the welding process. The leak path is a network of connecting small regions of lack of fusion between weld passes and small clusters of porosity/inclusions in the weld. The resultant leak paths have essentially no width or circumferential extent and may be classified as two pin holes.

2. Analyses of the existing flaw determined the flaw is stable and will not grow significantly between now and Kewaunee's scheduled outage in September of 1996. At that time, a code repair will be performed.

3. Conservative fracture mechanics calculations have been performed and determined that even if a flaw is assumed to exist, there is adequate margin to failure.

Additionally, WPS commits to the following actions:

1. If a plant shutdown or trip occurs prior to our scheduled outage in September, a code qualified repair will be performed.

2. The weld will be checked daily by the Quality Programs Department and once per shift by the Operations Department to identify changes in the characteristics of the flaw. If characteristics of the flaw change significantly, the plant will be shut down and a code repair will be performed.

3. When the code repair is implemented, a root cause analysis will be performed and corrective actions will be taken to preclude recurrence of the event.

The Plant Operations Review Committee has reviewed and concurred with this relief request.

Sincerely,

C. A. Schrock for

M. L. Marchi
Manager - Nuclear Business Group

TJW

Attach.

cc - US NRC - Region III
US NRC Senior Resident Inspector
Mr. Lanny Smith, PSCW

50-305 KEWAUNEE WPSC

RELIEF REQUEST NO. RR2-1 TO ALLOW CONTINUED PLANT OPERATION

Rec'd w/ ltr dtd 8/12/96......9609100373

ATTACHMENT 1

to Letter

from

M. L. Marchi (WPS)

to

Document Control Desk (NRC)

Dated

August 12, 1996

Relief Request RR2-1

INTRODUCTION

This attachment supplements the information provided in Reference 1 and serves as the basis for our relief request. Information has been presented as follows:

1.0 Components Affected

2.0 Section XI Requirements

3.0 Basis for Relief Request
- 3.1 NDE Results
  - 3.1.1 Radiography Testing (RT)
  - 3.1.2 Ultrasonic Testing (UT)
- 3.2 Analysis and Root Cause
- 3.3 Augmented Exams
- 3.4 Description of the Temporary Restraint

4.0 Conclusion

Section 1.0 - COMPONENTS AFFECTED

Chemical Injection System to Main Feedwater System pressure boundary:

Description	Flow Diagrams
Branch connection for 3/4" hydrazine injection piping to the 16" A main feedwater piping	M205 and M214

The branch connection consists of a carbon steel (ASTM A-105 Grade 2) 3/4" extra heavy sockolet, welded to a carbon steel (ASTM A-106 Grade B seamless) 16" diameter schedule 140 pipe (See Figure 1). The original fabrication of the P-1 to P-1 full penetration weld was manually made by the feedwater spool piece vendor using the shielded metal are welding process with E-6010 filler material for the root pass and E-7018 for the reinforcing fillet weld. The fabrication process required a liquid penetrant examination of the final weld surface.

The 3/4" hydrazine injection line is rarely used for secondary chemistry control.

Section 2.0 - SECTION XI REQUIREMENTS

Section XI requires that the feedwater system piping be inspected during periodic system pressure tests. This component was most recently inspected in 1993 with no recordable indications.

Table IWC-2500-1, Item C7.30, identifies Paragraph IWC-3516 as the acceptance standard for the system pressure test. WPS recognizes the NRC position that leakage identified during plant operation is also subject to this standard (see Generic Letter 91-18 addressing operational leakage). IWC-3516 is in the course of preparation and refers to the standards of Paragraph IWB-3522. Subparagraph IWB-3522.1, "Visual Examination, VT-2," (c) specifies that leakage from insulated components detected during the conduct of system pressure tests shall require correction to meet the requirements of IWB-3142 and IWA-5250 prior to continued service.

IWB-3142.4 permits acceptance for continued service by an analytical evaluation that demonstrates the component's acceptability. WPS has completed an analytical evaluation to demonstrate the component's acceptability for continued operation with augmented inspection. The evaluation is included in Reference 1 as supplemented by additional information provided in this attachment.

IWA-5250, "Corrective Action" specifies that, "The source of leakage detected during the conduct of a system pressure test shall be located and evaluated by the owner for corrective measures as follows: ... (3) Repairs or replacements of components shall be performed in accordance with IWA-4000 or IWA-7000 respectively." These articles require repairs be performed in accordance with the owner's design specification and the original construction code of the component or system. WPS plans to defer repair or replacement of this component until the next plant shutdown.

Therefore, WPS requests relief from IWA-5250 and the requirements of IWA-4000 and IWA-7000 of the 1989 Edition of Section XI of the ASME Boiler and Pressure Vessel Code for the hydrazine injection line sockolet weld to the A main feedwater pipe.

Section 3.0 BASIS FOR REQUEST

3.1 NDE RESULTS

In order to address NRC questions regarding the integrity of the main feedwater pipe, additional radiographs and ultrasonic exams were performed of the feedwater pipe and weldment on August 8 and 9. Sections 3.1.1 and 3.1.2 of this attachment provide the results of these exams.

3.1.1 RADIOGRAPHY TESTING (RT)

Radiography was performed to identify significant erosion/corrosion affects and detect the presence of flaws in the pressure boundary materials. Tangential radiography techniques pernit the evaluation of erosion/corrosion in the 3/4" sockolet branch connection and the outside diameter interface of the 16" feedwater piping. Standard Code radiography was performed to detect the presence of flaws in the 16" feedwater piping adjacent to the sockolet branch connection weldment.

The performance of radiography during the operation of the feedwater piping presents conditions not normally experienced in conducting standard code radiographic testing. The heat from the base metal materials and the flow of water through the feedwater pipe pose challenges for performance of the test and interpreting the results. The heat and water can cause false indications on the film, while the vibration can affect the quality. For these reasons, multiple exposures were taken in the same position to permit proper interpretation of the results.

DESCRIPTION OF RADIOGRAPHY TECHNIQUES

Two radiographic techniques were performed:

1) a double wall/tangential - double wall view, and
2) a double wall - single wall view.

The double wall/tangential - double wall views (refer to Figure 2A) were obtained by placing the radiation source above and below the weldment of the sockolet and placing the film on the side of the branch connection opposite the source. The film was placed slightly behind the curvature of the feedwater piping to capture the weldment of the branch connection and the interfacing surface of the feedwater piping.

The double wall - single wall view (refer to Figure 2B) was performed by placing the radiation source in contact with the feedwater piping on the opposite side of the branch connection. The film was notched and placed over and under the branch connection to capture the 16" feedwater piping adjacent to the sockolet weldment. A No.25 film side penetrameter was used.

RESULTS

Upon notification of the need to perform radiography on 08/07/96, the NDE vendor was contacted and arrived on-site prior to the completion of the insulation removal. Radiography commenced on the afternoon of 08/07/96, with the double wall/tangential - double wall view. This examination was completed later the same day.

The double wall/tangential - double wall view provided a profile of the sockolet, weldment, and a portion of the machined opening adjacent to the outside wall of the feedwater piping. The machined opening in the feedwater piping was visible on the film for a depth of approximately 3/8" from the outside diameter. The inside diameters of the sockolet and visible portion of the machined opening in the feedwater piping were smooth, indicating no evidence of erosion or corrosion at this branch connection.

Preliminary interpretation of the results was performed by the Level II, with no linear or rounded indications visible. To provide and independent review, the NDE Vendor's Level III was requested to review the results. This independent review was completed on 08/08/96 and confirmed the initial Level II interpretation of no linear or rounded indications visible.

A small amount of root weld undercut was visible on the inside diameter of the sockolet, as well as a slight opening at the edge of the weld at the outside surface. This condition was visually examined and characterized as cluster porosity at a start-stop point in the sockolet weldment. This condition was caused during the initial fabrication process. Our current NDE vendor judged this condition to be structurally stable.

In the early morning of 08/09/96 the double wall-single wall view technique was performed. The radiography and interpretation of the results by the Level II were complete by late morning.

The double wall - single wall view showed no indications in the base metal of the 16" feedwater piping adjacent to the sockolet weldment.

3.1.2 ULTRASONIC TESTING

An ultrasonic examination was performed to determine if planar flaws existed in the base metal of the 16" the main feedwater piping below the steam leakage from the sockolet weld downstream of the 3/4" chemical injection line to valve CI-122A. Refer to Figures 3A, 3B, and 3C for the documentation of the UT exam.

INITIAL DATA

Due to the high temperature of the inservice 16" Feedwater Piping (approximately 316°F), a high temperature transducer wedge was required to perform the ultrasonic examination. This wedge was supplied to the Kewaunee Nuclear Power Plant staff by its ASME Boiler and Pressure Vessel Code Section XI Program Nondestructive Examination Vendor - Lambert, MacGill and Thomas (LMT Inc.). A 45° shear high temperature wedge and the appropriate transducer (2.25 MHZ 0.5" x 0.5" diameter) were flown to Green Bay from San Francisco and arrived on Thursday August 8 at 2010. The wedge and transducer were picked up at 2015 and taken immediately to the site.

Calibration to perform the examination commenced at 2130 August 8. Calibration was originally performed at room temperature (73°F) on calibration block WPS-6: 16" Sch 140 1.438"T to determine sweep and amplitude settings. Calibration was performed as a prelude to actual exams due to the ASME Boiler and Pressure Vessel Code and procedure requiring the calibration block to be within 25°F of the part to be examined. The procedure used for examination (with temporary changes to allow for use of high temperature techniques) was Kewaunee Procedure NEP No. 15.18 "Ultrasonic Examination of Ferritic Piping For Inservice Inspection". This procedure is an existing approved ASME Boiler and Pressure Vessel Code Section XI 1989 Edition Ultrasonic Examination procedure.

SCANNING

To ensure the absence of planar flaws in the 16" Feedwater Pipe base metal located below the leakage from the 3/4" sockolet the following scan pattern was used to ensure maximum coverage:

1. A 3"-360° circular area on the 16" Feedwater Pipe around the 3/4" weld was examined.

2. Eight separate scans were performed: 4 parallel, clockwise, counterclockwise, angled into the weld and angled away from the weld. Reference Figure 3.

EXAMINATIONS

Following calibration, preliminary examinations at 0030 on August 9 were performed (prior to heating of calibration block WPS-6) to gather information. No indications were detected using the 45° shear angle beam in either of the 8 scan directions. Additional db settings (+6, +10 and +20 above calibration reference) were also used for scanning in the 8 directions and no indications were detected in the 16" Feedwater Base Metal.

Calibration Block WPS-6 was then placed on the Feedwater Piping Train A to increase the block temperature. When the calibration block temperature reached 225°F at 0700 on August 9 (still below required temperature) scanning for information was again performed at reference sensitivity, +6db and +10db. No indications were detected in the 16" Feedwater Base Metal.

Acceptable calibration block temperature 302.5°F (within 25°F of examination surface i.e., approximately 316°F) was achieved at 0910 on August 9 and complete procedure requirements were achieved. Scanning was performed at reference sensitivity, +6db and +10db in the 8 directions. No indications were detected in the base metal of the 16" Feedwater Piping located underneath the leaking 3/4" sockolet weld.

RESULTS

Eight separate scans at various calibration sensitivities and at various calibration block temperatures revealed no indications in the base metal of the 16" Feedwater Piping located underneath the leaking 3/4" sockolet weld.

Additionally all calibrations and examinations were witnessed by the Authorized Nuclear Inservice Inspector for ASME Code and Procedure compliance.

3.2 ANALYSIS AND ROOT CAUSE

A root cause investigation and analysis/evaluation of the integrity of the sockolet weldment and the connecting base metal in the 16" feedwater pipe included review of the fabrication process, inspection history, operating history, potential degradation mechanism(s), non-destructive examination results, and fracture mechanics evaluation. Each of these areas is briefly discussed below.

The branch connection weldment was constructed by Texas Pipe Bending Company using shielded metal arc welding. Together a root weld and reinforcement fillet weld form the full penetration weldment as shown in Figure 1. A single pass E-6010 electrode was used for the root weld and multiple passes of E-7018 were used to form the fillet weld. Following welding, as part of the fabrication process acceptance of the spool piece, the fabricator performed a liquid penetrant examination of the outside surface. After the spool piece was received on site during construction of KNPP, no additional nondestructive examination was required to be performed on the sockolet weldment.

The Section XI plant preservice examinations were limited to the ASME Section XI Code Class 1 boundary. The feedwater sockolet weldment is part of the ASME Section XI Code Class 2 boundary and therefore was not subject to preservice-examination. From 1974 to 1978, the 1971 Edition through the winter addenda of Section XI was required to be used at KNPP; this edition of Section XI limited examination to the ASME Section XI Code Class 1 boundary. From 1979 to 1984, the 1974 Edition through Summer 1995 addenda of Section XI was used for examination. This edition of Section XI expanded the scope of examinations from the Section XI Class 1 boundary to include Section XI Class 1, 2, and 3 components. Guidance for establishing the Section XI boundaries is defined in revision 2 of Regulatory Guide 1.26. The 1974 Edition of Section XI and all subsequent editions of Section XI exempt Class 2 piping and branch connections NPS 4 and smaller from nondestructive examination. However, all editions of the Section XI Code since and including the 1974 edition require that Class 2 and 3 piping (including connections NPS 4 and smaller) be pressure tested each inspection period. Consistent with this requirement, the feedwater system including the sockolet weldment of concern is subjected to a pressure test including VT-2 visual examination approximately every 40 months. The feedwater system was last inspected for leakage under the Section XI program in 1993.

Operation of the chemical injection piping has been reviewed to determine potential loads that likely contributed to the degradation of the 3/4" on 16" x/hvy sockolet weldment. The configuration of the piping is such that it shares common piping supports with another chemical injection line and is connected to piping that provides auxiliary feedwater during startup and shutdown operations. Through most of the plant operating history, this chemical injection line has been isolated; however, it was used for phosphate injection during the first operating cycle. Under this situation, the phosphate injection temperature would have been at ambient, while the feedwater would have been nominally 440°F. The resultant temperature difference of approximately 380°F would have caused high stresses in the area of concern. The other chemical injection line is used to inject boric acid into the secondary side to control steam generator tube degradation and operates nearly continuously during plant operation. WPS has been using the other chemical injection line for boric acid injection over the last five cycles. At times the chemical injection piping with the leak is known to have been subjected to pipe vibration; the vibration occurs during boric acid injection or during auxiliary feedwater operation. The total time of auxiliary feedwater operation since 1979 was recently estimated at 2981 hours.

As part of this investigation, the piping stress analysis report of record (point number 1174) was reviewed. The stress analysis report contains forces, moments, and stresses that act on the 3/4" on 16" x/hvy sockolet weldment. The piping stress analysis report does not include a thermal load for a large temperature difference. Degradation of the 3/4" on 16" x/hvy sockolet weldment is believed to have been initiated by the thermal stresses caused from the large delta temperature during the first operating cycle. Furthermore, degradation may have been assisted later in plant life by bending stresses associated with pipe vibration.

The following items were considered during investigation of the root cause of the leak: erosion-corrosion, mechanical fatigue, thermal fatigue, corrosion assisted fatigue, improper heat treatment, prior existing fabrication flaws, and poor weld quality. Fabrication records and the construction code were reviewed to ensure that no unexpected problems exist because of improper heat treatment. The welding process was reviewed to develop an understanding of what possible welding defects and other weld related problems could exist. Nondestructive examinations were selected and performed to verify that degradation was not caused from erosion-corrosion or prior existing fabrication flaws. As stated above, degradation of the 3/4" on 16" x/hvy sockolet weldment is believed to have been initiated by thermal stresses caused by large temperature difference during the first operating cycle. We believe that degradation started at a location in the root weld where the welder started/stopped weld deposition. This region of the weld root can easily have a small amount of lack of fusion and also acted as a point of stress concentration. The fillet weld was created by depositing E7018 weld metal by weaving from the inside to the outside of the weld joint in circumferential manner until the weld joint was full. This process of depositing weld metal in a weave pattern without stopping to clean between weld passes can result in small areas of lack of fusion, porosity, and inclusions. USAS B31.1.0 does not require radiography or liquid penetrant/magnetic particle examination between weld passes for fillet welds. Thus, any of these conditions might exist in the field.

Nondestructive examinations were applied to three primary areas: the 16" feedwater piping adjacent to the sockolet weldment; the base metal on the 16" feedwater pipe located directly under the weld that attaches the sockolet to the feedwater pipe; and the weld. A tabulation of examinations used to assess the integrity of these three areas is provided in Figure 4.

The 0° ultrasonic beam, 45° shear wave, and double wall-single view radiography confirmed that the 16" diameter pipe was free of cracking and erosion-corrosion. These examinations help eliminate mechanical fatigue, corrosion assisted fatigue, thermal fatigue, and erosion corrosion as possible active degradation mechanisms of the 16" diameter pipe.

The 16" diameter pipe located directly under the weld was found to be free of cracking by implementation of the 45° shear wave examination. Additionally, from the double wall exposure, (tangential) the interface region at the outer diameter of the feedwater pipe located directly under the weld and the sockolet was found to be free of cracking and erosion/corrosion. Confirmation that the 16" diameter pipe under the weld is free of cracking is noteworthy since the postulated/expected direction of crack growth (should cracking occur) is from the existing flaw in the fillet weld (located at the O.D. surface of the feedwater pipe) into the feedwater pipe.

The degradation in the branch connection weld is characterized as being related to the welding process. The location of the leak is shown Figure 6. The leak path has been determined to be a network of connecting small regions of lack of fusion between weld passes and small clusters of porosity/inclusions in the fillet weld. This network is characterized as a torturous path having essentially no width or circumferential extent. Tangential radiography shows that the network originates in the root weld and extends through the base of the fillet weld to the toe of the fillet weld. Tangential radiography of the branch connection weld and double wall-single view radiography of the feedwater pipe/fillet weld confirm that the flaw has no width or circumferential extent; it exists in the through wall direction only and may be classified as two pin hole leaks. Consistent with this data, visual examination of the branch connection weldment conclusively revealed that the leak is located in a cluster of weld porosity. Our NDE/Welding contractor independently concluded and confirmed our assessment that the flaw originates in the root weld and consists of a network of small weld defects (e.g., porosity). This information suggests that the area of degradation is small with respect to the total weld volume and weld length and therefore does not affect the structural integrity of the component.

The expected mode of degradation for this type of situation is believed to be leakage similar to what is currently being observed. Stains on the pipe insulation indicate that very small amounts of leakage have probably been present for some time. The volume of leakage is minuscule. No dripping of water can be seen on the pipe or under the pipe. The small amount of leaking steam evaporates readily once it comes in contact with the external surface of the feedwater piping. Upon discovery of the leak, WPS took appropriate steps to minimize bending stresses associated with pipe vibration by isolating both of the chemical injection lines that share common hangers. Future vibration of the chemical injection line should now only occur during shutdown when the auxiliary feedwater system is started. Since the high thermal and vibrational loads have been minimized, essentially no driving force exists to propagate a flaw in the near future. In fact, since pressure is the only remaining force acting on the weld, we believe that this situation is stable and would remain so for years. To determine the margin of safety for continued plant operation (for approximately six more weeks until the scheduled 1996 refueling outage when the branch connection weld will be repaired/replaced), KNPP contracted Westinghouse Electric Corporation to perform a fracture mechanics evaluation.

The results of the fracture mechanics evaluation are documented in Attachment 3 which was faxed to WPS on 8-12-96. These results show that the smallest critical crack size in the branch connection weld is approximately 2.22 inches and approximately 23.16 inches in the feedwater pipe. These critical crack sizes differ from those determined in Reference 1. The estimated time to failure has been revised accordingly. The margins of safety based on the calculated limit load pressure for the weld and feedwater pipe in the normal, upset, emergency, and faulted conditions (Levels A, B, C, and D respectively) are tabulated below.

SERVICE CONDITION	MARGIN ON LIMIT MOMENT		MARGIN ON FLAW SIZE	
	WELD	FEEDWATER PIPE	WELD	FEEDWATER PIPE
LEVEL A	--	38	--	270
LEVEL B	--	17.7	--	254
LEVEL C	--	--	--	--
LEVEL D	>3	8.9	22	232

With this information a crack was postulated and an upper bound crack growth rate was established to determine remaining life to ductile limit load failure. The size of the postulated crack is 0.062 inches and is based upon the size of the largest flaw that could go undetected during the ultrasonic and radiographic examinations. Double wall - single view radiography of the feedwater pipe was performed using a number 25 penetrameter. A number 25 penetrameter has a 0.050 inch hole that was readily visible on the film. Calibration for the 45° shear wave ultrasonic examination was performed on a 0.1438 inch deep notch. Scanning during the ultrasonic examination was performed from 6 db to 10 db above calibration level which increases detection sensitivity. It is estimated that scanning at this level will reliably ensure detection of a crack down to 0.03125 to 0.0625 inches in the through wall direction.

An upper bound crack growth rate is established based on the best conservative estimate of time required to grow a crack under plant operating conditions. As discussed earlier, the loads that are believed to have contributed to degradation of the weldment include hoop stress, thermal stress from temperature difference, and bending stress from possible vibration. Of these stresses, the thermal stress is judged to be the most severe. Since water hammer events are primarily associated with startup operations, they were determined to not have an impact on the evaluation of the existing flaw.

It is known that the chemical injection line was used for approximately one cycle for phosphate injection. To be conservative it will be assumed that all of the degradation was caused from the thermal stress over half the cycle, i.e., in 4380 hours. For purposes of establishing an upper bound crack growth rate the weld thickness at the base of the fillet weld is postulated to be 0.75 inches; the actual length along the base of the fillet weld is 0.625 inches. The resultant crack growth rate is 0.00017 inches/hour (0.75 inches/4380 hours). A crack of approximately 0.0625 inches, which bounds the largest crack that could go undetected during ultrasonic and radiographic examination, would grow to 2.22 inches in the weld and 23.16 inches in the feedwater pipe assuming an upper bound crack growth rate of 0.00017 inches/hour under operation with high thermal stresses after approximately 1.45 years and 15.51 years, respectively. Limiting plant operation to approximately six weeks ensures a safety factor based on an upper bound crack growth rate and operating time for the weld and feedwater pipe of 31 and 130, respectively.

In summary, fracture mechanics calculations have been performed to assess the structural integrity of the feedwater pipe and weldment. While the feedwater pipe and weld will see essentially only system pressure loads (over the next six weeks), the calculations have been performed using different loading cases consistent with service conditions A, B, and D. These calculations demonstrate that large margins exist on flaw size and failure by ductile limit load. Furthermore, remaining life calculations based on an upper bound crack growth rate show that the plant can safely operate in excess of the estimated six more weeks until the scheduled refueling outage.

3.3 AUGMENTED INSPECTIONS

To provide assurance that significant changes in the characteristics of the flaw are identified, an augmented inspection program has been established.

Trained inspectors from the Quality Programs Department will perform a daily visual examination of the identified surface indication in the sockolet-to-pipe weldment, and the pipe surface in the surrounding area. This ongoing inspection will monitor both quantitative and qualitative indicators to detect "significant changes".

For the purpose of these inspections, "significant changes" are defined as major, unexpected variations in visually observable indication characteristics contrary to that expected based on the conclusion of cluster porosity. The conclusion of cluster porosity leads us to expect little or no change in observable leak rate, and similarly little or no change in surface characteristics of the indication.

Quantification of leak rate will be done by counting the drops per minute condensing on the adjacent temporary restraint. Quantification of surface characteristics will be made by periodic visual confirmation that there are only two observable "pin holes" and that the distance between them, their size and their orientation with respect to the subject weldment has not changed.

Qualitative characteristics, those observable, but difficult to measure with some degree of certainty, include the visual appearance of the surface indication, the visual appearance of the wisp of steam/water issuing from the pin holes, and the visual appearance of the moisture spot on the feedwater pipe.

Qualitative inspections of the flaw will also be performed each shift by the plant operators. Guidance for these inspections has been provided by the Quality Programs Department.

Therefore, any significant change in these quantitative or qualitative characteristics will result in timely action to shut down the plant and repair the weld.

3.4 DESCRIPTION OF THE TEMPORARY RESTRAINT

WPS's assessment of the weld has determined that it has sufficient strength and margin to ensure continued, safe operation until the September refueling outage. However, in order to provide an added measure of safety, a temporary restraint has been installed. The purpose of the restraint device is to hold the fitting in place should the chemical injection sockolet to the A main feedwater line weldment fail. Note that the design has been modified slightly from that proposed in Reference 1; these changes were made to address an NRC concern with forces on the chemical injection pipe-to-sockolet weld and to limit compressive forces on the area of the flaw (a concern raised by the Plant Operations Review Committee). Further the bolted design permits easy removal should it be necessary after installation to accommodate additional NDE.

Design Description:

Carbon steel plate, angles, and U-bolts will be used to fabricate the restraint. The design allows the 3/4" chemical injection pipe to be completely surrounded by two plates, forming a collar around the 3/4" pipe.

- The hole in the collar includes a chamfer which accommodates the fillet weld, connecting the 3/4" pipe to the sockolet. There is a gap between the outer diameter of the 3/4" pipe and the inner diameter of the collar hole. The purpose of the gap is to minimize the potential bending moment on the sockolet due to restraint dead weight.

- Two (2) carbon steel angles will be alternately welded and bolted to the collar halves. These angles will extend perpendicular to the longitudinal axis and beyond the outer diameter of the FW pipe.

- Two (2) U-bolts will be connected to the angles to support the restraint from the FW pipe.

- Two (2) spacer bolts with rounded tips are threaded through the collar plate to provide contact points to support the restraint from the feed water piping. These spacer bolts, with lock nuts will be adjusted in the field to place the collar chamfer around the 3/4" pipe to sockolet weld. Measurements during installation will be used to minimize the gap between the chamfer and sockolet weld, while avoiding significant contact. This installation method will prevent significant loads on the weldment.

The restraint will be installed until the next plant shutdown when the chemical injection sockolet to the A main feedwater line weldment will be repaired/replaced.

A summary of the design considerations and loading combinations incorporated into the detailed design are as follows:

- Clear angles of vision are provided to permit complete visual inspection of the chemical injection sockolet to the A main feedwater line weldment. This will permit visual surveillance of the entire weldment as committed to in Reference 1.

- The design load on the restraint is derived from the resulting force from the FW system design pressure on the sockolet and attached 3/4" piping. This load, including impact considerations, will be used to size the individual restraint components. AISC allowable structural materials will be used in the restraint. AISC allowable stress limits, for structural materials, will be used to document the structural adequacy of the design.

- By design, the restraint will not place a compressive load on the chemical injection sockolet to the A main feedwater line weldment. The two spacer bolts are used to provide the friction contact points on the FW pipe and the load paths to support the restraint.

- The hole in the collar is larger than the outer diameter of the 3/4" pipe. The gap minimizes any contribution to the bending moment.

- The edges of the hole in the collar, in the immediate proximity of the 3/4" pipe to sockolet weld are beveled at a 45 degree angle creating a chamfer. This chamfer permits capturing the end of the sockolet within the collar should the restraint become necessary.

- During installation, in the process of tightening the U-bolts, the restraint will be supported to keep the 3/4" pipe centered in the hole of the collar. The U-bolt nuts will be tightened 1/4 turn past tight. The spacer bolts will be adjusted to bring the top of the 3/4" pipe to sockolet weld within the collar chamfer and the lock nuts tightened. After installation, the U-bolts will be re-tightened as necessary to accommodate heating from contact with the FW pipe and double nutted to prevent loosening. Using this installation technique, the U-bolts and spacer bolts support the dead weight of the assembly and minimize any loads imposed by the assembly upon the sockolet.

- The seismic or postaccident loads induced by the 3/4" pipe on the chemical injection sockolet to A main feedwater line weldment are minimally impacted by the restraint. Given the ratio of the cross-sectional moments of inertia between the FW pipe and the 3/4" pipe, the loads imposed on the chemical injection sockolet to the A main feedwater line weldment are primarily induced by the relative motion of the two pipes. The motion of the 16" pipe determines the stresses in the weldment. The restraint does not change the relative motion of the pipes. With the restraint supported by the 16" pipe, there is no contribution to the mass of the 3/4" pipe. Therefore, there will be no meaningful changes in the piping system response to seismic or postaccident loads.

- Additional compressive loads on the chemical injection sockolet to the A main feedwater line weldment are insignificant. The spacer bolts provide the load bearing path.

- The forces from the restraint on the FW piping were reconciled with the existing piping analysis of record. The evaluation determined the restraint has insignificant effect on the analysis of record. Given the size and wall thickness of the FW piping and the weight of the restraint, the added mass is negligible. The restraint is completely supported by the FW pipe and does not constrain pipe motion. Given the location of the restraint with respect to other structures or components in the area of the fitting there are no interference concerns. The loads imposed on the pipe wall by the U-bolts are in the direction opposite to pressure induced loads in the piping. There will be no pressure boundary concerns created by the restraint.

A summary of the design loads, calculated stresses and code allowable stresses for restraint design are as follows:

Restraint load from weldment failure: 3313 lb_f

Carbon Steel 3X3X1/4 Angles:

Bending stresses - 12,201 psi
AISC allowable (0.6*36,000) - 21,600 psi

Notched angle stresses - 18,773 psi
AISC allowable (0.6*36,000) - 21,600 psi

U-bolts - 1/2" dia. A-36 rods

Tensile stresses - 11,674 psi
AISC allowable - 21,600 psi

Collar plates

Bending stresses - 5,050 psi
AISC allowable - 21,600 psi

Shear stresses - 376 psi
AISC allowable - 14,400 psi

Welds and 1/2" diameter bolts between carbon steel angles and collar plates.

By standard practice, the 1/4" fillet welds and 1/2" bolts of specified material and installation torque value are acceptable.

Seismic adequacy of the design.

A review of the stress report FW-05A-003 rev 6, shows the seismic accelerations of the FW pipe are low. The loading from a seismic event is less than the resulting force from the assumed weld failure. Therefore, the restraint is adequate.

FW pipe effects:

The stress report for the feedwater line was reviewed to evaluate the effect of adding the weight of the assembly. Stress report FW-05A-003 rev.6 shows that the stress levels in the piping are low, and the seismic accelerations are low. Adding the 60 lbm weight of the restraint, will not result in a piping over stress condition. This is based on the fact that the additional weight is small in comparison with the design margin remaining in the 16" Feedwater pipe. The following table lists the stress report results and provides information on the design margin available used to evaluate the effect of the restraint.

Load Combinations	Calculated stress at the restraint location	Allowable stress
Internal pressure	11,639 psi	15,000 psi
Thermal expansion	2,596 psi	22,500 psi
Pressure + weight + O.B.E.	11,012 psi	18,000 psi
Pressure + weight + D.B.E.	16,942 psi	27,000 psi

A calculation was performed to determine the effect on the weldment should the restraint slip during operation. The full weight of the assembly was assumed to rest upon the outer edge of the sockolet resulting in a bending moment of 82.5 in-lb_f and a shear load of 60 lb_f. The resulting square root sum of the squares shear stress is 25 lb_f/in of weld. The evaluation determined the additional load is insignificant.

Section 4.0 CONCLUSIONS

The visual inspections made by qualified VT technicians and our experienced welding consultants (Professional Welding Associates) lead them to conclude that the pin hole leaks are a result of porosity in the weldment and are expected to remain stable. There is visual evidence that the leak is located at an undercut where one weld pass is ended and another begun. The weld porosity is further substantiated by the RT examination which confirms the porosity at the weld root.

An ultrasonic examination of the 16" main feedwater pipe base metal confirmed that no indications are present beneath the leaking sockolet weld, providing added assurance that the leak is due to the weld imperfection.

Having clear and substantial evidence of the location and character of the leak, engineering assessments of safety factors, under worst case faulted condition stress levels, show considerable margins.

In addition, the frequent visual inspections will confirm that the flaw and leak characteristics remain consistent with the type of weld defect understood to be present and allow us to take timely action should any significant or unexpected changes occur.

And although we are confident that a failure of the weld is not credible, a restraining device was installed to minimize leakage should the unlikely event of a complete weld failure occur.

In summary, the confirmed nature of this leak, the margins of safety remaining, and the conservative compensatory actions of physical restraint and monitoring provide definitive assurance that it is safe to continue plant operation for a six week period prior to scheduled shutdown at which time the weld will be repaired or replaced.

ATTACHMENT 2

to Letter

from

M. L. Marchi (WPS)

to

Document Control Desk (NRC)

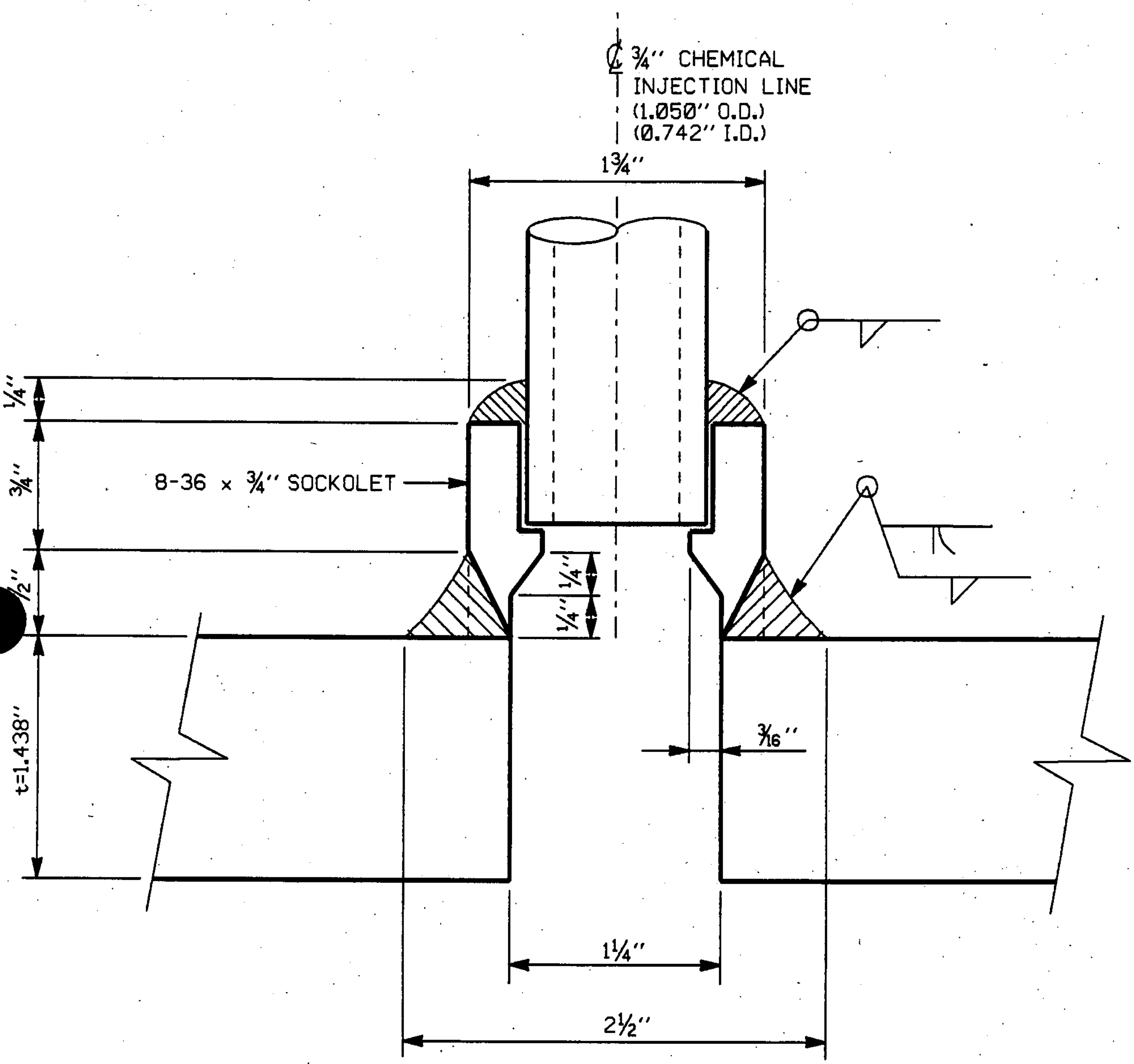
Dated

August 12, 1996

<u>Relief Request RR2-1</u>

LIST OF FIGURES

Figure #	Description
1	Sketch of Main Feedwater Pipe and Sockolet
2A & B	Radiography Technique
3A, B, & C	UT Technique
4	NDE Summary
5	Magnetic Particle Technique
6	Visual Examination Technique
7A, B, & C	Drawings of Temporary Restraint



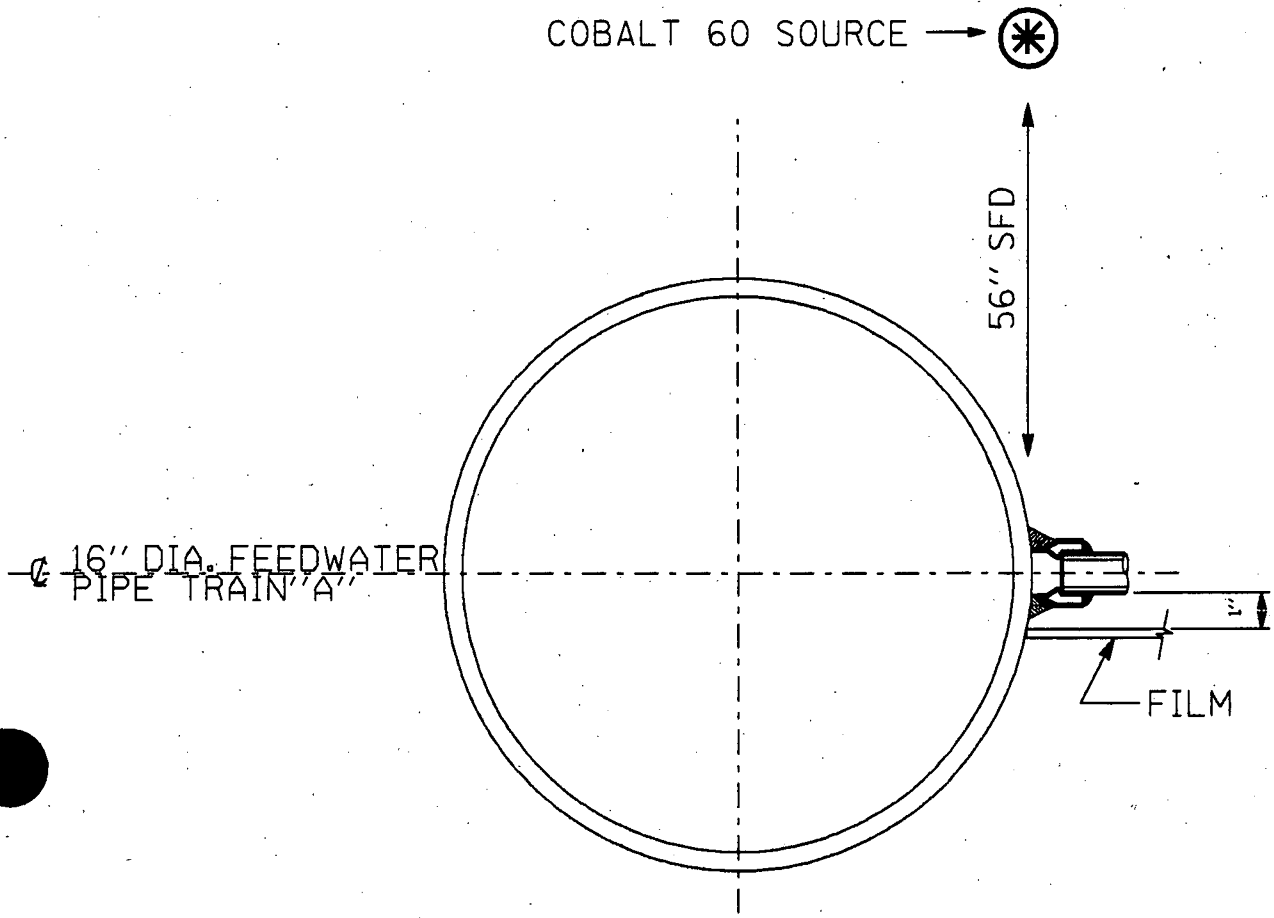
BASED ON FIELD MEASUREMENTS
AND RADIOGRAPHS

FIGURE 1

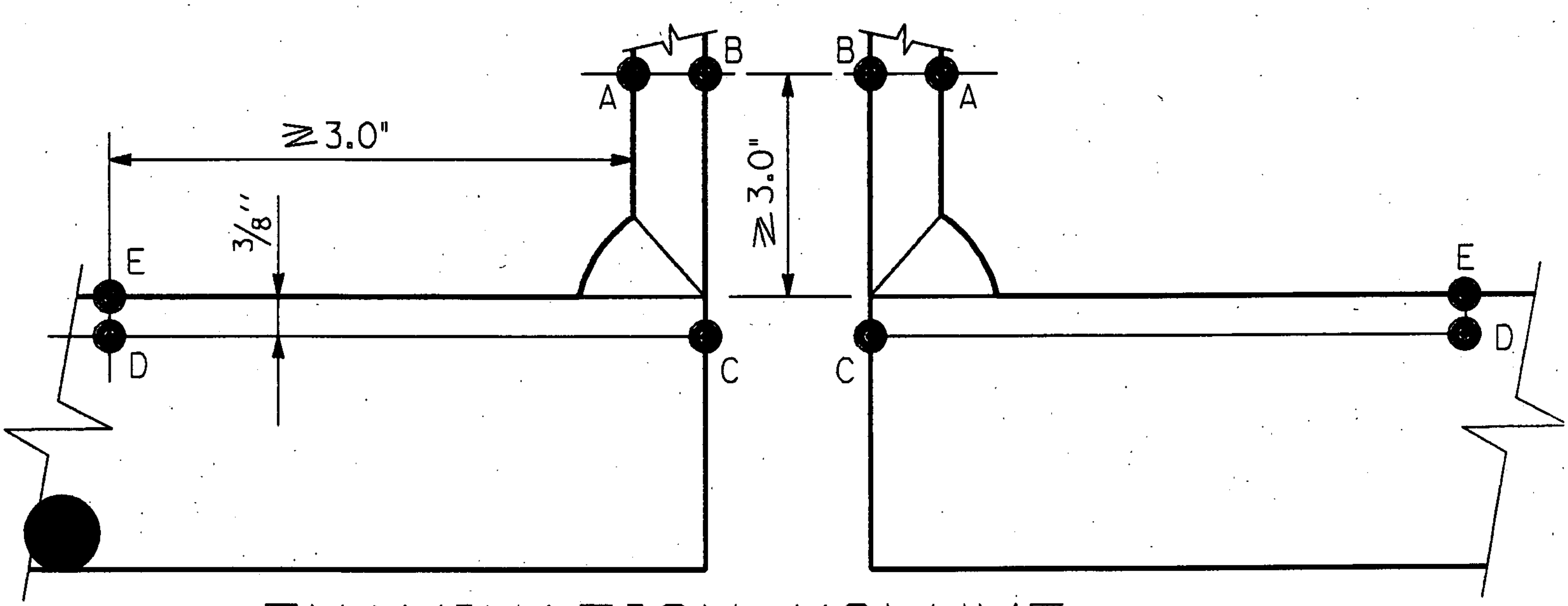
SCALE: 1:1

RADIOGRAPHY DOUBLE WALL/TANGENTIAL

DOUBLE WALL VIEW TECHNIQUE



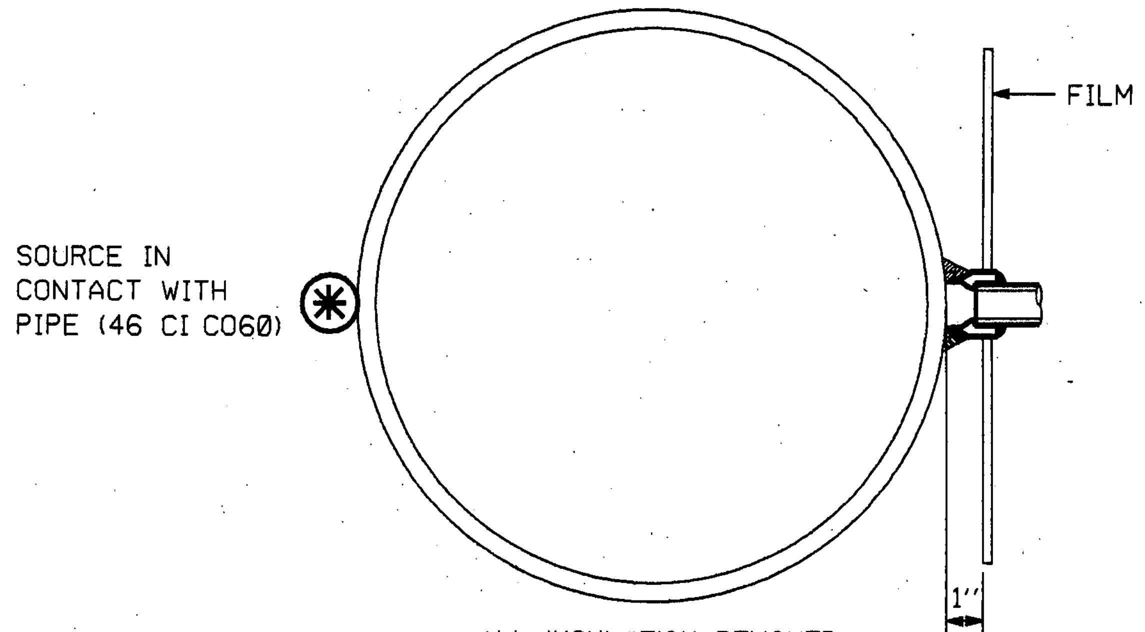
EXAMINATION VOLUME



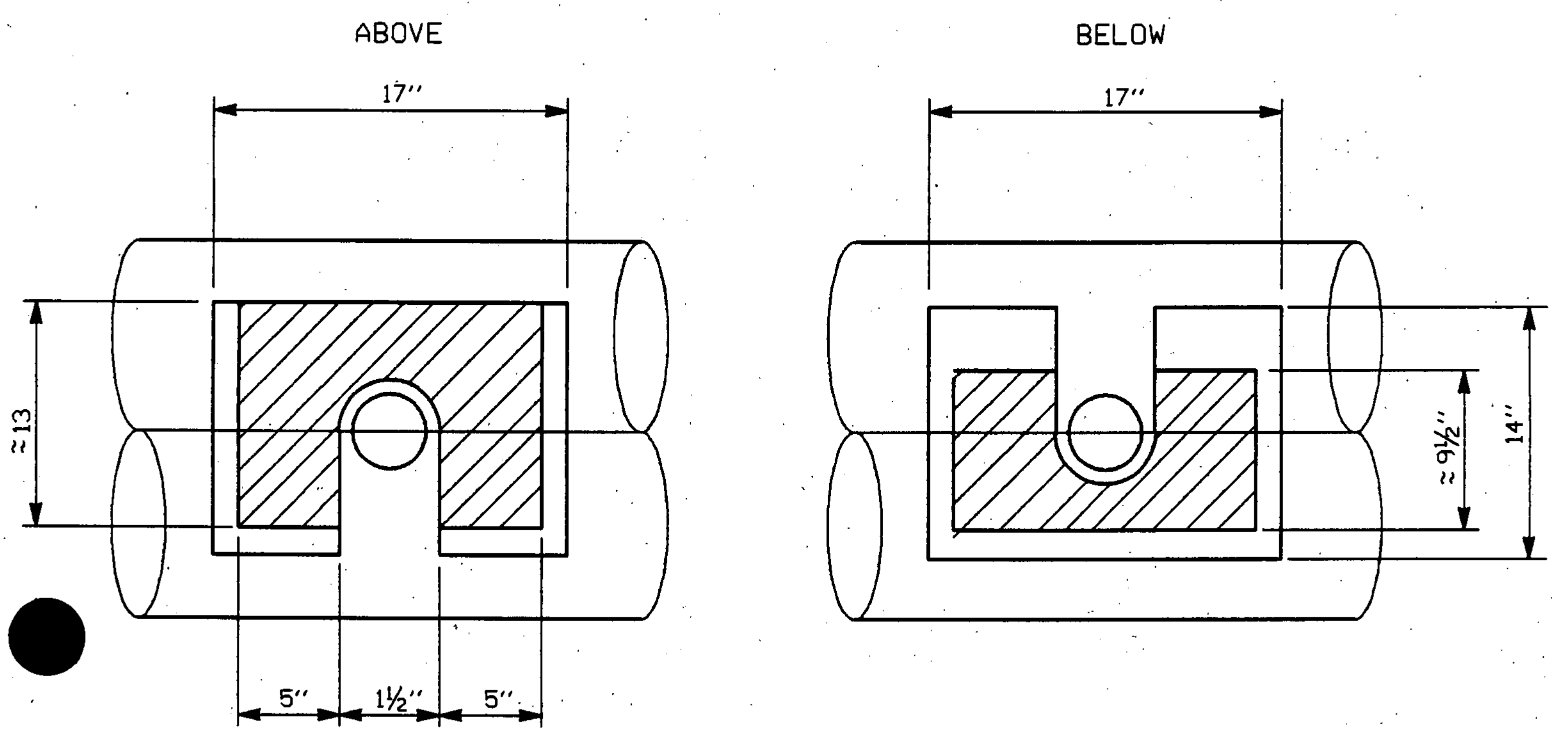
EXAMINATION VOLUME:
A-B-C-D-E

FIGURE 2A
NO SCALE

RT TECHNIQUE



ALL INSULATION REMOVED.
DOUBLE WALL CONTACT METHOD.



FILM PLACEMENT
HASH MARKS INDICATE
APPROXIMATE AREA OF INTEREST

FIGURE 2B
NO SCALE

WISCONSIN PUBLIC SERVICE CORPORATION
KEWAUNEE NUCLEAR POWER PLANT
VESSEL AND PIPING ULTRASONIC EXAMINATION RECORD

REV.: ORIG.

SYSTEM OR COMPONENT: FEEDWATER FROM ANCHOR NEAR HTRS TO ANCHORED ELLS INSIDE CNTMT   DRAWING NO.: ISIM-991 Sh.1
PROCEDURE: NEP No.15.18 REVISION: ORIG.
ASME SECTION XI EXAMINATION REQUIREMENTS/FIGURE NO.: IWC-2500-7 (Reference)
EXAM: PRESERVICE ☐ INSERVICE ☒   EXAM SURFACE: I.D. ☐ O.D. ☒

ULTRASONIC INSTRUMENT
MANUFACTURER: Panametrics
MODEL: EPocH IIB-2200
SERIAL NO.: 94087612
REP. RATE: Fixed - Yes
REJECT: 0
DAMPING: OFF - 150 OHMS
FILTER: 2.25 MHZ OFF
RANGE: 1.183 IN./DIV.

STRAIGHT BEAM 0° TRANSDUCER
MANUFACTURER:
TYPE:
SERIAL NO.:
FREQUENCY:
SIZE:
ANGLE/WAVE MODE:
CABLE TYPE:
CABLE LENGTH:
CABLE CONNECTORS:

ANGLE BEAM TRANSDUCER RIGHT ANGLE SCANNING (2&5)
MANUFACTURER: Harisonic
TYPE: AB M0208
SERIAL NO.: W6207
FREQUENCY: 2.25 MHZ
SIZE: 0.5" x 0.5"
ANGLE/WAVE MODE: 45°/Shear
WEDGE TYPE/I.D.: High Temp/HT02
CABLE TYPE: Bnc To mcd/RG-174
CABLE LENGTH: 6'
CABLE CONNECTORS: 0

ANGLE BEAM TRANSDUCER PARALLEL SCANNING (7&8)
MANUFACTURER: Harisonic
TYPE: AB M020B
SERIAL NO.: W6207
FREQUENCY: 2.25 MHZ
SIZE: 0.5" x 0.5"
ANGLE/WAVE MODE: 45°/Shear
WEDGE TYPE/I.D.: High Temp/HT02
CABLE TYPE: Bnc To mcd/RG-174
CABLE LENGTH: 6'
CABLE CONNECTORS: 0

ULTRASONIC COUPLANT
TYPE: ECHO LABS Thermosonic
BATCH NO.: 3391

TEMPERATURE INSTRUMENT
TYPE: Barnant 100
SERIAL NO.: 92359

CALIBRATION BLOCK
I.D.: WPS-6
TEMP.: 302.5°F

CALIBRATION REFLECTOR	STRAIGHT BEAM 0° REFLECTOR AMPLITUDE	STRAIGHT BEAM 0° REFLECTOR SWEEP	ANGLE BEAM RIGHT ANGLE REFLECTOR AMPLITUDE	ANGLE BEAM RIGHT ANGLE REFLECTOR SWEEP	RIGHT ANGLE BEAM SPREAD PEAK SWEEP/IN.	RIGHT ANGLE BEAM SPREAD 50% DAC. SWEEP/IN.	RIGHT ANGLE BEAM SPREAD 50% DAC. SWEEP/IN.	ANGLE BEAM PARALLEL REFLECTOR AMPLITUDE	ANGLE BEAM PARALLEL REFLECTOR SWEEP	PARALLEL ANGLE BEAM SPREAD PEAK SWEEP/IN.	PARALLEL ANGLE BEAM SPREAD 50% DAC. SWEEP/IN.	PARALLEL ANGLE BEAM SPREAD 50% DAC. SWEEP/IN.	CALIBRATION TIME
1T NoTcH			80%	3.0				80%	3.2				INITIAL 0910
2T NoTcH			20%	6.0									CHECKS
3T NoTcH			16%	9.0									
													FINAL 0950
	CAL. DB:		CAL. DB: 76					CAL. DB: 76					

COMPONENT IDENT.	TEMP.	TRANSDUCER SCANNING DIRECTION: 0° BASE METAL	0° STRAIGHT	RIGHT ANGLE 2	RIGHT ANGLE 5	PARALLEL 7	PARALLEL 8	SURFACE CONFIGURATION	ACCEPTABLE NO INDICATIONS 0°	45°	60°	ACCEPTABLE NO RECORDABLE INDICATIONS 0°	45°	60°	REJECTABLE RECORDABLE INDICATION(S) 0°	45°	60°	SKETCHED ATTACHED	REMARKS Work Request 210275
16" Base MeTal	316°F			Yes	Yes	Yes	Yes	Smooth Base MeTal		X								Yes - 2	16" SCH140 Base meTal Ground 3/4" Soc-o-LeT WelD To Valve CI-122A

EXAMINER: Phillip C. Bukes II LEVEL   DATE: August 9, 1996
EXAMINER: N/A LEVEL   DATE: N/A

KEWAUNEE NUCLEAR POWER PLANT REVIEW: ______ DATE: ______
AUTHORIZED NUCLEAR INSERVICE INSPECTOR REVIEW: ______ DATE: ______

FIGURE 3A

WISCONSIN PUBLIC SERVICE CORPORATION
KEWAUNEE NUCLEAR POWER PLANT
ULTRASONIC EXAMINATION INDICATION
CROSS SECTIONAL
PLOT RECORD

REV.: ORIG.

SYSTEM OR COMPONENT: FEEDWATER FROM ANCHOR NEAR HTRS TO ANCHORED ELLS INSIDE CNTMT DRAWING NO.: ISIM-991 Sh 1

COMPONENT IDENTIFICATION: 16" Base Metal PROCEDURE: NEP No. 15.18 REVISION: ORIG

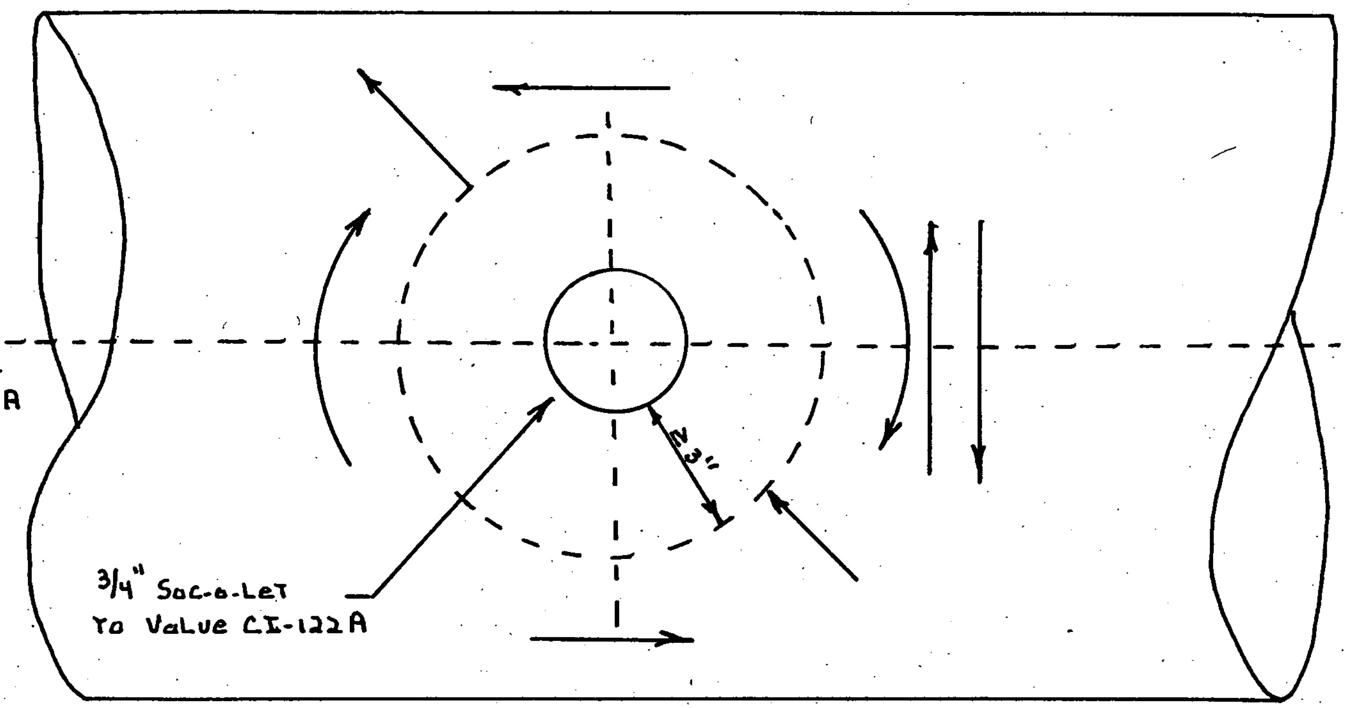
TYPE OF INDICATION: VALID FLAW ☐ GEOMETRIC ☐ METALLURGICAL ☐
(NOT APPLICABLE)

SKETCH TO PROVIDE: SIZE, LOCATION, ORIENTATION AND CROSS SECTIONAL VIEW OF INDICATION. LIST ADDITIONAL, EXTRA OR SPECIAL EQUIPMENT AND FABRICATION OR WELD PREP DRAWINGS UTILIZED FOR SIZING OR RECORDING.

CROSS SECTIONAL PLOT RECORD USED TO SHOW SCAN DIRECTIONS ONLY.

8 SCANS TOTAL EACH SCAN PERFORMED FOR 360° AROUND 3/4" SOC-O-LET

16" DIAMETER FEEDWATER PIPE TO VALUE FW-12A

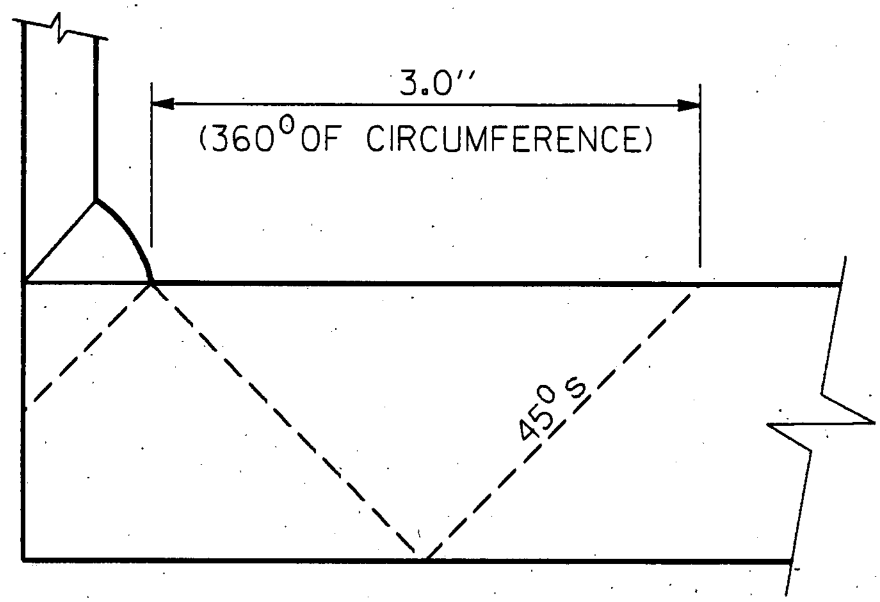


DOTTED LINE INDICATES SCAN REGION

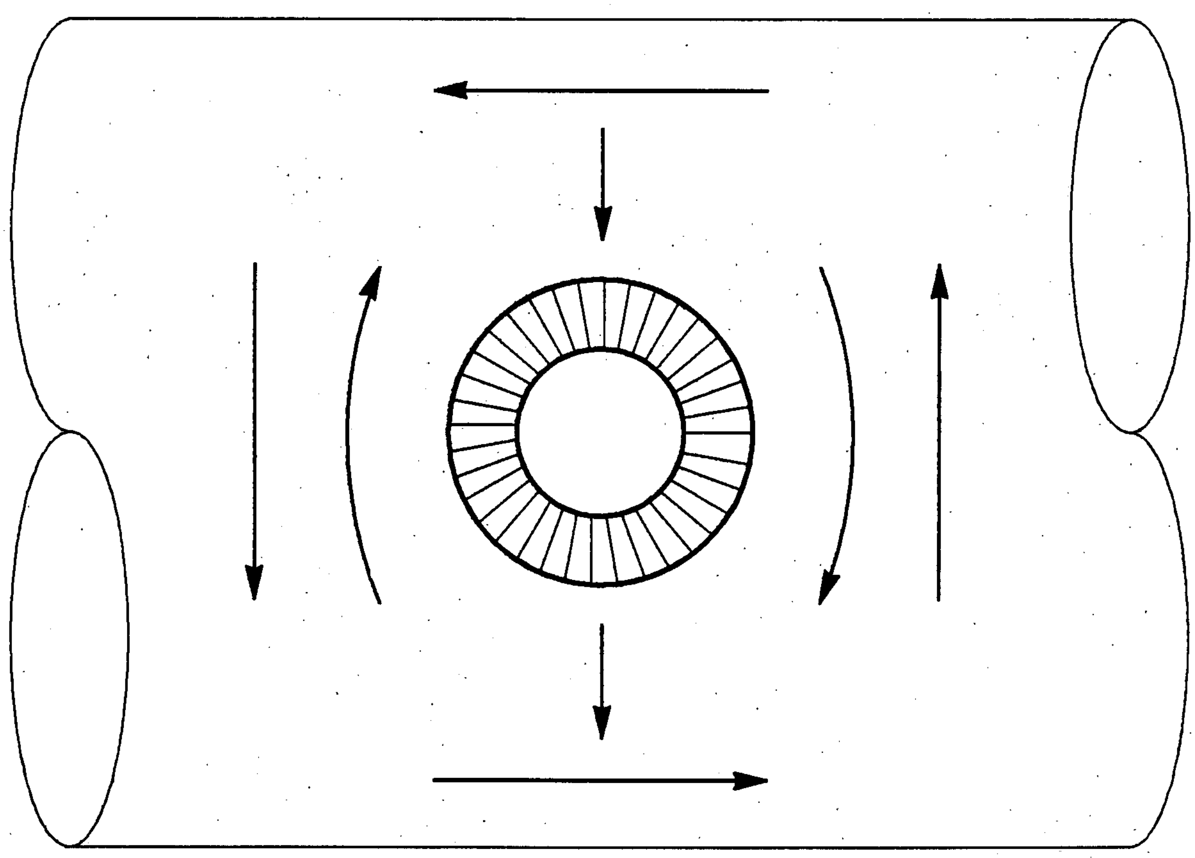
EXAMINER: *Phillip E. Bukes* II LEVEL	DATE: *August 9, 1996*	KEWAUNEE NUCLEAR POWER PLANT REVIEW:	DATE:
EXAMINER: N/A LEVEL	DATE: N/A	AUTHORIZED NUCLEAR INSERVICE INSPECTOR REVIEW:	DATE:

FIGURE 3B

EXAMINATION VOLUME



EXAMINATION METHOD:
ULTRASONIC (45° S)



SCAN DIRECTION

FIGURE 3C

NO SCALE

SUMMARY OF EXAMINATIONS AND RESULTS

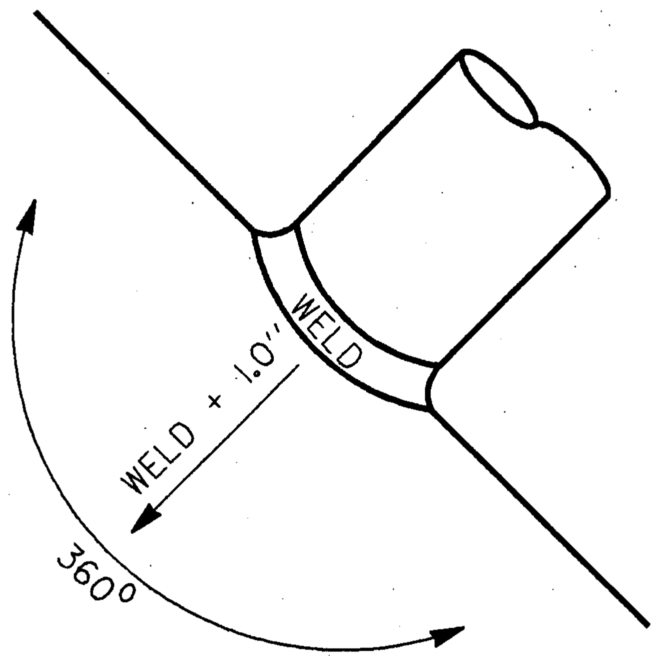
METHOD/DESCRIPTION	PROCEDURE USED	RESULT			CODE		SKETCH
		NI	NRI	RI	PROCEDURE	ACCEPTANCE CRITERIA	
RT 25 PEN 2T (.050" HOLE) DOUBLE WALL - SINGLE WALL VIEW	PWA PROCEDURE RT-1N REV 3	X			YES	USAS B31.1 - 1967	Figure 2B
RT DOUBLE WALL/TANGENTIAL - DOUBLE WALL VIEW	PWA PROCEDURE RT-WT REV. 3			X	NO	INFORMATION	Figure 2A
UT 45 DEG. SHEAR WAVE	WPS PROCEDURE NEP 15.18 REV. - 8/9/96	X			YES	ASME SECT. XI - 1989	Figures 3A, 3B and 3C
UT D-METER	PWA PROCEDURE UT-2 REV. 2	X			YES	USAS B31.1 - 1967 (MIN WALL)	Reference 1, Figure 6
MT	PWA PROCEDURE MPT-1N REV 4	X			YES	USAS B31.1 - 1967	Figure 5
VISUAL VT-1	WPS PROCEDURE NEP 15.5 REV. ORIGINAL			X	YES	ASME SECT. XI - 1989	Figure 6
THERMOGRAPHY (NON-NDE FOR INFORMATION ONLY)	WPS PROCEDURE GMP 210 REV. A	NA	NA	NA	NA	NA	NA

METHOD OF EXAMINATION AND AREA OF INTEREST

AREA OF INTEREST =====>	16" DIAMETER PIPE ADJACENT TO SOCKOLET	16" DIAMETER PIPE UNDER SOCKOLET	BRANCH CONNECTION WELD
METHOD / PROCEDURE			
RT / RT-1N	YES	NO (LIMITED - NONCODE EXAM)	NO (LIMITED - NONCODE EXAM)
RT / RT-WT	YES (LIMITED TO INTERFACE AREA ONLY)	YES (LIMITED TO INTERFACE AREA ONLY)	YES
UT (SHEAR WAVE)/ NEP 15.18	YES	YES	NO
UT [D-METER] / UT-2	YES	NO	NO
MT / MPT-1N	YES	NO	YES
VISUAL [VT-1] / NEP 15.5	YES	NO	YES
THERMOGRAPHY / GMP 210	YES	NO	YES

FIGURE 4

EXAMINATION AREA

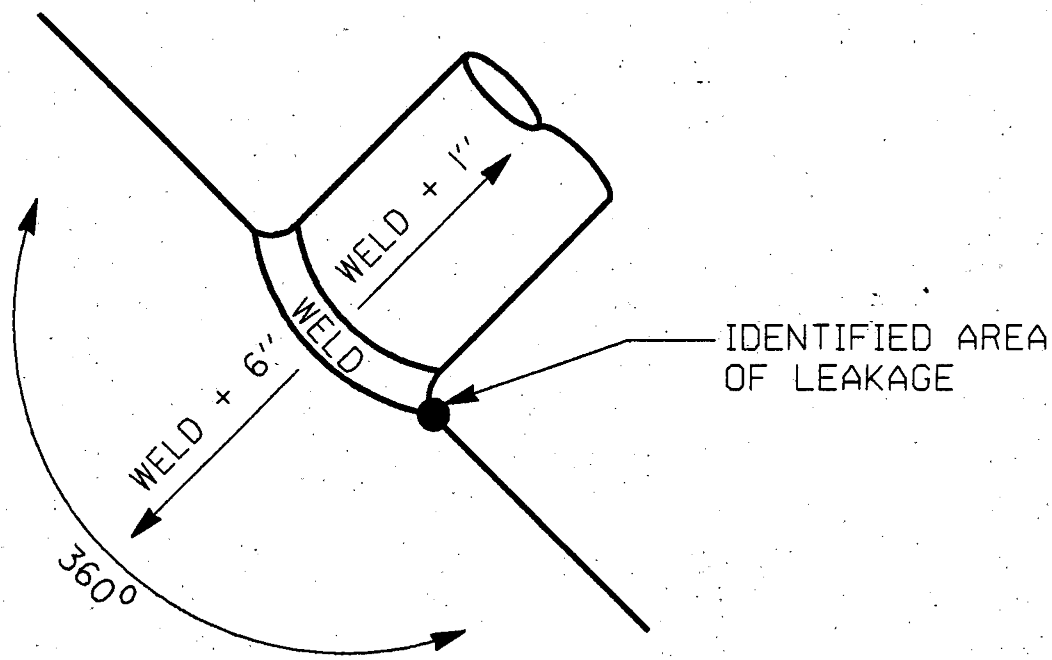


EXAMINATION METHOD:
MAGNETIC PARTICLE

FIGURE 5
NO SCALE

EXAMINATION AREA

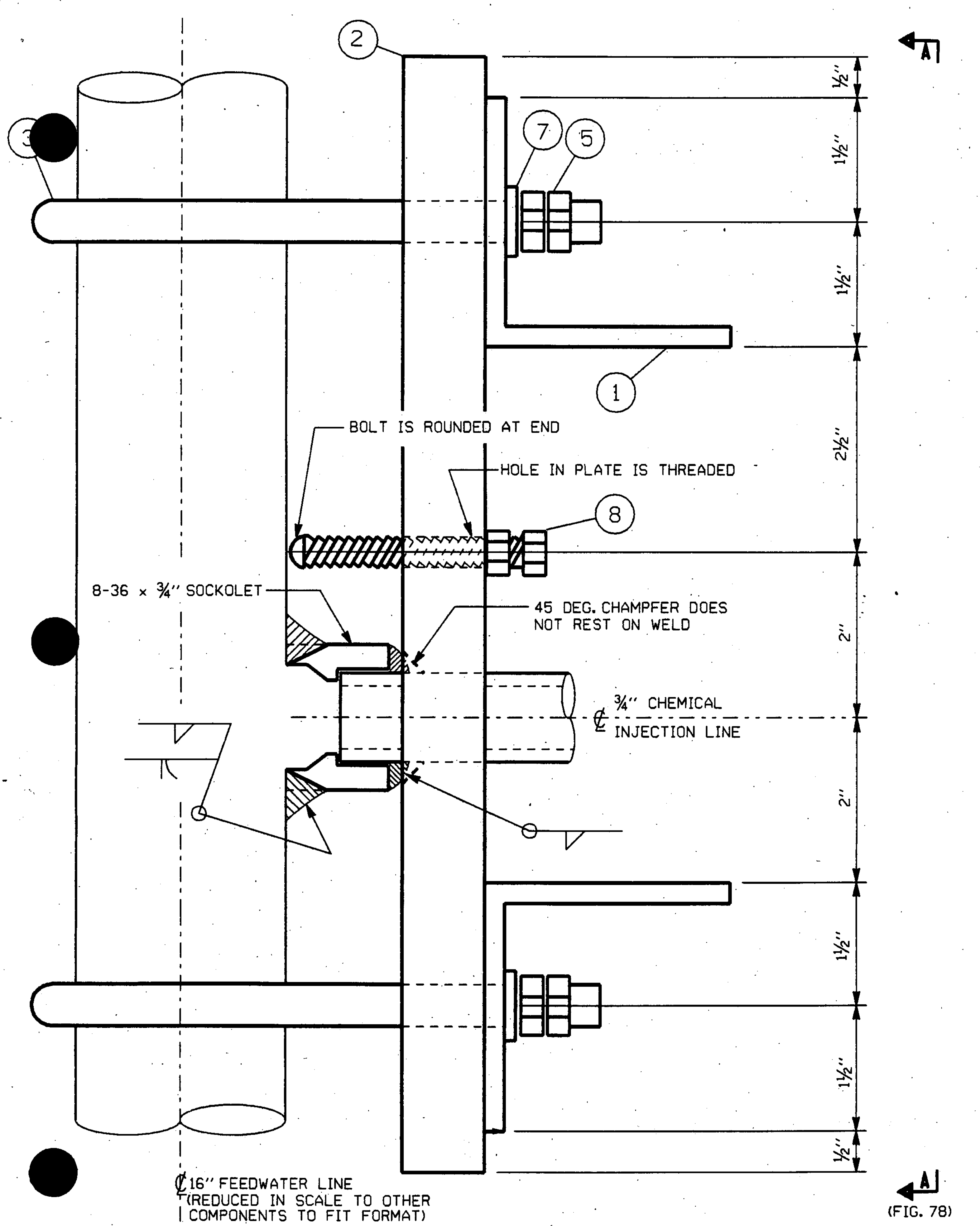
PLAN VIEW



VT-1 EXAMINATION METHOD

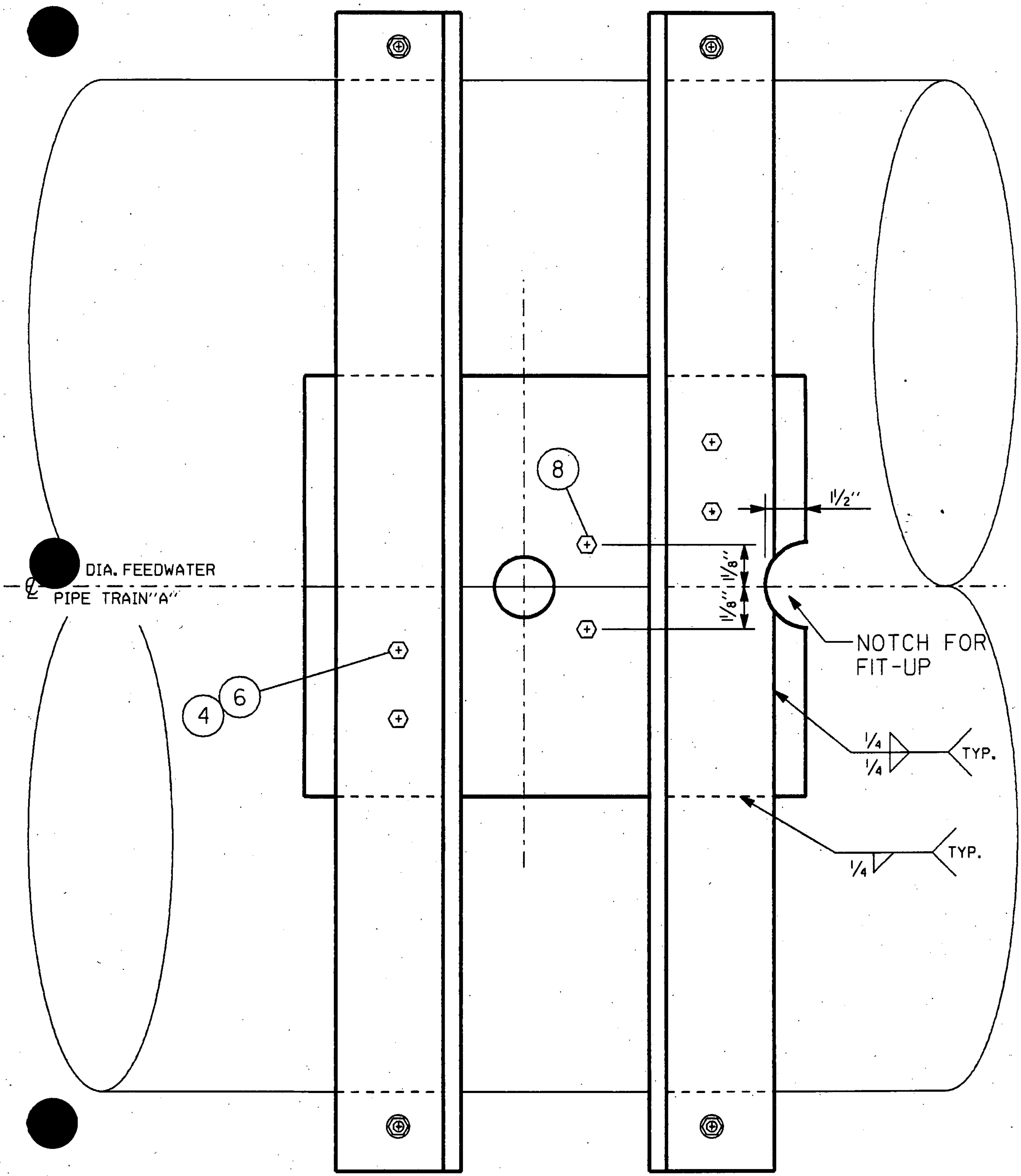
FIGURE 6

NO SCALE



PLAN VIEW LOOKING DOWN
INSTALLED RESTRAINT

FIGURE 7A
NO SCALE



SECTION A-A
SEE FIGURE 7A

FIGURE 7B
NO SCALE

BILL OF MATERIAL

ITEM#	QTY.	DESCRIPTION
1	2	L 3″ x 3″ x ¼″ x 1′-8″ ASTM A36 HOT ROLLED
2	2	PLATE 1″ x 10″ x 1′-1½″ (CS) ASTM A36
3	2	½″ x 12′-0″ LG. BAR (BENT AND THREADED) ASTM A36
4	4	½″ x 2½″ LG. BOLT Gr. 5 W/NUT
5	8	½″ HEAVY HEX NUT (FOR ITEM #3) ASTM A194 Gr. 2H
6	4	½″ HEX NUT (FOR ITEM #4)
7	8	½″ FLAT WASHER (FOR ITEMS #3 & #4)
8	2	⅜″ Gr. 5 BOLT W/NUT & THREADED END ROUNDED

FIGURE 7C

ATTACHMENT 3

to Letter

from

M. L. Marchi (WPS)

to

Document Control Desk (NRC)

Dated

August 12, 1996

<u>Relief Request RR2-1</u>

Westinghouse
Electric Corporation

Systems and Major Projects Division

PO Box 355
Pittsburgh Pennsylvania 15230-0355

August 12, 1996

MSE-SMT-96-156

Mr. Chuck Tomes
Wisconsin Public Service
600 North Adams
P. O. Box 19002
Green Bay, WI 54307-9002

Subject: Letter Report on Evaluation of the Indication in the Sockolet to Feedwater Line Junction at Kewaunee Plant

Dear Mr. Tomes:

Enclosed is a brief letter report documenting our evaluation of the indication in the sockolet to feedwater line junction at the Kewaunee plant.

Best regards,

WESTINGHOUSE ELECTRIC CORPORATION

W. H. Bamford
Structural Mechanics Technology

/ts

Enc.

MSE-SMT-96-156

Evaluation of Circumferential Flaw Limit Load Conditions: Kewaunee Feedwater Line

August 1996

W.H.Bamford
K.R.Hsu
C.K.Ng

Westinghouse Electric Corporation
Energy Systems
P.O.Box 355
Pittsburgh, PA 15230

Evaluation of Circumferential Flaw Limit load conditions: Kewaunee Feedwater Line

A pin-hole indication has been found in one of the sockolet to feedwater line welds at Kewaunee, and the purpose of this note is to discuss the flaw tolerance of the weld region, in order to establish the margins of safety that exist in this region.

The calculation will be carried out using established procedures to predict the ductile limit load of the region, as a function of flaw size. The feedwater line operates at a nominal temperature of 440F, so the mode of possible failure is clearly ductile. An enormous data base of flawed pipe experimental results exists to support this conclusion.

Two calculations were performed, one considering the flaw to be in the sockolet itself, and the second considering the flaw to be in the feedwater pipe. For each location, calculations were done considering the applied forces and moments from the stress analysis of record for the piping system. As will be seen, the results for all cases showed that a very large flaw would be necessary to cause a limit load failure. The methods used in these calculations are from reference 1, and the derivation of the limit moment expressions is shown in detail in Appendix A of this report.

<u>Sockolet</u>. The sockolet has an outside diameter of 2.5 inches, and the throat of the attachment weld was found to be no smaller than 0.625 inches, making this a very strong structure. The sockolet is made of 106B carbon steel. Results of the evaluation showed that a through wall circumferential flaw would be necessary to cause a limit load failure. The calculations show that if the pipe had a through-wall flaw as long as 70% of the circumference of the weld, the limit load pressure would still be 28,000 psi, a factor of safety of more than 20 over the maximum operating pressure of 1200 psi. A best estimate of the limit load pressure for the flaw as it exists is 47,600 psi, for a safety margin of nearly 40.

The detailed line loadings are not available at this time for the sockolet line, so the effect of a range of moments was investigated, as shown in figure 1. The results, as expected, show large moments are necessary to fail the line. A worst case loading was applied to the line for illustration, as seen in the figure. This loading was developed from the application of a load which would just meet the B31.1 criteria for Level D conditions, and even this load results in a very large through-wall critical flaw size. For a flaw which is not a through-wall flaw, a separate analysis was done, and the results for the same loading are shown in figure 2. Here we see that a flaw with a depth of 69 percent of the wall is needed for failure, assuming that the flaw extends all the way around the pipe.

<u>Feedwater line</u>. The feedwater line at this location has an outside diameter of 16 inches, and a wall thickness of 1.4 inches, and is made of 106B carbon steel. Results of the evaluation showed that the critical length for a through-wall circumferential flaw is 27 inches, or 58% of the pipe circumference. This corresponds to the maximum operating pressure of 1200 psi. The nominal operating pressure is 700 psi under normal conditions. A conservative estimate of the limit load pressure for the existing flaw is 1370 psi.

The complete piping analysis is available for the feedwater line, and so a range of calculations were carried out for the three different loading cases considered in the original design (ANSI B31.1). These load cases are shown in Table 1, where it may be seen that there are no specific load criteria for level C conditions. We have considered each of the other conditions, and the results are given in the figures listed below:

Level A	P + DW + TH	Figure 3
Level B	P + DW + OBE	Figure 4
Level D	P + DW + DBE	Figure 5

The equivalent results for through-wall flaws are shown in figures 6,7,and 8, which are also attached.

Therefore it may be concluded that there is a very large margin against failure in this region, in general. Specific margins have been developed for both locations, and are shown below. Margins are provided on both flaw size and limit moment. These were calculated based on the conservative charcterization of the existing flaw as through wall with a length of 0.1 inches.

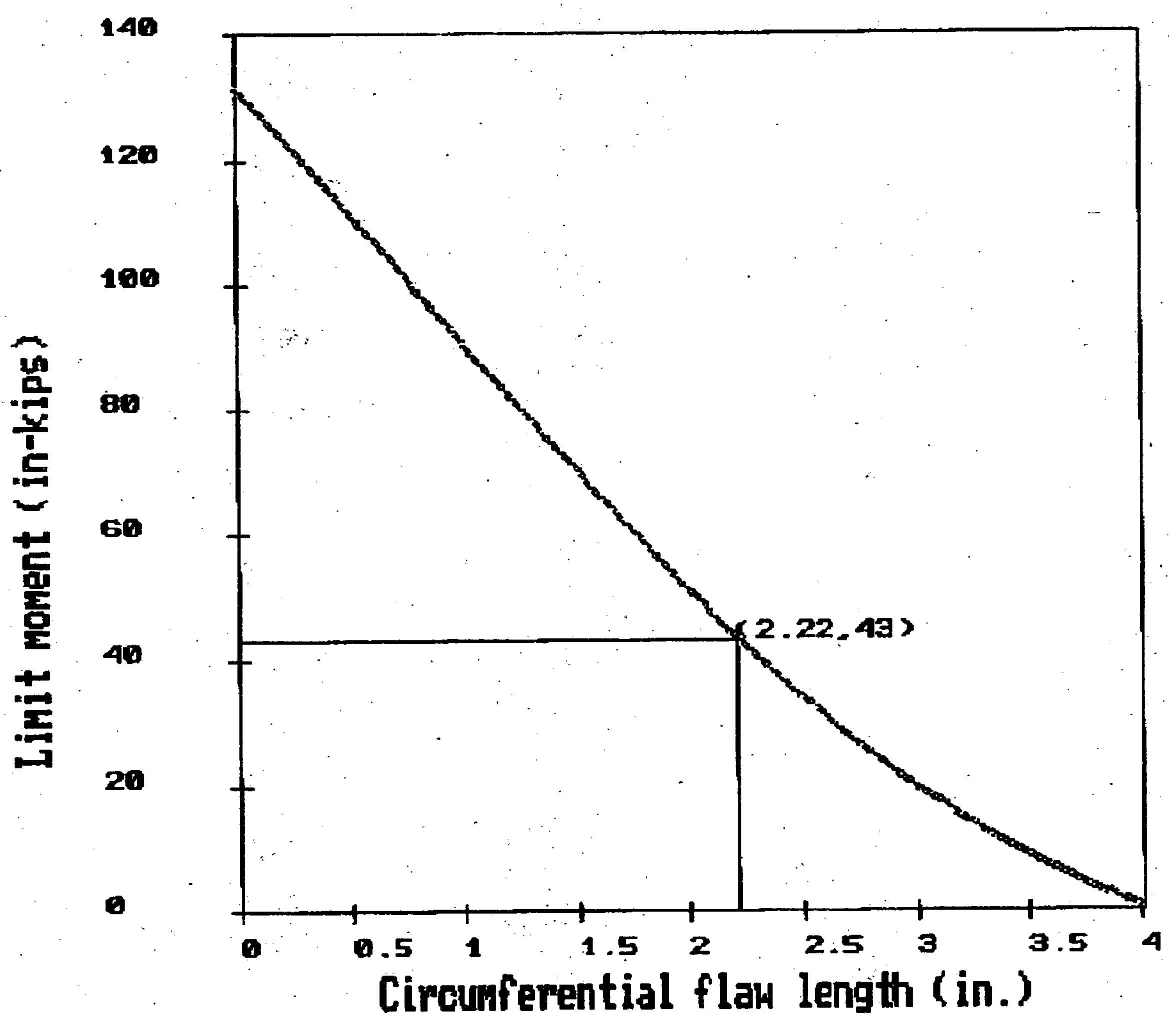
Condition	Margin on flaw size	Margin on limit moment
************ Sockolet *********		
A		
B		
C		
D	22	>3
************ Feedwater Line ******		
A	270	38
B	254	17.7
C		
D	232	8.9

References

1. Bamford, W.H. and Begley, J.A., "Techniques for Evaluating the Flaw Tolerance of Reactor Coolant Piping". Presented at the 1976 PVP Conference, Paper 76-pvp-48.

Table 1: ANSI B31.1 Stress Limits

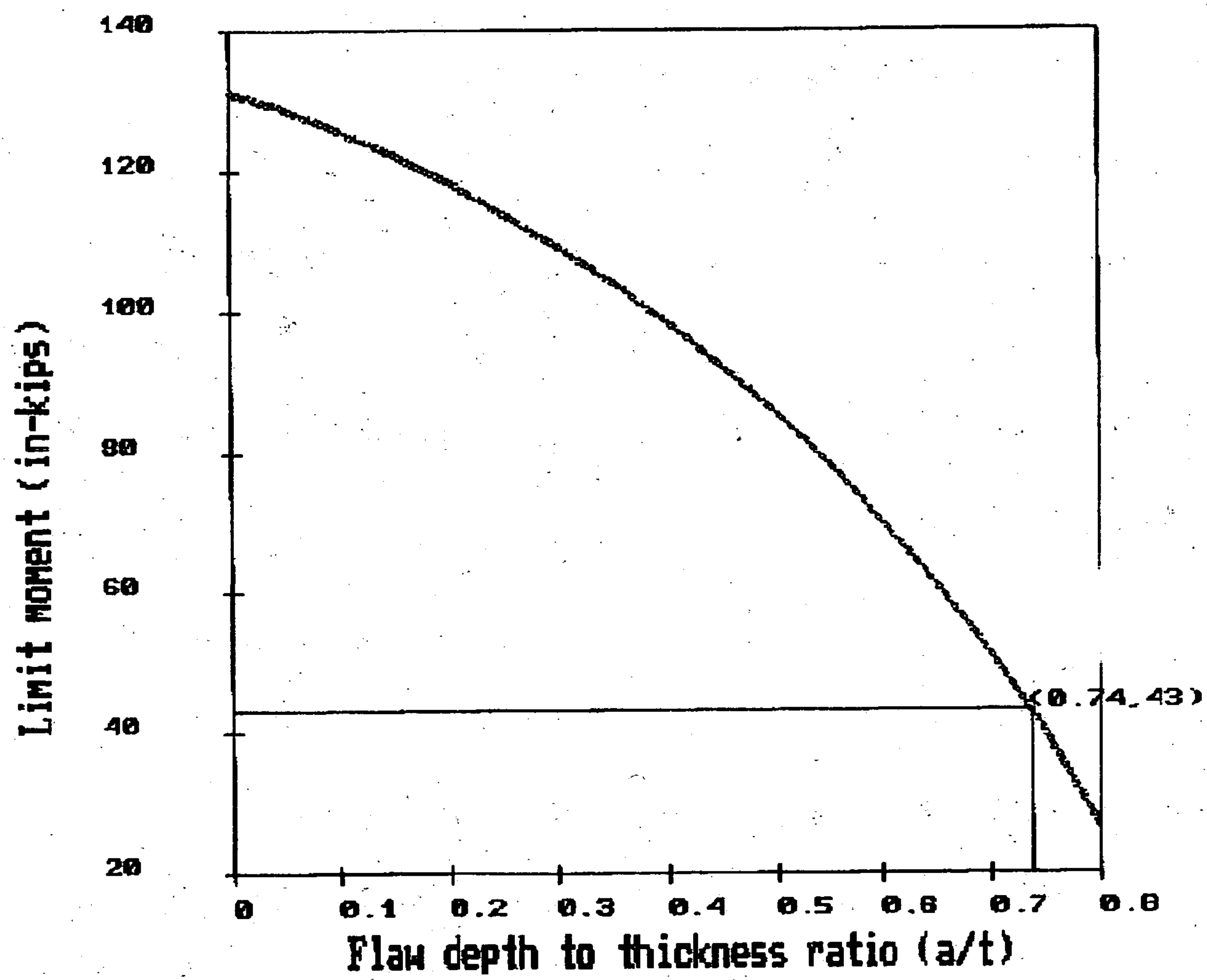
Service Level	ANSI B31.1 1973	Stress Category	Load Combination	Allowable stress	Carbon Steel A106B
Level A	102.3.2D 102.3.2C 102.3.2D	P_m+P_b P_b P_m+P_b	P+DW TH P+DW+TH	S_h S_A S_h+S_A	15.0 ksi 22.5 ksi 37.5 ksi
Level B	102.3.3A 102.3.2C 102.3.2D	P_m+P_b P_b P_m+P_b	P+DW+OBE TH P+DW+TH	$1.2S_h$ S_A S_h+S_A	18.0 ksi 22.5 ksi 37.5 ksi
Level C			N/A	$1.8S_h$	27.0 ksi
Level D		P_m+P_b	P+DW+DBE	$2.4S_h$	30.0 ksi



OD= 2.500   Thk=.625   P=1.20   F=.400E-01   Torque=30.8

WEP Sockolet - Bounding Loads

Figure 1



OD= 2.500 Thk=.625 P=1.20 F=.480E-01 Torque=30.8

WEP Sockolet - Bounding Loads

Figure 2

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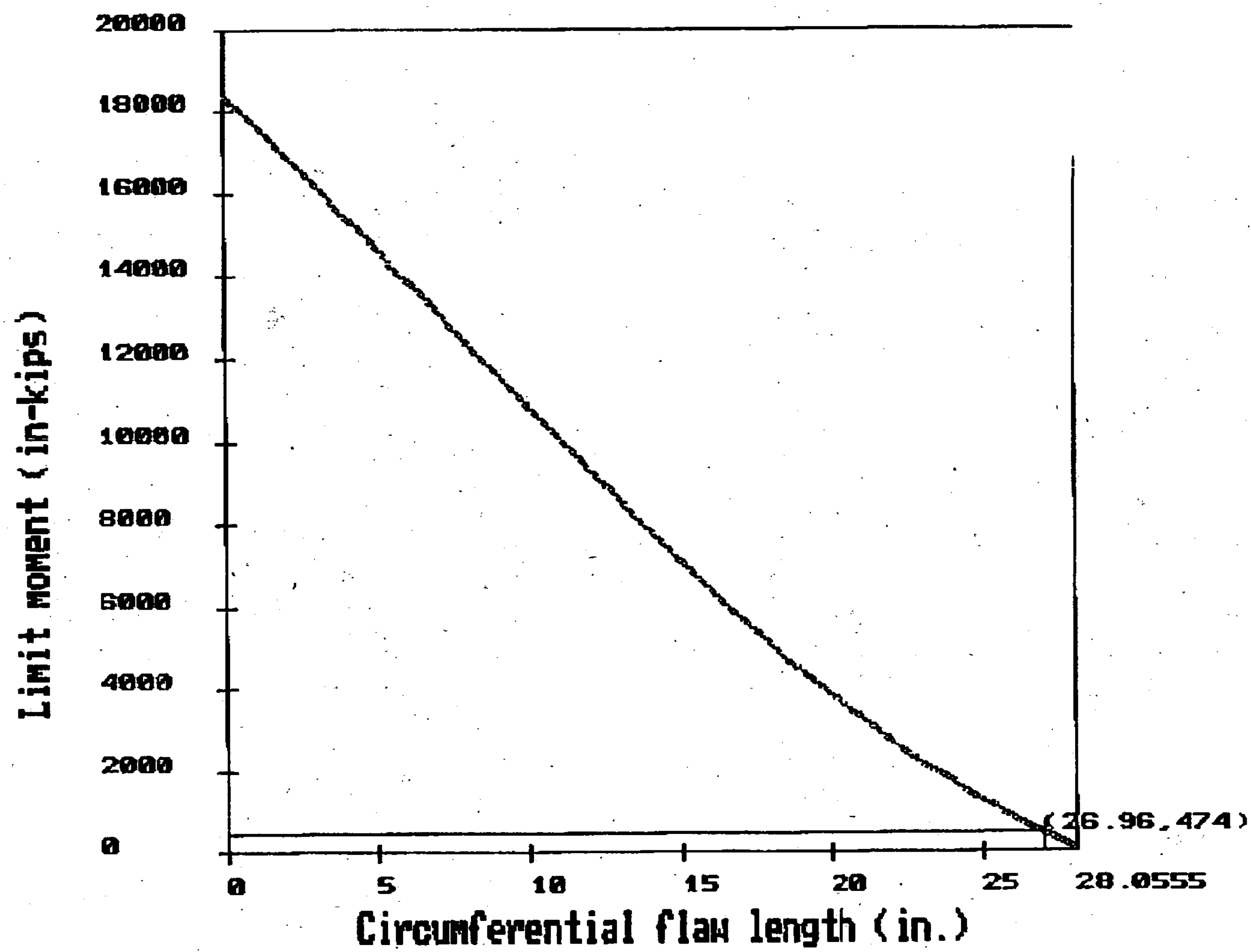
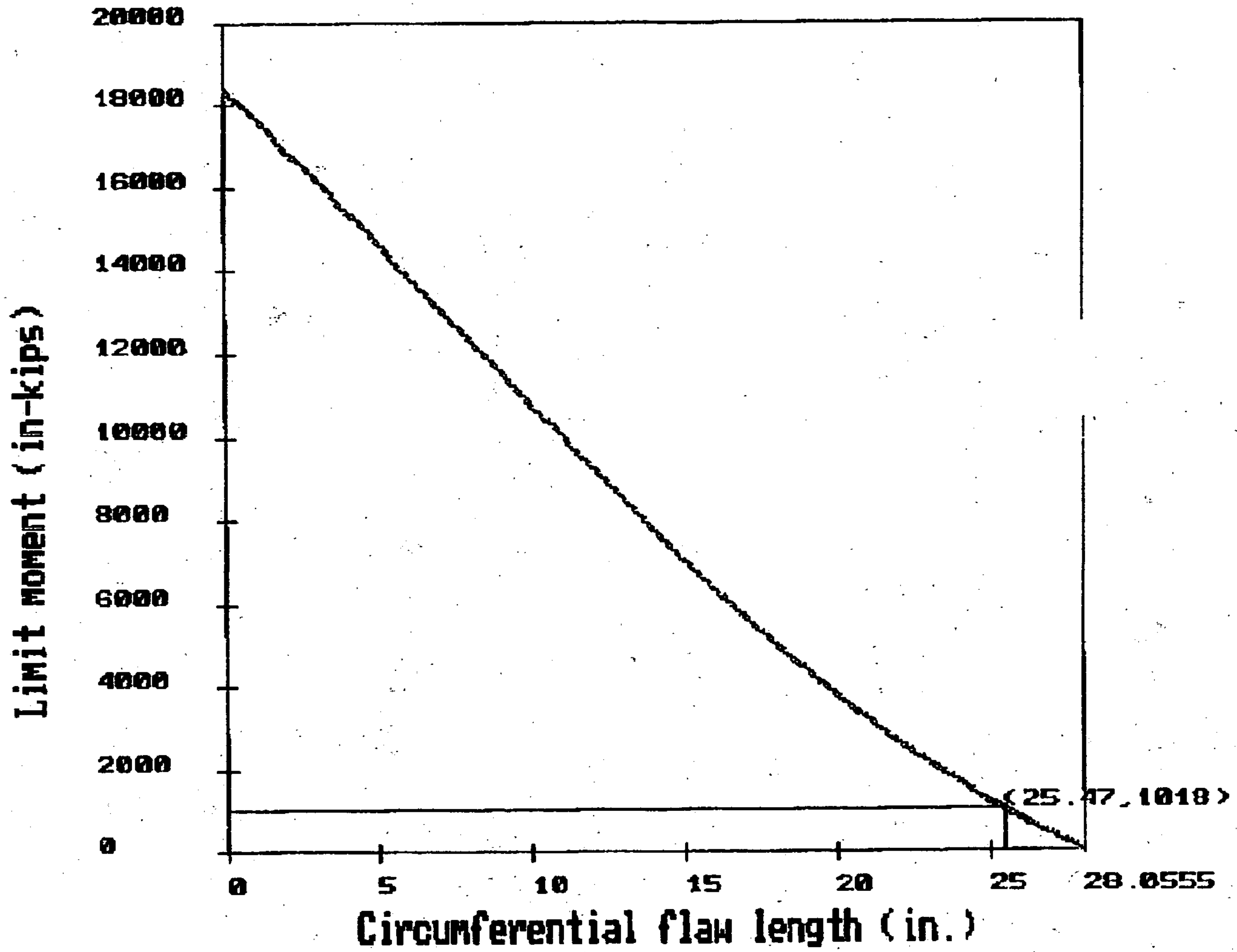


OD=16.000 Thk=1.40 P=1.20 F=1.40 Torque=53.0

WEP FW line - normal

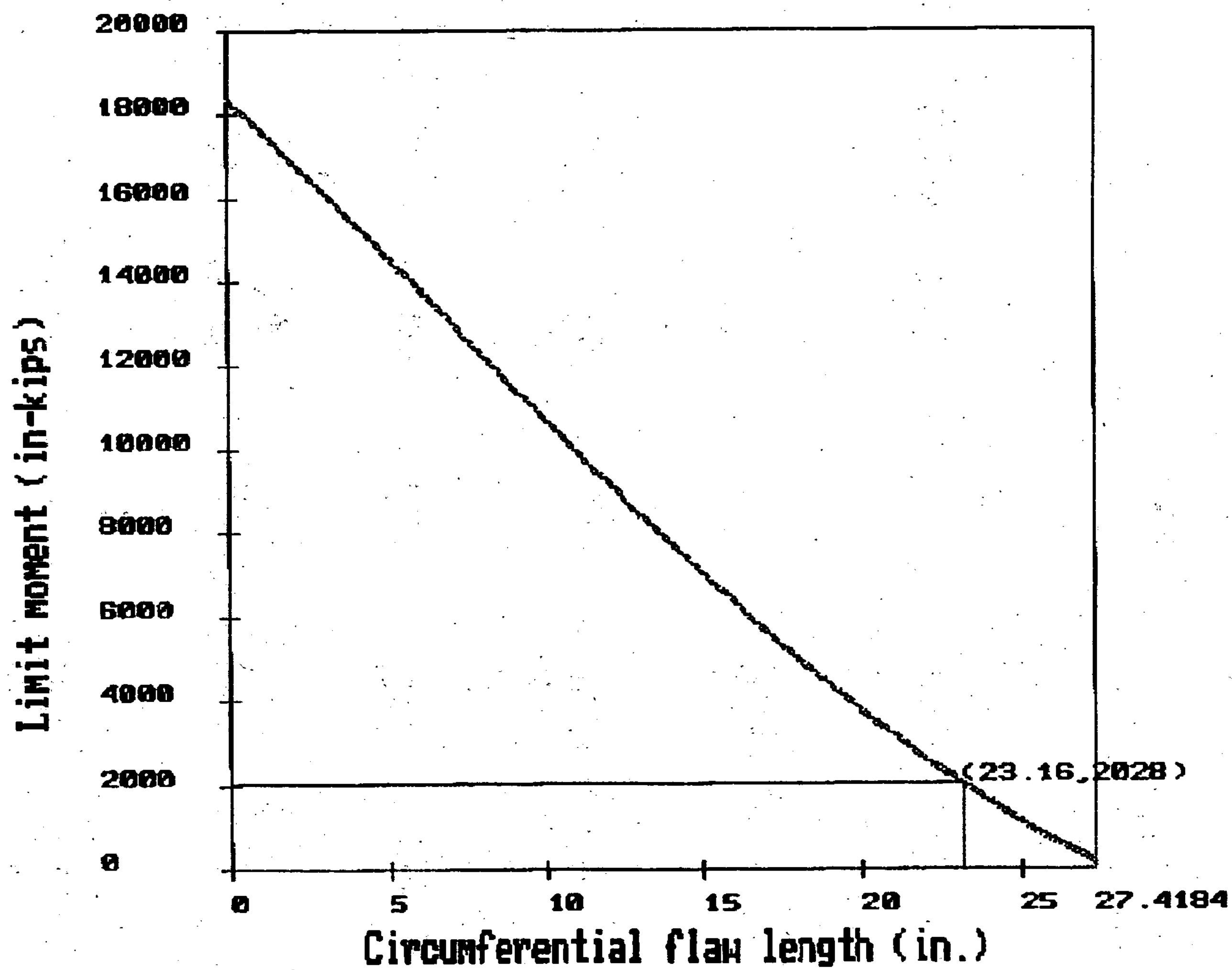
Figure 3



OD=16.000 Thk=1.40 P=1.20 F=10.6 Torque=98.2

WEP FW line - dw + OBE

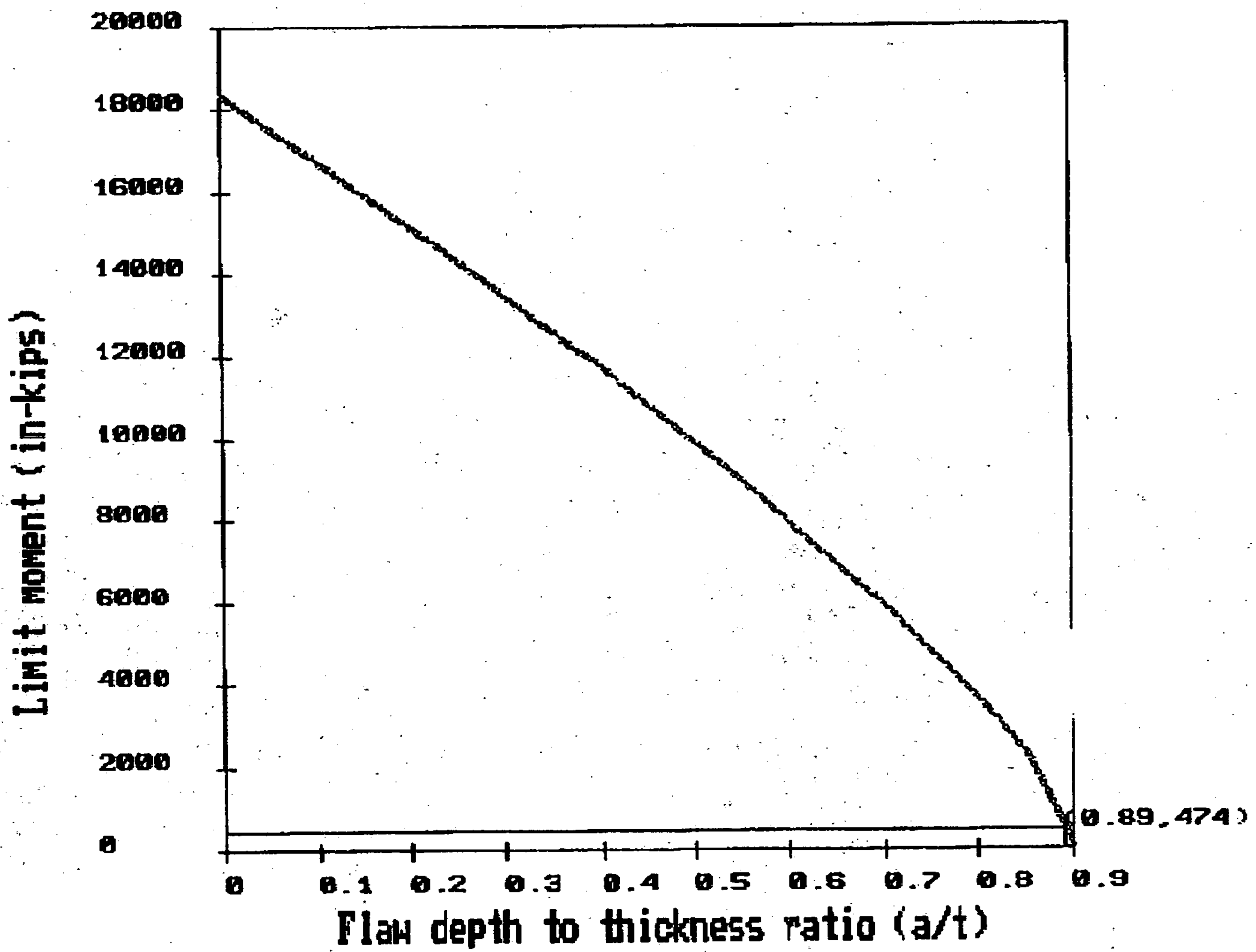
Figure 4



OD=16.000 Thk=1.40 P=1.20 F=21.1 Torque=143

WEP FW line - DW + DBE

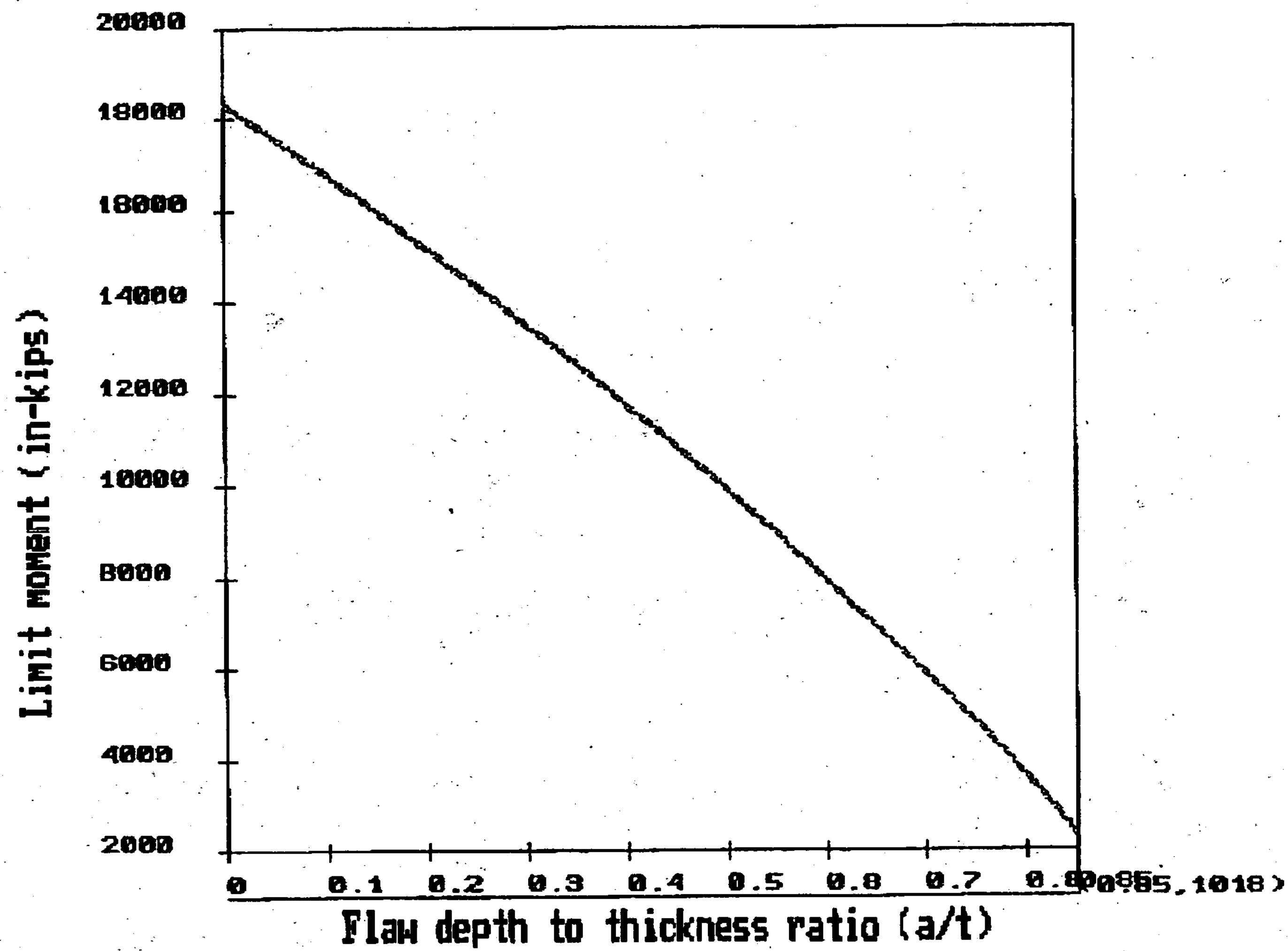
Figure 5



OD=16.000 Thk=1.40 P=1.20 F=1.40 Torque=53.0

WEP FW line - normal

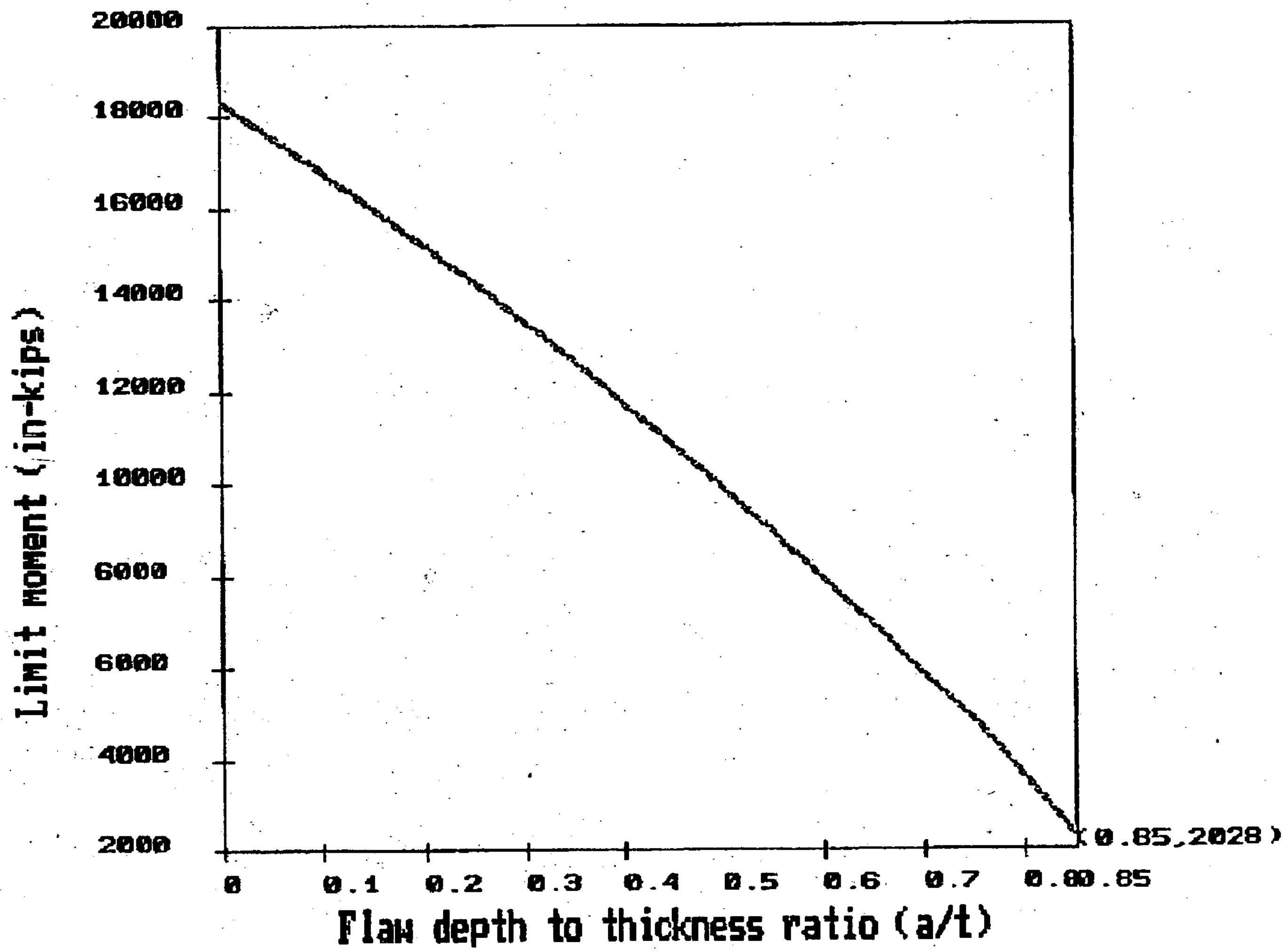
Figure 6



OD=16.000 Thk=1.40 P=1.20 F=10.6 Torque=98.2

WEP FW line - dw + OBE

Figure 7



OD=16.000 Thk=1.40 P=1.20 F=21.1 Torque=143.

WEP FW line - DW + DBE

Figure 8

APPENDIX A

LIMIT ANALYSIS OF A CIRCUMFERENTIAL THROUGH WALL CRACKED PIPE SUBJECT TO MULTIPLE LOADS

A-1 INTRODUCTION

Limit load solutions have been published for thin pipes containing through wall circumferential cracks. These solutions have been presented for various loading conditions. In this appendix the lower bound limit load solution will be presented for a combined loading condition consisting of a bending moment, an axial load, an internal pressure, and a torsional moment. The limit solution for all of these loading components acting simultaneously is not available in the literature. The solution is obtained following the approach that Larson et al.[1] used in the analysis of an uncracked pipe subject to the same multiple loading conditions.

A-2 SOLUTION

A thin walled pipe of mean radius R and wall thickness t, contains a through-wall circumferential crack of total angular length 2α (Figure A-1). The cracked cross-section of the pipe is subject to a bending moment M (about the y-axis), and axial load N, an internal pressure p, and a torsional moment T. The bending moment is assumed to be acting about the y-axis and the cross section is analytically divided into region 1 and 2 (Figure A-1). The stress state of the cracked cross-section consists of the hoop stress, axial stress, and shear stress. The hoop stress (σ_Θ) and shear stress ($\tau_{r\Theta}$) are constant on the uncracked portion of the circumference. The axial stress is uniform tension (σ_{zT}) in region 1 and uniform compression (σ_{zC}) in region 2. Region 1 is above the neutral axis (N.A.) of the cross section and region 2 is below the neutral axis. The position of the neutral axis is geometrically defined by the angle Θ_o.

Dimensionless load parameters to be used in the analysis are defined below:

$m = M/M_o$

$n_z = N/N_o$

$n_\Theta = p/p_o$

$q = T/T_o$

where $M_o = 4tR^2\sigma_{YS}$, $N_o = 2\pi tR\sigma_{YS}$, $p_o = t\sigma_{YS}/R$, $T_o = 2\pi R^2 t\sigma_{YS}/\sqrt{3}$, and σ_{YS} is the uniaxial yield stress. Each of the normalizing loads (M_o, N_o, p_o, T_o) are the respective limit loads when only the load component that is being normalized is operating on the uncracked pipe cross-section.

The dimensionless load parameters can be related to the stress components by integrating the stresses over the cross-section (Figure A-1).

$$m = [(\sigma_{zT} - \sigma_{zC}) \cos\Theta_o - \sigma_{zT} \sin \alpha]/(2\sigma_{YS}) \quad \text{(A-1)}$$

$$n_z = [(\pi + 2\Theta_o - 2\alpha)\, \sigma_{zT} + (\pi - 2\Theta_o)\, \sigma_{zC}]/(2\pi\, \sigma_{YS}) \quad \text{(A-2)}$$

$$n_\lambda = \sigma_\Theta/\sigma_{YS} \quad \text{(A-3)}$$

$$q = \sqrt{3}(\pi - \alpha)\, t\tau_{z\Theta}/(\pi\, \sigma_{YS}) \quad \text{(A-4)}$$

Assuming that the pipe material yields according to the von Mises yield criteria, the yield relationship between the tube stress components takes the form

$$\sigma_{YS} = [\sigma_z^{\,2} + \sigma_\Theta^{\,2} - \sigma_z\, \sigma_\Theta + 3t\tau_{z\Theta}^{\,2}]^{1/2} \quad \text{(A-5)}$$

where σ_z represents σ_{zT} in region 1 and σ_{zC} in region 2. For a given set of loading conditions there are three unspecified parameters (σ_{zT}, σ_{zC}, and Θ_o). By using equations (A-1) and (A-2), which are equilibrium relationships and equation (A-5), the yield criteria, these parameters can be determined and a lower bound on the yield locus can be obtained in terms of the normalized load parameters. First equation (A-5) is rewritten in quadratic form for σ_z.

$$\sigma_z^2 - \sigma_\Theta \sigma_z + (\sigma_\Theta^2 + 3\tau_{z\Theta}^2 - \sigma_{YS}^2) = 0 \qquad \text{(A-6)}$$

This equation is solved for σ_z, taking the positive root for σ_{zT} and the negative root for σ_{zC}. Using the relationships of equations (A-3) and (A-4), the solutions to equation (A-6) are:

$$\frac{\sigma_{zT}}{\sigma_{YS}} = \frac{n_\Theta}{2} + [1 - \frac{3}{4} n_\Theta^2 - (\frac{\pi}{\pi - \alpha})^2 q^2]^{1/2} \qquad \text{(A-7)}$$

$$\frac{\sigma_{zC}}{\sigma_{YS}} = \frac{n_\Theta}{2} + [1 - \frac{3}{4} n_\Theta^2 - (\frac{\pi}{\pi - \alpha})^2 q^2]^{1/2} \qquad \text{(A-8)}$$

Substituting equations (A-7) and (A-8) into equations (A-1) and (A-2) leads directly to the lower bound yield locus.

$$\lambda m^2 + (\frac{1}{2} \lambda \sin \alpha) n_\Theta m + (\frac{1}{16} \lambda \sin^2\alpha + \frac{3}{4}) n_\Theta^2 + (\frac{\pi}{\pi - \alpha})^2 q^2 = 1 \qquad \text{(A-9)}$$

where

$$\lambda = (\cos\Theta_o - \sin \alpha)^{-2} \qquad \text{(A-10)}$$

and

$$\Theta_o = \frac{\pi n_z + \alpha[\frac{n_\Theta}{2} + (1 - \frac{3}{4} n_\Theta^2 - (\frac{\pi}{\pi - \alpha})^2 q^2)^{1/2}] - \frac{\pi}{4} n_\Theta}{2\,[1 - \frac{3}{4} n_\Theta^2 - (\frac{\pi}{\pi - \alpha})^2 q^2]^{1/2}} \qquad \text{(A-11)}$$

Equation (A-9) defines a lower bound on the yield surface in a load space defined by the four dimensionless load parameters (m, n_z, n_λ, and q).

For specific values of three of the four load parameters, assuming they define a condition inside the limit surface, the magnitude of the fourth parameter which will put the load condition right on the limit surface can be obtained from equation (A-9). For example letting m be the fourth parameter leads to the equation

$$m=(-\frac{1}{4}\sin\alpha)\,n_\Theta + [1-\frac{3}{4}n_\Theta^2 - (\frac{\pi}{\pi-\alpha})^2 q^2]^{1/2}\,(\cos\Theta_o - \frac{1}{2}\sin\alpha) \qquad \text{(A-12)}$$

where Θ_o is obtained from equation (A-11).

REFERENCES (Appendix A)

1. L. D. Larson, W. F. Stokey, and J. E. Panarelli, "Limit Analysis of a Thin-Walled Tube Under Internal Pressure, Bending Moment, Axial Force, and Torsion," Journal of Applied Mechanics, pp. 831-832, September 1974.

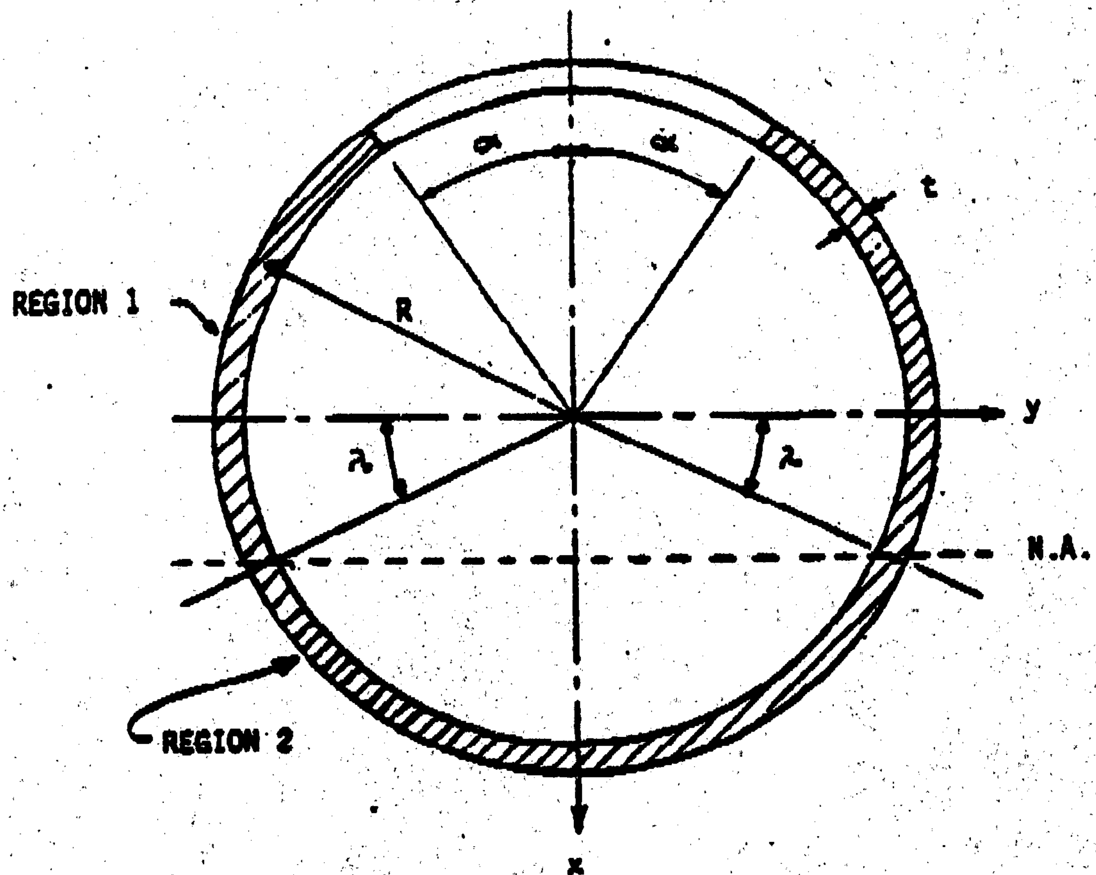


Figure A-1. Cross Section Of Pipe With A Through-Wall Circumferential Crack of Length 2α.