Entergy

Entergy Operations, Inc.
1448 S.R. 333
Russellville, AR 72802
Tel 501 858 5000

2CAN080302

August 2, 2003

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

SUBJECT: Arkansas Nuclear One, Unit 2
Docket No. 50-368
License No. NPF-6
Response to Request for Additional Information on Relaxation from Performing a Bare Metal Visual Inspection on the ANO-2 Reactor Vessel Head

REFERENCES:

1. NRC letter dated February 11, 2003, *Issuance of Order Establishing Interim Inspection Requirements for Reactor Pressure Vessel Heads at Pressurized Water Reactors* (0CNA020302)
2. Entergy letter dated May 8, 2003, *Request for Relaxation from Section IV.C(1)(a) of the Order Establishing Interim Inspection Requirements for Reactor Pressure Vessel Heads* (2CAN050301)
3. Entergy letter dated June 26, 2003, *Response to Request for Additional Information on the ANO-2 Relaxation from Performing a Bare Metal Visual Inspection from the February 11, 2003 Reactor Pressure Vessel Head Order* (2CAN060308)
4. Entergy letter dated June 17, 2002, *Submittal of Demonstration Report for Volumetric Examination of Vessel Head Penetration Nozzles* (0CAN060201)

Dear Sir or Madam:

On February 11, 2003, the Nuclear Regulatory Commission (NRC) issued an Order addressing interim inspection requirements for reactor pressure vessel (RPV) heads at pressurized water reactors (Reference 1). The NRC stated that the actions in the Order are interim measures, necessary to ensure that licensees implement and maintain appropriate measures to inspect and, as necessary, repair RPV heads and associated penetration nozzles. On May 8, 2003, Entergy Operations, Inc. (Entergy) requested relaxation from Section IV.C(1)(a) of the Order (Reference 2) to perform a bare metal visual (BMV) inspection of 100 percent of the RPV head surface for Arkansas Nuclear One, Unit 2 (ANO-2). In response to initial requests for additional information (RAI), Entergy submitted examination and inspection approaches for the upcoming ANO-2 refueling outage to provide diverse and complementary actions for relaxation of the Order (Reference 3).

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The primary supplemental examination techniques are the J-weld (Triple Point) examination using the Westinghouse open housing ultrasonic testing (UT) process and the application of the low frequency eddy current testing (LF ECT) process. These non-destructive examination (NDE) approaches have been demonstrated by Westinghouse using mockups which validate the capability of the examination techniques. A summary of the NDE testing results for both the UT of the J-weld and the LF ECT was provided in Reference 3. However, more detailed technical reports have been prepared by WesDyne that document the testing conducted on these techniques.

During a conference call with the NRC staff on July 14, 2003, the NRC requested additional information which included details of the supplemental examination technique demonstrations that were performed. Entergy's response to the RAI is provided in Attachment 1. The referenced WesDyne technical reports are of a proprietary nature to Westinghouse. Therefore, non-proprietary versions of these reports are being enclosed. Proprietary versions of these reports are being submitted under a separate cover letter.

Commitments contained in this submittal are identified in Attachment 4. If you require additional information, please contact Steve Bennett at 479-858-4626.

Sincerely,

for Sherrie R. Cotton
Director, Nuclear Safety Assurance

SRC/sab

Attachments

1. Response to Request for Additional Information on Relaxation from Performing a Bare Metal Visual Inspection on the ANO-2 Reactor Vessel Head
2. Decision Matrix for RPV Head Penetration Acceptance Criteria
3. Enlarged Excerpt of Page 14 of 43 from WesDyne Report WDI-TJ-007-02
4. List of Regulatory Commitments

Enclosures

1. WesDyne Report WDI-TJ-001-02 Rev 02, Rev. 01, Detection of Reactor Head Base Metal Loss from Inside the CRDM (Non-proprietary)
2. WesDyne Report WDI-TJ-012-03 Rev. 0, Triple Point Inspection using TOFD Ultrasonic Methods (Non-proprietary)
3. MRP Inspection Demonstration Program Report Excerpts Updated: December 11, 2002
4. WesDyne Report WDI-TJ-006-03 Rev 01, UT of Interference Fit Samples for Leak Path (Non-proprietary)

cc: Mr. Thomas P. Gwynn
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

U. S. Nuclear Regulatory Commission
Attn: Mr. Thomas W. Alexion MS O-7D1
Washington, DC 20555-0001

Mr. Bernard R. Bevill
Director Division of Radiation
Control and Emergency Management
Arkansas Department of Health
4815 West Markham Street
Little Rock, AR 72205

Attachment 1

2CAN080302

Response to Request for Additional Information on Relaxation from Performing a Bare Metal Visual Inspection on the ANO-2 Reactor Vessel Head

Response to NRC Request for Additional Information (RAI) Regarding the Entergy Relaxation Request for Performing a Bare Metal Visual Inspection of the Reactor Vessel Head

NRC RAI 1

The BMV examination required by Order EA-03-009 has two purposes, to act as diverse and complimentary to the non-visual examination requirements of the Order Section IV.C(1)(b) (ensure that there is no leakage from nozzle) and to ensure that there is no degradation of the low alloy steel head by boric acid corrosion. Please provide the following information directly addressing each item:

a) Complete information that demonstrates that the methods described in the licensees' proposal, public meeting and RAI response that demonstrate that the alternate inspections (i.e., UT into the welds, "Triple Point" and low frequency Eddy Current Testing) will provide a diverse and complimentary examination to that described in Order Section IV.C(1)(b).

Response:

The various non-destructive examination (NDE) technologies being applied for Arkansas Nuclear One, Unit 2 (ANO-2) are relatively new and the reporting of these demonstrations has been in various stages of documentation. Recently, Westinghouse has compiled demonstration information into technical reports that provide details of how testing and mockups were applied. The following reports are provided as enclosures in this letter:

1. WesDyne Report WDI-TJ-001-02 Rev. 01, *Detection of Reactor Head Base Metal Loss from Inside the CRDM (Non-Proprietary)*
2. WesDyne Report WDI-TJ-012-03 Rev. 0, *Triple Point Inspection using TOFD Ultrasonic Methods* (including excerpts from "MRP Inspection Demonstration Program" Updated December 11, 2002*) *(Non-Proprietary)*
3. MRP Inspection Demonstration Program Report Excerpts Updated: December 11, 2002 (The final published EPRI demonstration program report is expected to be released in August 2003)
4. WesDyne Report WDI-TJ-006-03 Rev 01, *UT of Interference Fit Samples for Leak Path (Non-Proprietary)*

The enclosed documents provide the test data to support the basis for the use of alternative inspections to provide a diverse and complimentary examination in lieu of a bare metal visual (BMV) inspection from the top of the reactor vessel head. The overall inspection strategy employs NDE techniques that have been demonstrated through the MRP/EPRI and Westinghouse programs to be able to detect nozzle inner diameter (ID) and outer diameter (OD) flaws using ultrasonic testing (UT). The nozzle ID and OD flaw demonstrations are straightforward with definitive information on detection, location and depth of flaws. This information is provided in enclosed excerpts from "MRP Inspection Demonstration Program" dated December 11, 2002 (Enclosure 3).

The augmented inspection strategy includes two examinations over and above the typical examinations used to comply with the Order. The NDE strategy involves the following elements:

1. Inspect for wastage in the carbon steel of the reactor pressure vessel (RPV) head using low frequency eddy current testing,
2. Interrogate partially into the weld metal at the triple point (weld/butter/nozzle intersection) using UT to assure that no flaws have propagated at that point in the weld resulting in leakage.

Additionally, Westinghouse has established the inspection techniques for any erosion/ corrosion creating a leak path above the weld and through the interference fit region between the nozzle and RPV head using ultrasonic methods.

Wastage Detection - Enclosure 1 describes the low frequency eddy current (LF ECT) test method for wastage detection in the RPV head behind the nozzle. A rotating eddy current pancake coil is used to detect the presence, or absence, of carbon steel loss. For the small volumes of interest, the response is essentially linear with volume loss. Assuming an axial flaw length greater than the coil's field size, the circumferential cross section can be used for response comparison. Since a leak path through the RPV head thickness is considerably larger than the coil field, this approach provides reasonable assurance in detecting a loss of metal.

To demonstrate this method, a series of mockups with various axial and circumferential grooves and various wall loss geometries were fabricated. In addition, the reactor vessel head at the Westinghouse Waltz Mill Service Center was inspected to determine the ability to detect the upper counter bore (0.015" on the radius). The results from the mockup tests demonstrate that a machined flaw 0.25" x 0.125" deep (0.03 sq in) and the upper counter bore 1.5" (assumed maximum coil field extent) x 0.015" deep (0.022 sq in) were detectable. Based on this testing it was determined that the equivalent depth for this detection limit is 0.060".

During actual inspections on site, the leak path configuration that Westinghouse typically encounters begins as a very wide area at the top of the weld, which can neck down to as low as 0.375" wide region (riverbed area) and then slowly widens as it approaches the OD of the reactor vessel head. The laboratory work that was performed during the demonstration is bounding in terms of detectable lengths and volumes of flaws. A real leak path in a RPV head would be much longer (reaching from the top of the J-weld to the OD of the reactor vessel head) than any of the notches provided in the mock-ups that were tested. The mockups used by WesDyne are considered to be very conservative from the standpoint of detection capability. The notches provide good information about the response comparison of different volumes of metal.

Triple Point Inspection - Enclosure 2 reports the results of the ultrasonic inspections performed on blind mockups for the MRP/EPRI Inspection Demonstration Program. As part of these demonstrations, the ability to detect flaws in the weld that extended into or near the triple point was included in the blind test sample. The majority of flaws in these mockups were in the nozzle base metal, however, there were some flaws in the J-weld only.

During the Entergy mockup testing, WesDyne was able to detect 4 flat-bottomed holes ranging from 0.050" to 0.200" in the J-weld, as well as all 3 standalone circumferential flaws in the weld, which ranged in depth from 25% to 100% thru-weld. During the EPRI/MRP

Phase II demonstration mockup testing, WesDyne successfully detected the axial-radial flaw that was 100% thru-weld in depth. With these tests, the ability to detect flaws that extend to near the triple point region of the J-weld has been successfully demonstrated.

Leak Path Detection - Enclosure 4 describes the UT technique used to determine if a leak path exists above the J-weld. The basis for this inspection is the difference between the ultrasonic reflections from an interference fit versus a free surface. In theory, sound will partially transmit through a metal to metal interface with an interference fit while an interface with a free surface will be virtually 100% reflective. This concept has been widely used in ultrasonic testing for a variety of applications, such as shrink fit retainer rings on turbine/generators. In order to demonstrate this technique for this application, mockups were built to simulate a leak path based on observations from field examinations.

The mockups were built using a carbon steel collar that was heated and shrunk fit onto a nozzle section. Prior to assembly, two grooves were cut along the length of the collar, 0.06" and 0.12" wide nominally (approximately 0.06" deep, however the depth is irrelevant for the purpose of this test). The results showed that the 0.12" wide groove is clearly detectable using the ultrasonic inspection methods intended for ANO-2. The narrower groove (0.06") was only detectable over 50% of its length. In actual field inspections where leak path grooving has been reported, the ultrasonic responses were greater than 0.25" wide, so the detection limit is considered conservative for the intended purpose.

A second mockup was built with similar grooves, but with no interference fit. As expected, the leak path simulation grooves were not detectable. The mockups also included the counter bore design used in RPV head construction with a 0.003" diametrical increase at the bottom of the mockup (drawing design dimension for this counter bore is 0.003"-0.010"). Again, as expected, the leak path simulation was not detectable in this region. In actual RPV head designs, such as ANO-2, the weld shrinkage causes an interference fit in this region. Therefore, the tested configurations provide a high level of confidence in detecting a leak path.

Summary - The overall ANO-2 inspection program applies two new augmented inspection methods along with the required leakage path assessment in the annulus. The base inspection employs an ultrasonic technique that has been demonstrated to detect flaws in the nozzle base metal as well as J-weld flaws extending near the triple point region. For these types of flaws, there is flaw detection independent of whether a leak actually occurs. In addition, there is also an ultrasonic inspection to detect the presence of any potential leak path above the J-weld in the interference fit region. This approach is used to address the possibility that a leak path exists without a flaw in the nozzle or J-weld, however, flaws in or behind the butter have not been experienced in the CE manufactured heads. As an added complementary approach, Entergy will use a low frequency eddy current examination to detect possible wastage in the RPV head that is independent of the existence of an interference fit and provides a third inspection barrier of defense for detecting potential leakage. The inspection approach defined by Entergy exceeds the capabilities of bare metal inspections since a crack in the weld could be detected prior to leakage. Additionally, potential subsurface degradation in the bore could be readily detected with the low frequency eddy current and would not be seen with visual examinations.

b) *In particular, describe how the proposed alternative addresses both BMV functions of leakage detection and head corrosion detection.*

Response:

The ANO-2 inspection strategy includes the LF ECT and the Triple Point examination techniques to augment the standard approaches typically used to examine RPV head penetrations for identifying flaws in the nozzle or J-weld. These along with the leakage assessment technique of the UT provide defense in depth for detecting both leakage and RPV head corrosion as described below.

<u>Leakage Detection</u> – The primary leakage assessment determination to comply with Section IV.C(1)(a)(i) of the Order uses the UT probe to verify an interference fit and to identify if an apparent flow path within the annulus exists. This process is discussed in detail in Enclosure 4. In addition, the LF ECT examination will provide a determination of a change in carbon steel depth that also provides a means of leakage detection. The LF ECT assesses leakage beyond the interference fit extending to the outside diameter of the vessel.

The Triple Point examination also provides a leakage detection capability. The UT scan using the Westinghouse open housing probe has the capability to detect flaws at the interface of the J-weld and the OD of the nozzle wall. In order to initiate a leak, a flaw originating in the J-weld or the OD of the nozzle is expected to propagate through the triple point. Therefore, such flaws would be detected at the triple point of the weld, which provides an additional confidence for leakage detection. As previously noted, the CE constructed RPV heads do not have weld butter to carbon steel damage mechanisms.

<u>RPV Head Wastage Detection</u> – Since the cooling shroud and insulation design of the ANO-2 RPV head does not readily allow inspection of the head surface at the CEDM nozzles, Entergy is crediting other means to assess the integrity of the head surface in this region. The primary means that will be used for wastage detection will be the LF ECT technique. This technique is capable of determining wastage at or below the top of the nozzle to head annulus including the non-interference fit region. The process has been shown to have a sensitivity that will detect and measure small amounts of carbon steel wastage. In addition, the UT scan can also determine a loss of contact of the nozzle to the base metal of the head. If a leak path is detected, the UT scan can be extended to the top of the annulus to further confirm the presence or absence of interference fit at or near the top of the annulus.

The ability to see below the OD surface of the RPV head with LF ECT technology for wastage provides a capability for examination that cannot be determined by the bare metal visual inspection. Therefore, Entergy considers this technique to be superior in this regard to a bare metal visual inspection for identifying wastage in areas that cannot be measured otherwise. The examinations proposed by Entergy address both leakage detection and RPV head integrity.

c) *The information should be very specific as to how the demonstrations of these methods give a level of confidence as to the accuracy of the information that will be attained during the inspection process.*

Response:

The details contained in the enclosed WesDyne reports provide confidence in the ability of the NDE methods that will be applied to ANO-2 during the upcoming outage. The combined NDE techniques provide comprehensive examination capabilities for ensuring RPV head integrity.

d) *Information should also include the methodology used to establish the test matrix for the demonstrations that the licensee or vendor used to demonstrate the alternative inspection methods and be very specific as to what level of confidence the test matrix provides.*

Response:
The testing that was performed was conducted in combination with Westinghouse and EPRI/MRP. The details of the tested configurations are contained in the enclosed WesDyne reports.

e) *Also explain how demonstrations (mockups) are representative of field occurring anomalies.*

Response:

As discussed in the attached WesDyne reports, test mockups, to the extent practical, were fabricated to confirm detection capability comparable to field conditions.

NRC RAI 2

In the licensee's RAI response letter, 2CAN060308, the licensee states on page four that "Entergy will determine the appropriate means of establishing detection criteria for the low frequency ECT examination prior to the 2R16 refueling outage." The following items must be specifically and thoroughly addressed by the licensee in order for the staff to properly evaluate the licensee's relaxation request.

a) *Please explain how an adequate demonstration of the low frequency ECT to detect nozzle bore degradation could have been performed without establishing acceptable detection criteria prior to the demonstration.*

Response:

The historical testing of the LF ECT technique was performed to demonstrate that the technology could be used to detect wastage in the annulus region of the nozzle penetration. It was not originally conceived as being one of the primary examination techniques that Entergy was crediting for determining RPV head integrity. As a result, a blind mockup and established acceptance criteria were not prescribed. However, as a result of the proposed use of this technology for providing a means of determining head integrity in lieu of

performing a bare metal inspection, Entergy with Westinghouse will perform additional testing of the LF ECT technique under comparable field conditions. To augment the technical justification for the LF ECT, available data will be collected from test mockups, the reactor vessel head at the Westinghouse Waltz Mill Service Center and replacement head inspections performed to date. Any signal above a 0.060" depth threshold will be evaluated to determine if any contiguous path from the J-groove weld to the top of the RPV head exists. From the top of the RPV head, the LF ECT axial scan length will be a minimum of 1.5". The inspection procedure presently contains the analysis guidelines for reporting indications. Specific training will be provided to NDE analysts on this method prior to field implementation. As part of this training, each analyst will be given a blind test from the established data set. This blind test will be independently reviewed regarding the technique's capability. This blind test will be performed prior to the end of August 2003, to support the ANO-2 Fall 2003 refueling outage.

b) *Given that detection criteria is a critical component to demonstrating the accuracy and sensitivity of a non-destructive testing method, a thorough testing regime that clearly demonstrates the ability of the low frequency ECT process as well as acceptance criteria to detect degradation to the RPV head due to a leaking CEDM nozzle is necessary to allow a thorough evaluation of the adequacy of the relaxation request.*

Response:

Enclosure 1 provides the details of demonstrations conducted to date on the LF ECT technology. Entergy with Westinghouse will perform additional demonstrations as discussed above. A representative acceptance criteria decision matrix for determining additional NDE for the RPV head penetrations is provided in Attachment 2.

NRC RAI 3

Previously, Entergy submitted WesDyne International Report WDI-TJ-007-02-P Demonstration of Volumetric Ultrasonic Inspection of CRDM Nozzles Using The Open House Scanner for ANO-2, by letter dated June 17, 2002. The diagram on the bottom of page 14 of 43 is extremely difficult to read. Please provide a legible copy of page 14.

Response:

The excerpted portion of Page 14 of 43 of the WesDyne Report WDI-TJ-007-02, *Demonstration of Volumetric Ultrasonic Inspection of CRDM Nozzles Using the Open Housing Scanner for ANO-2* (originally provided in Reference 4) has been enlarged and is contained in Attachment 3.

Attachment 2

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Decision Matrix for RPV Head Penetration Acceptance Criteria

Decision Matrix for RPV Head Penetration Acceptance Criteria

The UT examination of the nozzle wall, UT examination of the J-weld, leakage assessment of the penetration annulus, and the LF ECT examination will be performed on the CEDM and ICI nozzles and will be used to provide comprehensive conclusions on the integrity of the penetration. Any PWSCC flaw identified in the nozzle wall will be repaired in accordance with ASME Section XI requirements.

Flaw Identified by UT Exam in Nozzle Wall

If a flaw is identified in the nozzle and it is suspected that it has extended through the nozzle, Entergy's evaluation of the leak path and LF ECT data will determine if leakage has leached into the annulus region of the nozzle-to-RPV head interface. Absent any data that would indicate a loss of contact of the nozzle to the carbon steel (UT leakage assessment) or from a loss of metal (LF ECT), no additional action is necessary to evaluate the condition of the RPV head.

Flaw Identified in J-weld by UT Exam of the Triple Point

If a flaw is identified in the J-weld representative of PWSCC, additional data will be reviewed and/or obtained. For any "special interest" indications detected in the J-weld, Entergy will compare the data from the previous outage examinations. If the comparison of data reveals no change in characteristics and it is determined to be a weld anomaly, no further actions are required. For indications that are suspect of a PWSCC flaw, a supplemental wetted surface examination, such as an ECT or dye penetrant examination (PT), will be performed in the area of special interest.

Riverbed Identified by UT Leak Path

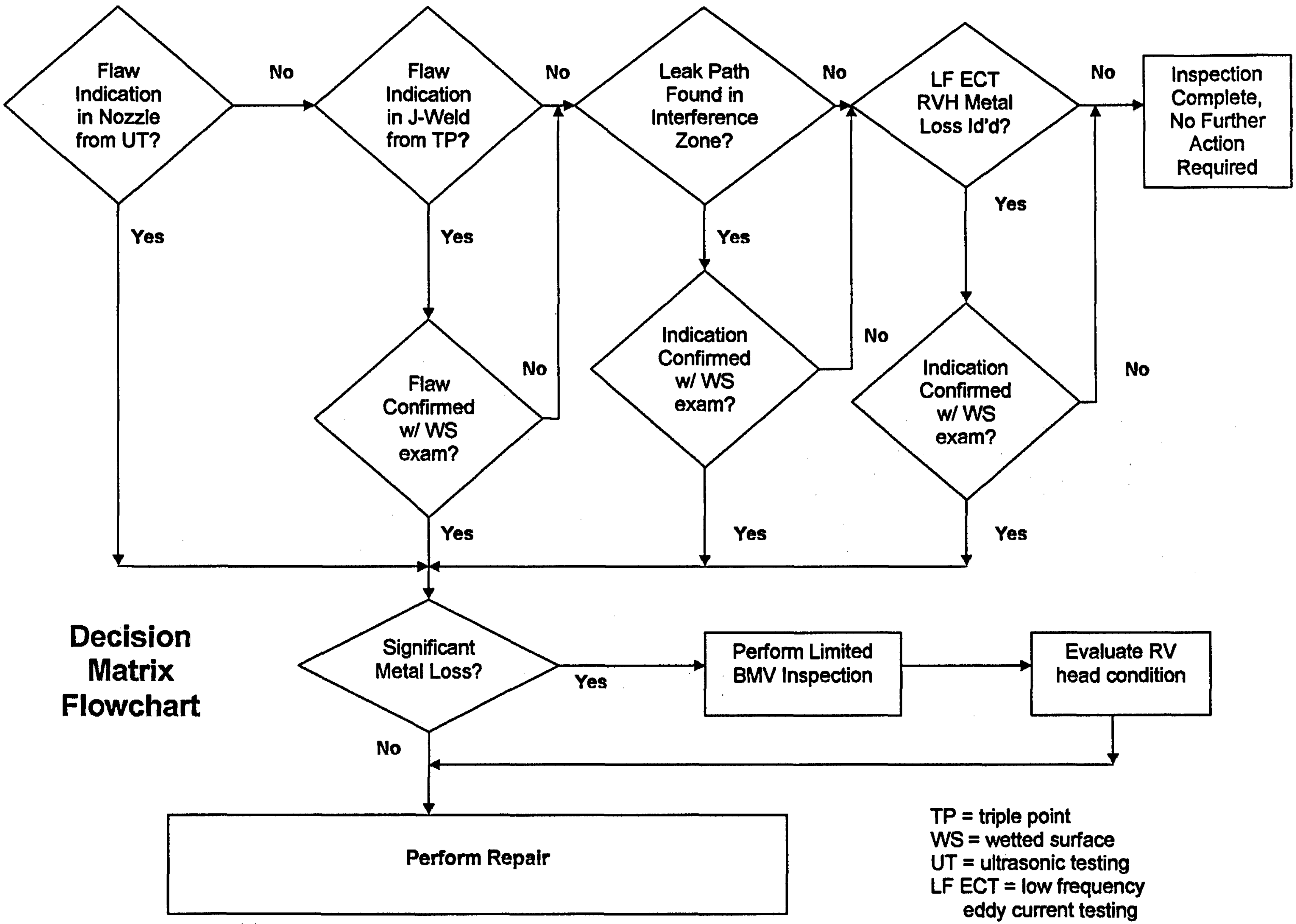
If no flaws are identified in either the nozzle wall or in the J-weld, but there appears to be a loss of interference fit in the annulus that would indicate a flow path of boric acid, an additional wetted surface examination will be conducted to confirm the presence or absence of a flaw.

RPV Head Carbon Steel Loss Identified by LF ECT

If there is no indication from any of the examinations discussed above, but there appears to be degradation in excess of the acceptance criteria from the LF ECT examination, a wetted surface examination of the J-weld will be conducted to determine if there is a leak path present.

If loss of metal is apparent an evaluation will be performed for the extent of damage to the nozzle annulus. Given only minor wastage to the carbon steel, no additional action is considered necessary. For metal loss that would be indicative of significant damage to the RPV head, Entergy will take additional action to remove all or a portion of the cooling shroud/insulation package to perform a visual examination and make repairs, as required.

A flowchart of this decision process is as follows:



Flaw Indication in Nozzle from UT?
No
Flaw Indication in J-Weld from TP?
No
Leak Path Found in Interference Zone?
No
LF ECT RVH Metal Loss Id'd?
No
Inspection Complete, No Further Action Required
Yes
Yes
Yes
Yes
Flaw Confirmed w/ WS exam?
No
Indication Confirmed w/ WS exam?
No
Indication Confirmed w/ WS exam?
No
Yes
Yes
Yes
Decision Matrix Flowchart
Significant Metal Loss?
Yes
Perform Limited BMV Inspection
Evaluate RV head condition
No
Perform Repair
TP = triple point
WS = wetted surface
UT = ultrasonic testing
LF ECT = low frequency eddy current testing

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Attachment 3

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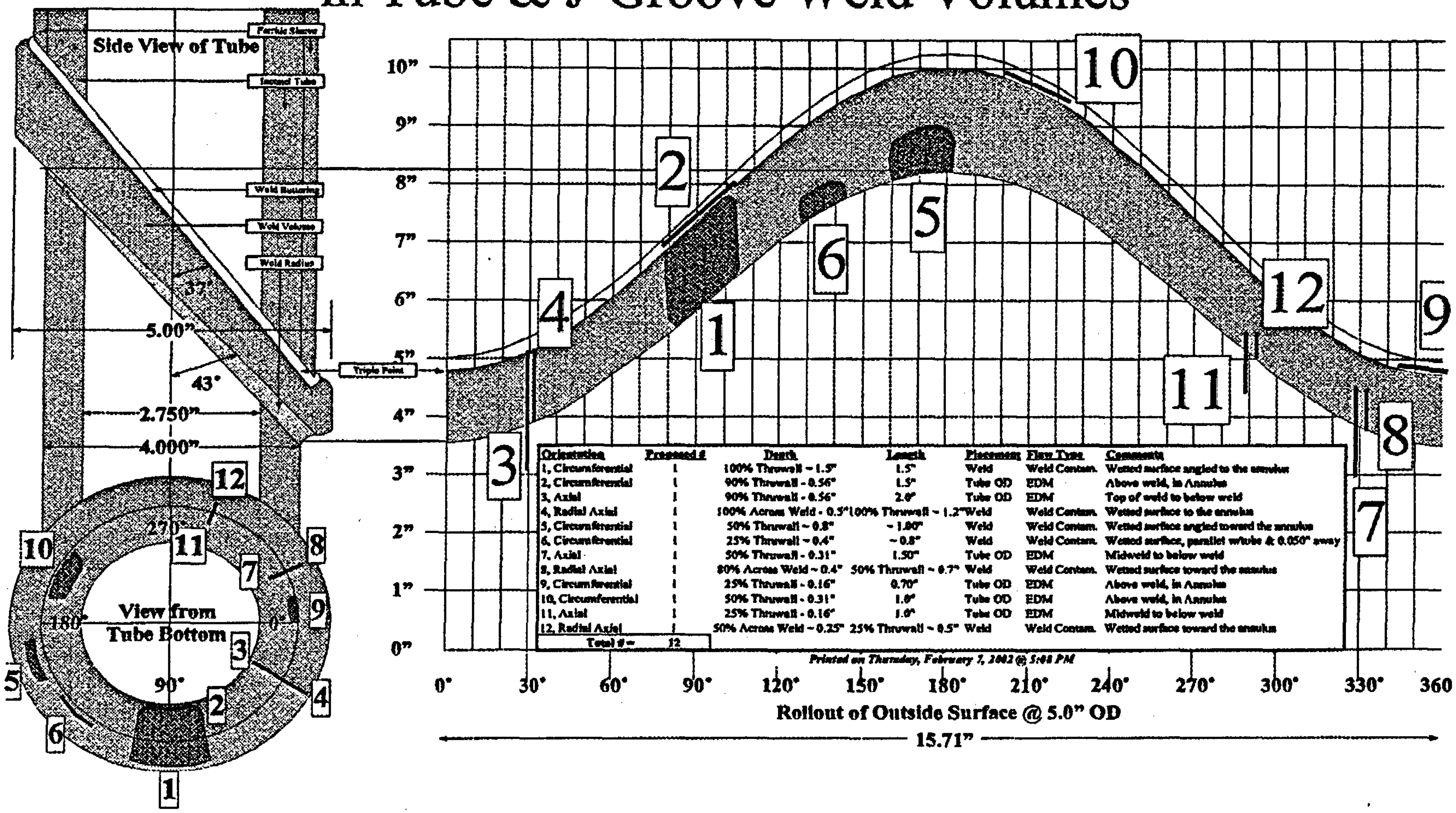
Enlarged Excerpt of Page 14 of 43 from WesDyne Report WDI-TJ-007-02

Mockup Proposal for Entergy/MRP CRDM & Flaw Placement in Tube & J-Groove Weld Volumes



Orientation	Proposed #	Depth	Length	Placement	Flaw Type	Comments
1, Circumferential	1	100% Thruwall ~ 1.5"	1.5"	Weld	Weld Contam.	Wetted surface angled to the annulus
2, Circumferential	1	90% Thruwall - 0.56"	1.5"	Tube OD	EDM	Above weld, in Annulus
3, Axial	1	90% Thruwall - 0.56"	2.0"	Tube OD	EDM	Top of weld to below weld
4, Radial Axial	1	100% Across Weld - 0.5"	100% Thruwall ~ 1.2"	Weld	Weld Contam.	Wetted surface to the annulus
5, Circumferential	1	50% Thruwall ~ 0.8"	~ 1.00"	Weld	Weld Contam.	Wetted surface angled toward the annulus
6, Circumferential	1	25% Thruwall ~ 0.4"	~ 0.8"	Weld	Weld Contam.	Wetted surface, parallel w/tube & 0.050" away
7, Axial	1	50% Thruwall - 0.31"	1.50"	Tube OD	EDM	Midweld to below weld
8, Radial Axial	1	80% Across Weld ~ 0.4"	50% Thruwall ~ 0.7"	Weld	Weld Contam.	Wetted surface toward the annulus
9, Circumferential	1	25% Thruwall - 0.16"	0.70"	Tube OD	EDM	Above weld, in Annulus
10, Circumferential	1	50% Thruwall - 0.31"	1.0"	Tube OD	EDM	Above weld, in Annulus
11, Axial	1	25% Thruwall - 0.16"	1.0"	Tube OD	EDM	Midweld to below weld
12, Radial Axial	1	50% Across Weld ~ 0.25"	25% Thruwall ~ 0.5"	Weld	Weld Contam.	Wetted surface toward the annulus
Total # =	12					

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Attachment 4

2CAN080302

List of Regulatory Commitments

List of Regulatory Commitments

The following table identifies those actions committed to by Entergy in this document. Any other statements in this submittal are provided for information purposes and are not considered to be regulatory commitments.

COMMITMENT	TYPE (Check one)		SCHED COMP DATE
	ONE-TIME ACTION	CONT. COMP	
Entergy with Westinghouse will perform additional testing of the LF ECT technique under comparable field conditions. To augment the technical justification for the LF ECT, available data will be collected from laboratory mockups, the reactor vessel head at the Westinghouse Waltz Mill Service Center and replacement head inspections performed to date. Any signal above a 0.060" depth threshold will be evaluated to determine if any contiguous path from the J-groove weld to the top of the RPV head exists. From the top of the RPV head, the LF ECT axial scan length will be a minimum of 1.5". The inspection procedure presently contains the analysis guidelines for reporting indications. Specific training will be provided to NDE analysts on this method prior to field implementation. As part of this training, each analyst will be given a blind test from the established data set. This blind test will be independently reviewed regarding the technique's capability.	X		End of August 2003
If potential flaws exist in the RPV head penetrations, Entergy will perform additional evaluations to confirm the presence or absence of flaws. Specifically, Entergy will perform a wetted surface examination of the J-weld if it is identified that a flaw appears to exist in the J-weld, a riverbed type loss of interference fit in the nozzle annulus exists, or boric acid corrosion appears to exist at the top of the annulus of the RPV head.	X		Fall 2003 refueling outage

Enclosure 1

2CAN080302

WesDyne Report WDI-TJ-001-02 Rev 01,
Detection of Reactor Head Base Metal Loss from Inside the CRDM
(Non-proprietary)

WesDyne International

Title:		
Detection of Reactor Head Base Metal Loss from Inside the CRDM Penetration		
Key Words: Technical Justification	**Date:** 07/24/03	**Document Number:** WDI-TJ-001-02-NP Rev.1

WesDyne International LLC Non-Proprietary Class 3

Author(s):	Cognizant Manger:							
Zoran Kuljis (for ZK)	Don Adamonis D.C. Adamonis							
Customer	Required		Yes		No		Date	

Detection of Reactor Head Base Metal Loss from Inside the CRDM Penetration

Introduction

In February of 2002 significant loss of the base metal of the reactor head was discovered at David Besse Nuclear Power Station. The material loss was the result of Boric Acid corrosion of the carbon steel. The particular region of the head where the corrosion had taken place was not identified by visual inspection.

ANO has limited access to the outside surface of the head. As such a program was instituted to develop an inspection that can detect the presence of the carbon steel base metal of the head adjacent to a CRDM penetration. The available examination surface is the inside of a CRDM penetration. The technique chosen as having the highest probability of success was a low frequency eddy current technique.

Technique Description

The CRDM penetrations are of a non-magnetic NiCrFe alloy and the head base metal is a magnetic low alloy carbon steel. The magnetic properties associated with the head base metal offer a means to determine its presence adjacent to the penetration. The simplest inspection to implement for detecting the presence of magnetic is with the use of eddy current techniques.

Eddy current techniques rely on an Electro-magnetic field generated by a coil to interact with a part under test. This applied field generates eddy current flow in the part and this in turn alters the electrical impedance the coil. The Electro-magnetic properties of the part determine the strength and type of interactive response experienced by the coil. For the detection of the base metal of the head adjacent to a CRDM penetration, a coil configuration operates at a low frequency is required to assure that the coil's Electro-magnetic field extends through the CRDM penetration tube. The probe selected for its compatibility with the existing scanner and eddy current instrumentation [

] a.c.e

To perform the inspection, the eddy current probe is mounted into a tool that scans the probe on the ID surface of the penetration over an extent coincident with the head base metal. Figure 1 shows the probe mounted in a sled on the scanning tool. As the probe is scanned over the area of interest a loss in the base metal is detected as a change in the response of the coil.

Technique Evaluation

After a series of bench top tests, the eddy current probe selected for evaluation is [ ] a.c.e The probe was operated at an inspection frequency of [ ] a.c.e The

probe evaluation was conducted with the probe mounted in a 7010 manipulator. The evaluations were conducted using a head from cancelled reactor located at the Westinghouse Waltz Mills and machined samples. These tests were aimed at understanding the parameters governing the response to the material loss and the "noise" associated with field implementation. The scan increments, reference sensitivities etc. were in accordance with the parameters in the procedure WDI-ET-005.

Figure 2 shows the samples that were machined for this evaluation. They include two material loss morphologies. The first is uniform loss that is simulated by rings cut into the inside of a hollow cylinder. The second is localized loss that is simulated by axially oriented grooves cut into the inside of a half-cylindrical section. Table 1 lists the nominal dimensions for all of these samples. The samples in Table 1 were machined to fit the CRDM penetration tube R 6517-2 with an outside diameter of 4.10 inches and a wall thickness of 0.685 inch.

Table 1 Simulated loss dimensions in machined samples

Sample	Axial Length (in)	Circumferential Length (in)	Radial Depth (in)
SK-WB020408-1/A			
SK-WB020408-1/B			
SK-WB020408-2/A			
SK-WB020408-2/B			
SK-WB020408-3/B			
SK-WB020408-2/A			

a,c.e

As a further check on inspection sensitivity an additional sample was fabricated from a section of pipe that was bored to fit over a penetration of 4.150 inch diameter. The resulting tube had an approximately ¼ inch thick wall into which two through holes of [ ] a.c.e were drilled (Figure 3).

Tests using the machined samples were performed either on a test stand or with the samples surrounding a penetration tube on the head. Figure 4 shows two of the half cylinder samples mounted in the test stand. Figure 5 shows the ring sample (SK-WB020408-3) mounted on a penetration on the head.

Results

Machined Samples

The first tests performed were designed to determine the sensitivity of the inspection to a loss of carbon steel adjacent to a penetration. In these tests the half cylinder sample sections were clamped together and placed over the penetration in the test stand. Figure 6 shows the results of the test. Arrows in the figure indicate the location where responses from the various groves are anticipated. As can be seen in

the figure only the [ ]a.c.e has a poor detection resolution in the C-scan presentation. Additional detection resolution (S/N ratio > 3) is achievable with evaluation of the Lissajous signals the response from the [ ]a.c.e [ ]a.c.e Only the shallowest produced a week signal response (S/N ratio < 1) and has remain in practically undetectable signal response range. From these results it was concluded that the total volume of material lost is governing the signal responses.

A supplemental test was conducted to evaluate the sensitivity of the loss response to the area presented to the probe. Two of the half sections were mounted end to end on the test stand. The two sections were then separated at various increments. Measurements of the coil response associated with the gap between the samples were taken. This test duplicates the response of a very long deep loss of various widths. Figure 4 shows the position of the two samples at their maximum separation. The results of these measurements are found in Figure 7. As expected, the ability to detect the presence of the gap falls dramatically, as the width (area) becomes small. As the gap width increases the change in response saturates when [ ]a.c.e

The final test performed with the machined samples on the test stand determined the dependence of the coil response on the radial depth of material loss. To simulate this type of loss, shims were placed under the upper half section shown in Figure 3. This gives an approximation to the rings machined into Sample SK-WB020408-3 (A and B) but with more flexibility in terms of radial dimension. The measurements consisted of taking the difference in the amplitude of the vertical component of the eddy current response at approximately 1.5 inches within each sample on the same scan line. The measurements from four scan lines were then averaged for the final result. The results of these measurements are found in Figure 8. As a check on the validity of the approach the response of the two grooves in Sample SK-WB020408-3 (A and B) displayed in Figure 9 are shown in Figure 8 as the triangles.

James Port Head

Inspections were performed on six penetrations in the James Port reactor head. This head is from a cancelled plant. All of the displays for these inspections can be found in Appendix A. In general the variations seen in the head inspection are smaller than the variations observed in the machined samples. This fact allows for the counter bore at the top of the head to be observed. The counter bore is a radial opening of the hole in the head though which the penetration is inserted. The counter bore extends over the portion of the hole that is on the "high" side down to the "low" side. Figure 10 shows the results from Penetration 26 with the counter bore obvious in the display.

A further test was conducted where the ¼ inch thick tube sample with the two holes through the wall was slipped over a penetration that had been cut-off. The results of this inspection are found in Figure 11. Again as with the counter bore the presence of the [ ]a.c.e

Discussion

In reviewing the results the variations in response observed in the machined samples figure 9 is significantly (two times) higher than that observed in the head Figure 10. The origin of the variation has not been definitively identified but is believed to originate with a combination of material variability with in the penetration tube being used in the test stand and residual magnetic fields within the samples. These variations limit the detection of low level loss. Without these variations the signal to noise should improve allowing the detection level in the head to also improve over that observed in the samples.

The penetrations on the head are slightly smaller in diameter (4.0 inch diameter) than the penetration used in the test stand so that the pipe sample had a gap between the OD of the penetration and the inside of the pipe. This may have contributed to the [a.c.e] Bench tests had observed a response for the hole but as expected, at smaller amplitude than the responses of the 1-inch hole.

The results associated with a variation in the gap width (Figure 7) suggest that quantitative measurement of the material loss is indeed possible so long as the area of loss is [a.c.e] Further these results suggest that even if the area of loss is smaller, quantitative measurement of the loss may be possible by correcting the measurements (Figure 8) with a factor derived from the gap dependence (Figure 7).

The extension of the inspection to a CRDM penetration tube of slightly different dimensions should not present a significant problem. During this evaluation penetration diameters from 4.0 to 4.15 inches in diameter were considered. As the diameter and wall thickness of a penetration decrease the sensitivity of the inspection will improve and the curve in Figure 8 will become conservative.

Summary

These tests found that the key parameter determining the response of the inspection is the volume of the loss presented to the probe. Three out of four [a.c.e] Further the tests on the head found that the material noise was lower than that of the machined samples and that the counter bore at the top of the head could be readily detected. At present the technique is capable of estimating the amount of material lost, so long as it extends over a "wide" area. The measurement is based upon a calibration curve developed by displacing a ring section radially from the OD of the CRDM penetration. For assessing small areas of loss additional work will be required.

References

1. WDI –ET-005, Rev 0, "RPV Head CRDM Penetration EC Examination for Wastage Detection"

Figure 1 Eddy current probe mounted in the sled of a 7010 manipulator.

a,c,e

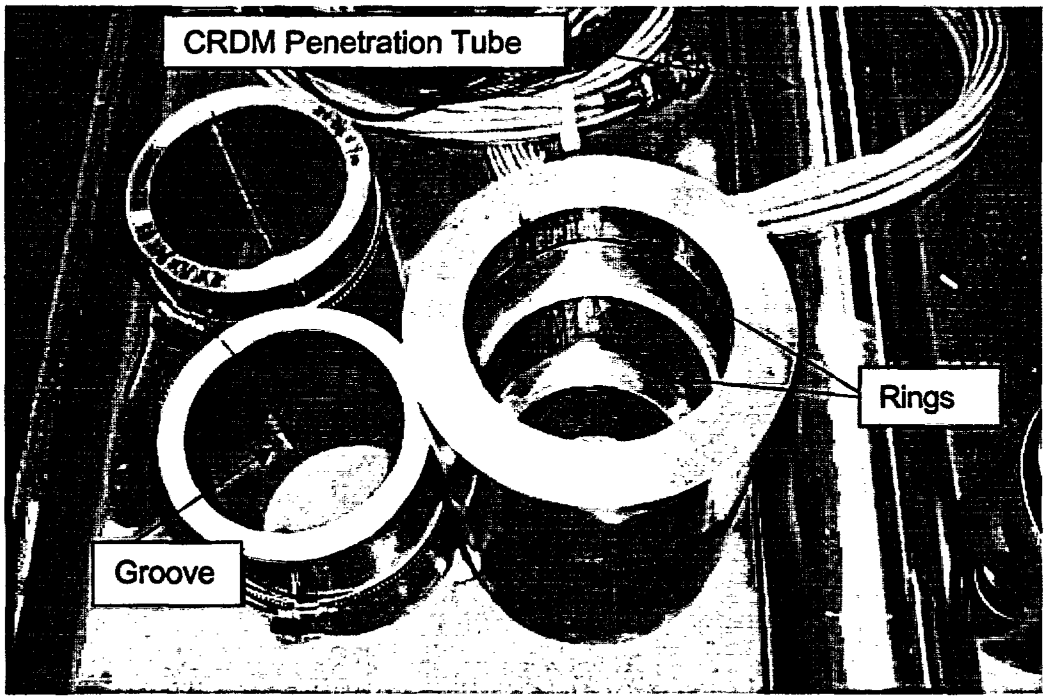


Figure 2 Machined samples used in this evaluation. The samples SK-WB08-1 through – 4 are shown clamped together. The penetration tube was used in the test stand.

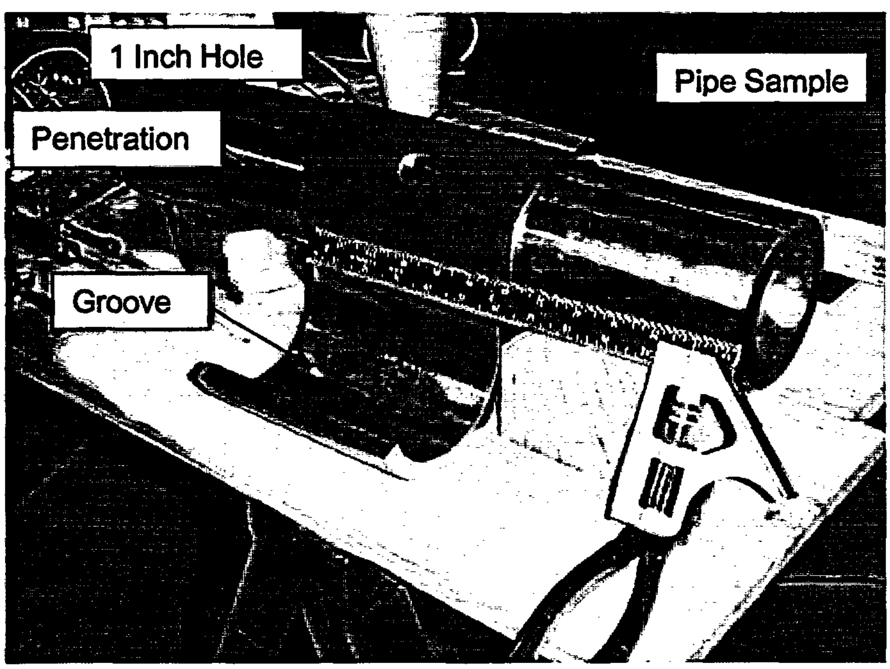


Figure 3 The tube sample with the through wall holes mounted on the penetration tube. In front is the groove Sample SK-WB08-04.

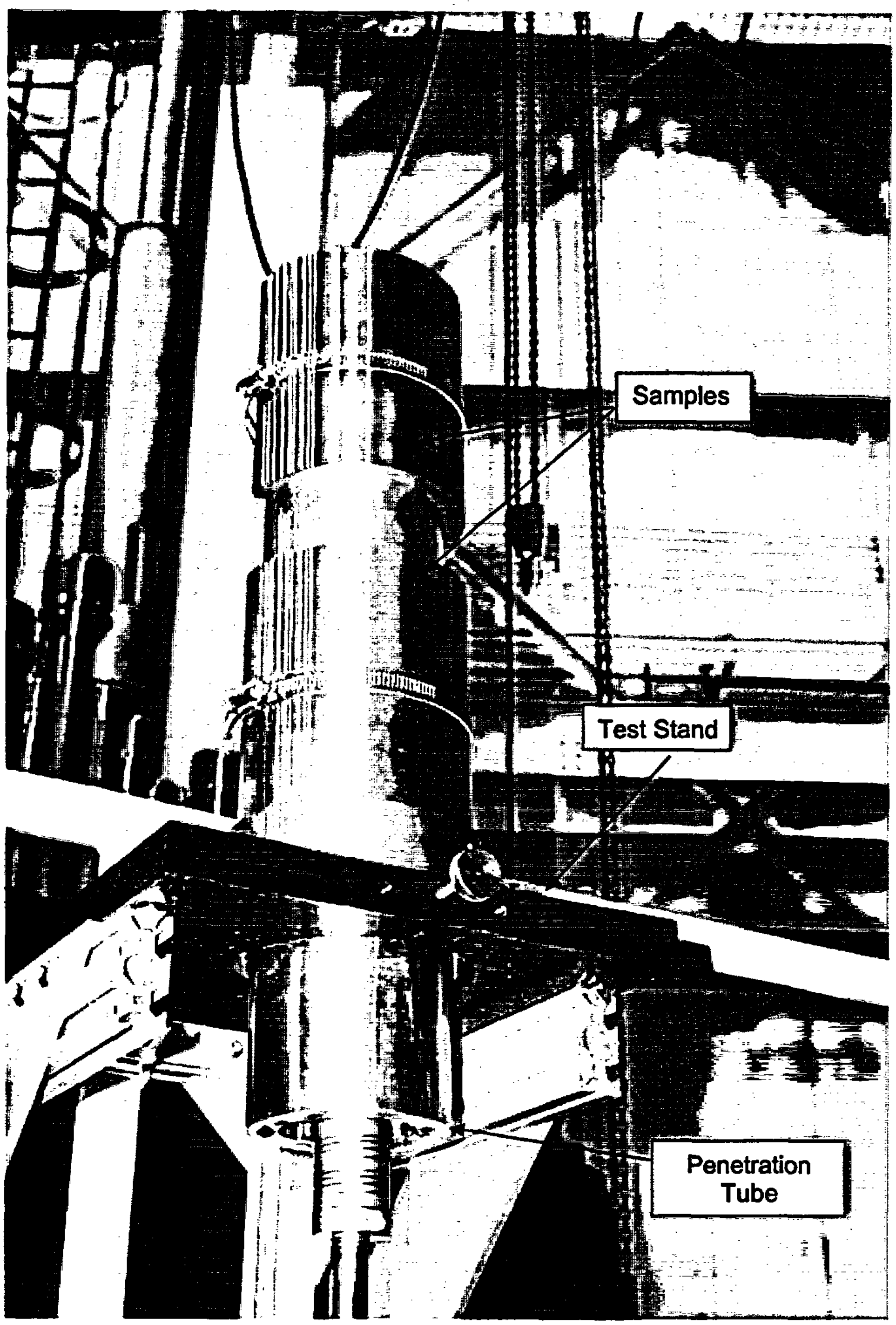


Figure 4 Half Cylinder Samples mounted on test stand. The samples are shown mounted for the "Gap" dependence study and are at the 2.0-inch separation.

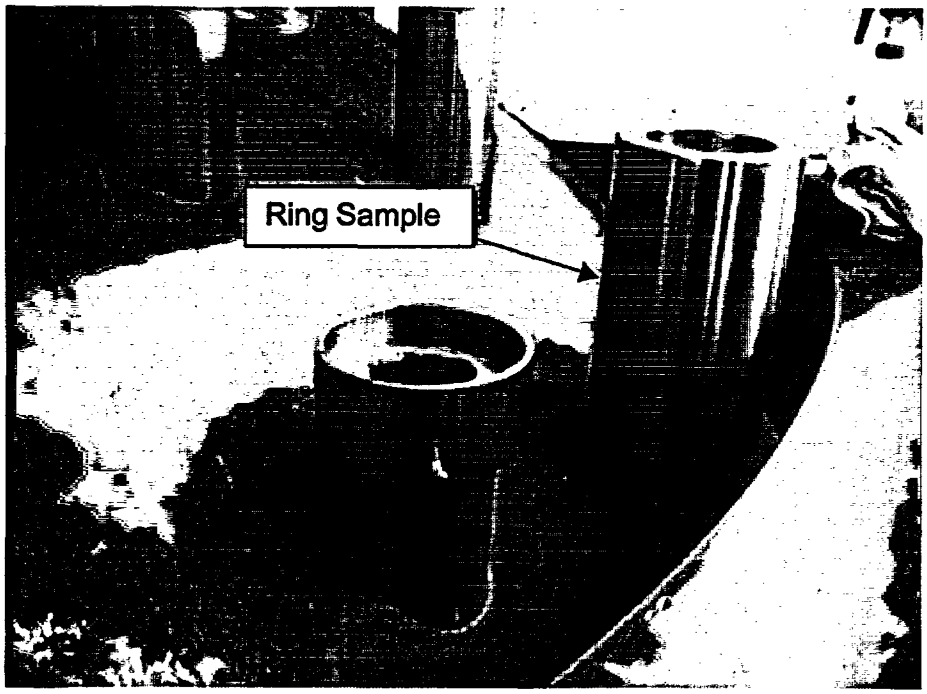


Figure 5 James Port Head with calibration ring and ring sample in position.

a.c.e

Figure 6
Results from the inspection of the Half Cylinder Samples mounted on the test stand. Arrows indicate location where groove response should be located in the sample identified by the number.
1) SK-WB020408-1/A, 2) SK- WB020408-1/B, 3) SK- WB020408-2/A, 4) SK- WB020408-2/B

a.c.e

Figure 7 Influence of the width on the reduction in the eddy current response of a long deep simulated loss. Note that the reduction in the response due to the gap saturates when the width is [ ] a.c.e

a.c.e

Figure 8 The dependence of the reduction in the eddy current response on the radial loss of the base metal. The squares are the result of placing shims between the OD of the penetration tube and the inside of the half cylinder. The triangles are measurements performed on Sample SK-WB08-5 (A and B).

a.c.e

Figure 9
Eddy current response from Circumferential Rings SK- WB020408-3/A and B.

a.c.e

Figure 10
Eddy current responses from inspection of CRDM Penetration 26 in the James Port head. The arrows identify the counter bore region in both the C-Scan and strip chart displays.

a.c.e

[ ]

Figures 11 Eddy current responses from ¼ inch thick pipe sample with through wall holes placed on a cut penetration on the head. The response from the[ ]a.c.e

Appendix A

Graphical displays of data obtained on the James Port Head. Note all presentations are at the same sensitivity level.

a.c.e

Figure A1 Eddy Current Responses from Penetration 2 of the James Port Head.
(Higher ECU represents the presence of carbon steel adjacent to the penetration.)

a.c.e

Figure A-2 Eddy Current Responses from Penetration 3 of the James Port Head. (Higher ECU represents the presence of carbon steel adjacent to the penetration.)

a.c.e

Figure A-3 Eddy Current Responses from Penetration 4 of the James Port Head. (Higher ECU represents the presence of carbon steel adjacent to the penetration.)

a.c.e

Figure A-4 Eddy Current Responses from Penetration 22 of the James Port Head. (Higher ECU represents the presence of carbon steel adjacent to the penetration.)

a.c.e

Figure A-5 Eddy Current Responses from Penetration 26 of the James Port Head. (Higher ECU represents the presence of carbon steel adjacent to the penetration.)

a.c.e

Figure A-6 Eddy Current Responses from Penetration 29 of the James Port Head. (Higher ECU represents the presence of carbon steel adjacent to the penetration.)

Enclosure 2

2CAN080302

WesDyne Report WDI-TJ-012-03 Rev. 0,
Triple Point Inspection using TOFD Ultrasonic Methods

(Non-proprietary)

WESDYNE INTERNATIONAL

WesDyne International Non-Proprietary Class 3

DOCUMENT NUMBER & REV:

WDI-TJ-012-03–NP Rev. 0

TITLE: Triple Point Inspection using TOFD Ultrasonic Methods

COVER SHEET FOR:

- ☐ DESIGN SPECIFICATION
- ☐ FUNCTIONAL SPECIFICATION
- ☐ QUALIFICATION PROCEDURE
- ☐ FUNCTIONAL TEST PROCEDURE
- ☐ USERS MANUAL
- ☐ TRAINING PLAN
- ☒ TECHNICAL JUSTIFICATION
- ☐ CALIBRATION PROCEDURE
- ☐ OTHER

PLANT SITE/PLANT ALPHA:

KEY WORDS:

WESDYNE INTERNATIONAL LLC
P.O. Box 409
Madison, Pennsylvania 15663

The procedure approval signature of the cognizant manager below confirms that prior concurrence of required review groups has been obtained.

Originator – Jack Lareau	Signature (for JL)	Date 7/31/03
Don Adamonis	Signature	Date* 7/31/03

*Effective/Revised Date

WDF-19.10-2. Rev. 0

Triple Point Inspection using TOFD Ultrasonic Methods

Reference 1 - Excerpts from "MRP Inspection Demonstration Program" Updated December 11, 2002, 2002

Reference 2 - WDI-TJ-007-02, Rev. 0, Demonstration of Volumetric Ultrasonic Inspection of CRDM Nozzles Using the Open Housing Scanner for ANO-2

Reference 3 - WDI-UT-013, Rev. 2 CRDM/ICI UT Analysis Guidelines

Reference 4 - WDI-UT-10, Rev. 4, IntraSpect Ultrasonic Procedure for Inspection of Reactor Vessel Head Penetrations, Time of Flight Ultrasonic, Longitudinal Wave & Shear Wave

Reference 5 - E-mail- EPRI (Kietzman) to Entergy (Hamilton), February 28, 2002 Demonstration of Westinghouse Procedures on the Entergy Weld Flaw Mock Up

Introduction:

The purpose of this test sequence was to determine the feasibility of using the open housing scanner (7010 end effector) to interrogate the penetration tube/J-weld triple point region. A series of mock ups were used during this test sequence. The results of this testing is provided in the description below.

Description:

The ultrasonic volumetric inspection of the CEDM nozzles includes the ability to interrogate into the J–groove weld approximately [ ][a,c,e] beyond the OD of the nozzle. The open housing scanner employs a TOFD pair of transducers that are [ ][a,c,e]

In order to demonstrate the ability of the open housing end effector to interrogate the triple point region, a series of laboratory tests were conducted using mockups fabricated by EPRI for the MRP demonstration project. In particular, two mockups were used, the first is referred to as the Entergy mockup and the second is referred to as the "K" mockup. Both of these mockups have reflectors in the weld metal. These mockups are described in references 1 and 2. A summary of these mockups is provided in Figures 1 and 2.

Entergy Mock Up (Figure 1) - In the Entergy mockup, there is a series of [ ][a,c,e] outboard of the nozzle OD. These reflectors were used to demonstrate that the TOFD pair focal length was sufficient to detect reflectors at these depths. The flat bottom holes down to [ ][a,c,e] beyond the nozzle OD were detected, as reported in reference 2. This was documented in the demonstration report provided to the NRC on June 17, 2002. Accordingly, the inspection procedure, reference 4, specifies that the range of applicability is up to [ ][a,c,e] thickness. This depth range encompasses the thickness of the penetration tube material and the demonstrated depth into the attachment weld.

In addition, the Entergy mockup has a series of axial and circumferential Cold Isostatic Pressure (CIP) notches that are entirely in the weld metal. These notches are[ ]a,c,e through the thickness of the J-groove weld starting from the wetted surface (ID surface of RPV head). It was determined that the axial notches were not suitable for demonstration purposes because they were beneath a corresponding axial flaw in the nozzle wall which completely masked the presence of the weld flaws. The circumferential-oriented flaws (i.e. flaws in the circumferential-axial plane) in the attachment weld were detected during the blind phase of the demo. These are flaws 1, 5 & 6 in the mock-up drawing. See Figures 3 through 8.

Phase II EPRI Mock Up ("K" Mock Up) (Figure 2) - Further demonstration of the capability to examine the nozzle-to-weld interface using the Westinghouse open housing probe was conducted in the spring of 2002 as part of the MRP Phase II demonstrations. This second mockup ("K" mock up) contains radial, axial CIP notches in the weld within[ ]a,c,e inches of the weld fusion line.

During this demonstration, a pure axial/radial squeezed notch flaw was detected from the ID of the J-weld that extended thru-weld to the triple point of the J-weld. The flaw location was approximately[ ]a,c,e beyond the fusion line which provided the additional basis for the capability of the open housing probe.

Accordingly, the analysis guidelines, reference 3, were modified to include the requirement to evaluate the weld metal up to[ ]a,c,e beyond the nozzle OD (See Table 1). The extra examination depth[ ]a,c,e If crack tip type signals are detected in this zone, the indication is identified as a Weld Volume Indication (WVI). If a WVI is reported in field examinations, the analysis guidelines flow chart designates this as a "Special Interest" condition which calls for a confirmatory surface examination of the j groove weld. In the analysis training sessions, the topic of WVI's is specifically described in detail to assure that each analyst is aware of the triple point inspection issue.

In actual field experience, a number of WVI/Special Interest indications have been identified and surface exams have been performed.[ ]a,c,e A number of WVI signals were identified in the weld and a J-groove weld penetrant test was conducted. The results were negative and the source of the reflectors was concluded to be grain boundary reflections in the weld.

The overall process with WVI/Special Interest designations is designed to be conservative and is predominated by false positives due to weld grain boundary reflectors. Early field experience has shown that approximately[ ]a,c,e of the nozzles have this type of false positive results. The confirmatory surface examination is used for the final determination for this type of indication.

Conclusions:

It has been demonstrated, based on the Entergy and EPRI mockups, that PWSCC-type indications in the triple point region can be detected with TOFD UT technique employed by the open housing scanner (7010). Radial – axial and circumferential CIP flaws within [ ][a,c,e] inches of the weld interface were detected.

The analysis guidelines specify that indications of this type be classified as WVI, a special interest category. J-groove welds of penetrations containing special interest findings are examined using surface inspection techniques to establish if cracking exists on the J-groove weld, the anticipated initiation site for such degradation.

Figure 1- ENTERGY MOCK-UP GRAPHIC

a,c,e

a,c,e

Figure 2 - "K" MOCK-UP GRAPHIC

a,c,e

a,c,e

Figure 3 - Weld Flaw to Triple Point

Entergy Indication: # 1

WesDyne Indication: # 1F. This reflector was detected with the circ shooting transducer

Figure 4 - WDI-TJ-007-02

a,c,e

Entergy Indication: # 5

WesDyne Indication: # 1A and 1B. This reflector was detected with the circ. and axial shooting transducer. There were two signals associated with this indication noted on both channels one down in the weld and one at the weld to tube interface.

a,c,e

Figure 5 - WDI-TJ-007-02

Entergy Indication: # 5

WesDyne Indication: # 6. This reflector was detected with the circ and axial shooting transducer. There are two signals associated with this indication noted on both channels one down in the weld and one at the weld to tube interface. On the original analysis we only reported the indication @ the weld fusion zone on this channel

Figure 6 - WDI-TJ-007-02

a,c,e

Entergy Indication: # 5

WesDyne Indication: # 6. This reflector was detected with the circ and axial shooting transducer. There are two signals associated with this indication noted on both channels one down in the weld and one at the weld to tube interface. On the original analysis we only reported the indication @ the weld fusion zone on this channel (the reflector in the weld was not reported with this channel)

a,c,e

Figure 7 - WDI--TJ-007-02

Entergy Indication: # 6

WesDyne Indication: # 5. This reflector was detected with the both the circ and axial shooting transducers.

Figure 8 - WDI-TJ-007-02

a,c,e

Entergy Indication: # 6

WesDyne Indication: # 1D. This reflector was detected with the both the circ and axial shooting transducers.

Table 1 – PENETRATION TUBE FLAW EVALUATION (Page 1 of 4)

CRDM Inspection Result Codes

Open Housing Probe Inspections

NDD: No Detectable Defect

WII: Weld Interface Indication

PTI: Penetration Tube Indication Note that an axial flaw may show up on only 2-3 scans on Channel 2

IPA: Indication Profile Analysis Resolution of indication

LOB: Loss of Backwall, linear indication. Main area of interest is just above the weld. This may indicate a deep flaw that is in the "blind" zone of the PCS24.

LCS: Loss of Coupling-Scanner, note the circ extent

LCG: Loss of Coupling-Geometry, note the circ extent

LIF: Loss of Interference Fit (Channel 4, second backwall)

VOL: Volumetric indication (Ch1 and 2 response comparison)

WVI: Weld Volume Indication (within 0.1" beyond fusion interface)

LOF: Lack of Fusion at the tube to weld interface (Channel 3) >50% of weld width

WBI: Weld butter indication (Channel 3, large area indication)

Criteria:

Weld region at 0 and 180 degree covered

PTI and WVI are special interest results

Channel 2 is the primary inspection channel for PTI and WVI indications. Channel 1 is used for additional and confirmatory data. Review every B scan on Channel 2 for axial and circumferential indications.

Table 1 - PENETRATION TUBE OD FLAWS EVALUATION (Page 2 of 4)

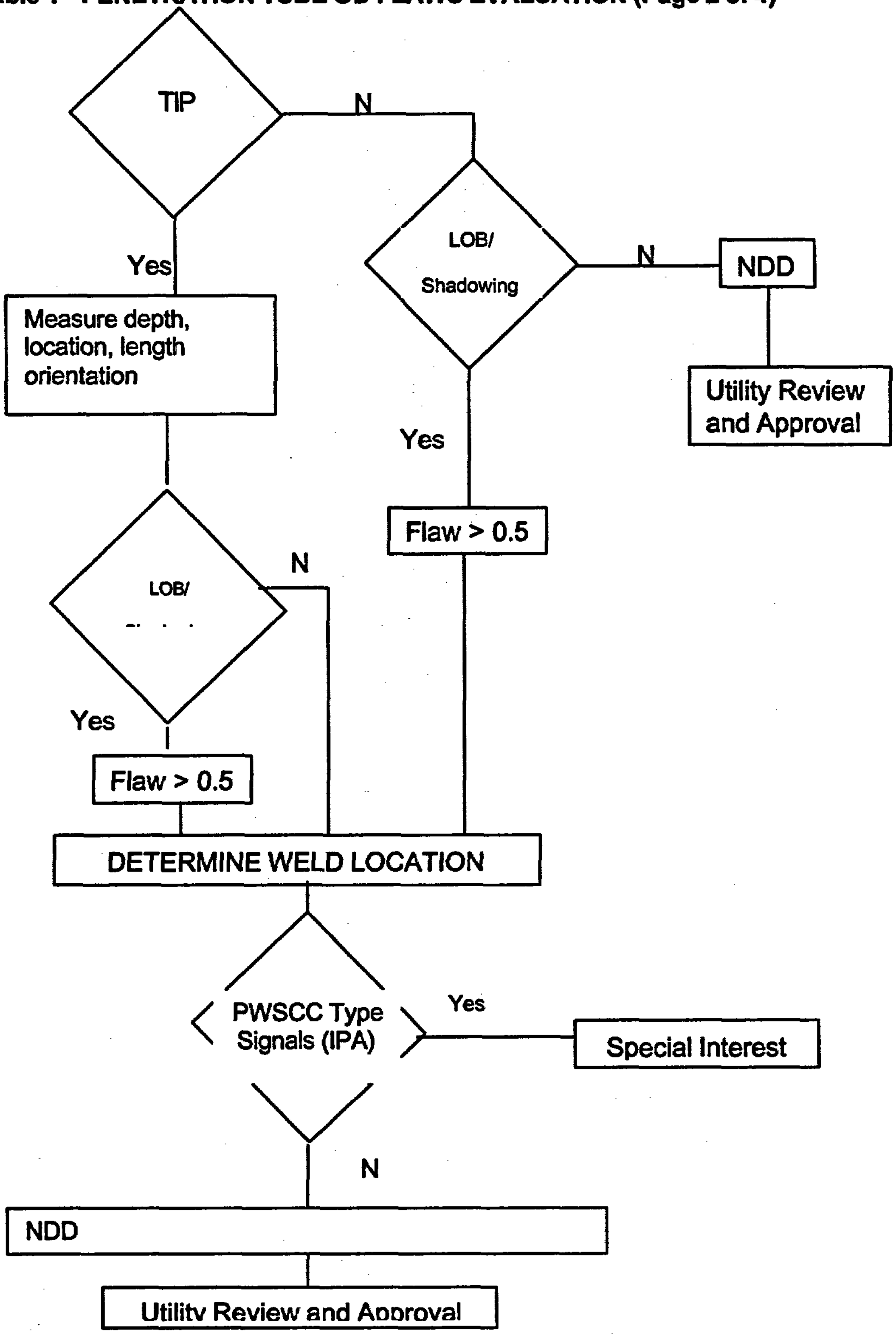


Table 1 - PWSCC TYPE SIGNALS (Page 3 of 4)

Linear in one direction, TOF like in the other hyperbolic echodynamic intermediate amplitude, does not

OR

Linear region with loss of blackwall for PWSCC >0.5" deep from OD

False positives can be caused by

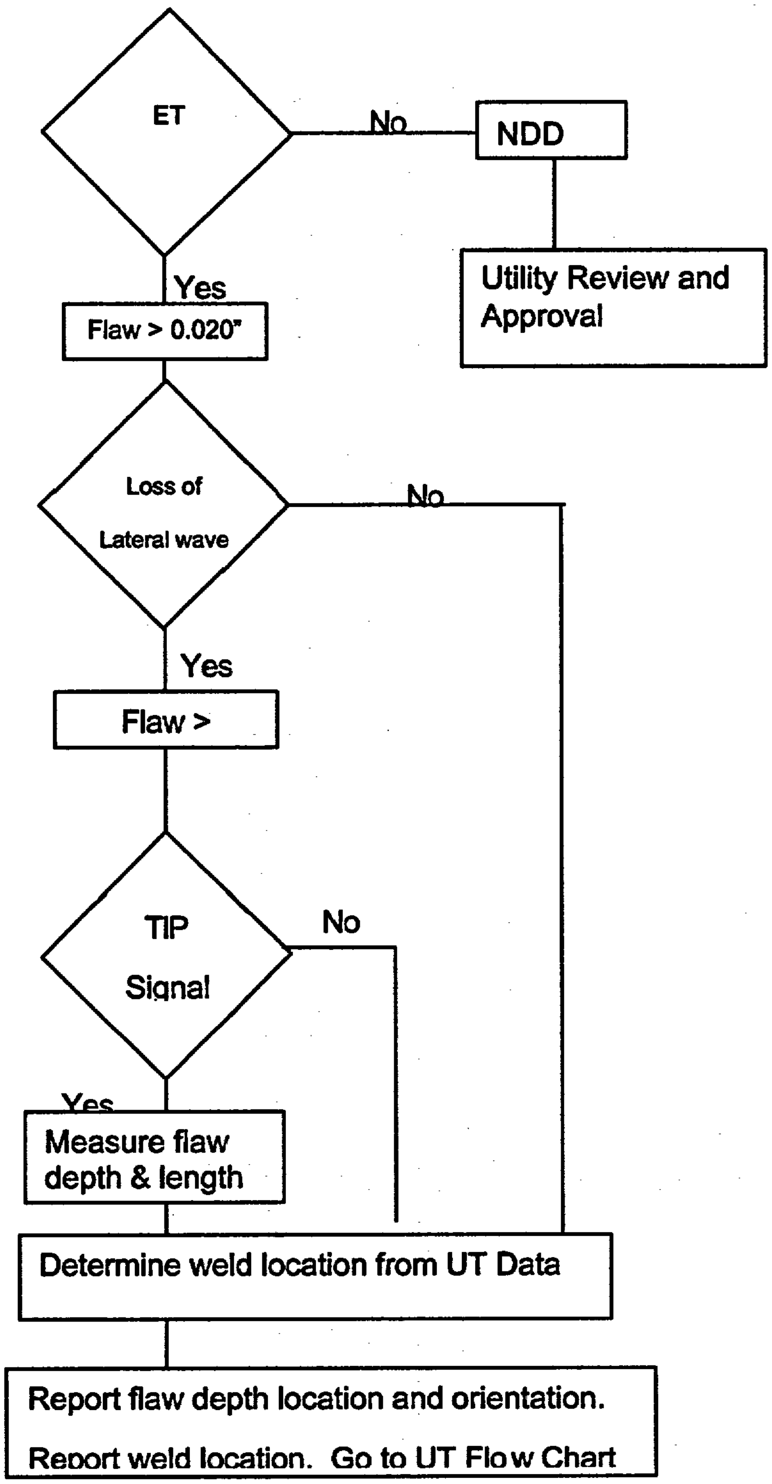
- Weld repairs
- Reflective weld interface grain structure
- Lack of fusion

Suspect signals are categorized as:

Special interest for additional surface inspection on the J groove weld surface

PWSCC, by definition must start on a wetted surface. The tube ID & OD

Table 1 - PENETRATION TUBE ID FLAW EVALUATION (Page 4 of 4)



Enclosure 3

2CAN080302

MRP Inspection Demonstration Program Report Excerpts
(Updated: December 11, 2002)

MRP Inspection Demonstration Program Report Excerpts
(Updated: December 11, 2002)

MRP has conducted inspection demonstrations in two phases. Phase 1 demonstrations were conducted in the fall of 2001 to support Fall 2001 and Spring 2002 inspection activities. The mock-ups addressed flaw detection in the RVHP tube material only. The second phase of the vendors demonstrations are currently underway and will:

- Quantify detection limits of inside-diameter (ID) and outside-diameter (OD) connected flaws from the ID of the penetration tube,
- Document sizing capabilities of ID and OD connected flaws from the ID of the penetration tube,
- Evaluate capabilities to detect defects on the wetted surface of the RVHP attachment weld, and
- Investigate the capability to detect flaws approaching the weld-to-tube interface (triple point flaws) using ultrasonic (UT) inspection from the ID surface of the penetration tube.

Phase I Demonstrations
Mock-ups for the first phase (base metal inspection only) included field-removed tube specimens and a full-scale mock-up of the tube, weld and vessel head. The field-removed tube specimens from Oconee Unit 3 contained a variety of pressurized water stress corrosion cracks (PWSCC) ranging from shallow flaws initiating at the OD surface of the tube to through-wall flaws. The full-scale mock-up contained electro-discharge machined (EDM) notches and was used to evaluate the influence of component geometry since defect detection and sizing capabilities are influenced by the presence of the attachment weld and the configuration of the component.

WesDyne conducted demonstrations of inspection equipment and procedures for inspection with thermal sleeves in place and open-tube UT equipment for inspection with thermal sleeves removed. During this phase, WesDyne successfully demonstrated the ability to detect 2-3 mm OD-initiated PWSCC and determined flaw position with an accuracy of 6 mm.

Phase II Demonstrations
The second phase of demonstrations added additional mock-ups containing manufactured flaws. These flaws are appropriate for quantifying the performance of UT and eddy current (ET) techniques for the tube and weld volume, and for the use of surface methods (i.e. ET) on the wetted surface of the attachment J-groove weld.

The morphology of the manufactured flaws in the second phase of demonstrations is based on metallurgical investigations of tube and weld flaws removed from Oconee Nuclear Plant, Units 1 and 3. Supporting information located from other field-removed Alloy-182 weld defects was also used. The UT and ET responses of these manufactured flaws have been shown to be comparable to responses from service-induced PWSCC. Wide ranges of flaw sizes are included in the mock-ups to quantify the performance of demonstrated inspection techniques.

Tube Flaw Mock-up
RVHP tube flaws are manufactured using the cold-isostatic processing (CIP) technique. The technique uses extremely high pressure to compress EDM notches, thereby reducing the volume and sharpening the notch tips. Studies show they deliver UT and ET responses closely representative of PWSCC. A CIP flaw can be implanted with exact size, shape, orientation, and location as required to quantify inspection performance. Service-induced flaws are not available in adequate numbers for this purpose and the size is not known to the precision required for the scope of this type of demonstration. Figure 1 shows an illustration of the placement of flaws in the tube mock-up.

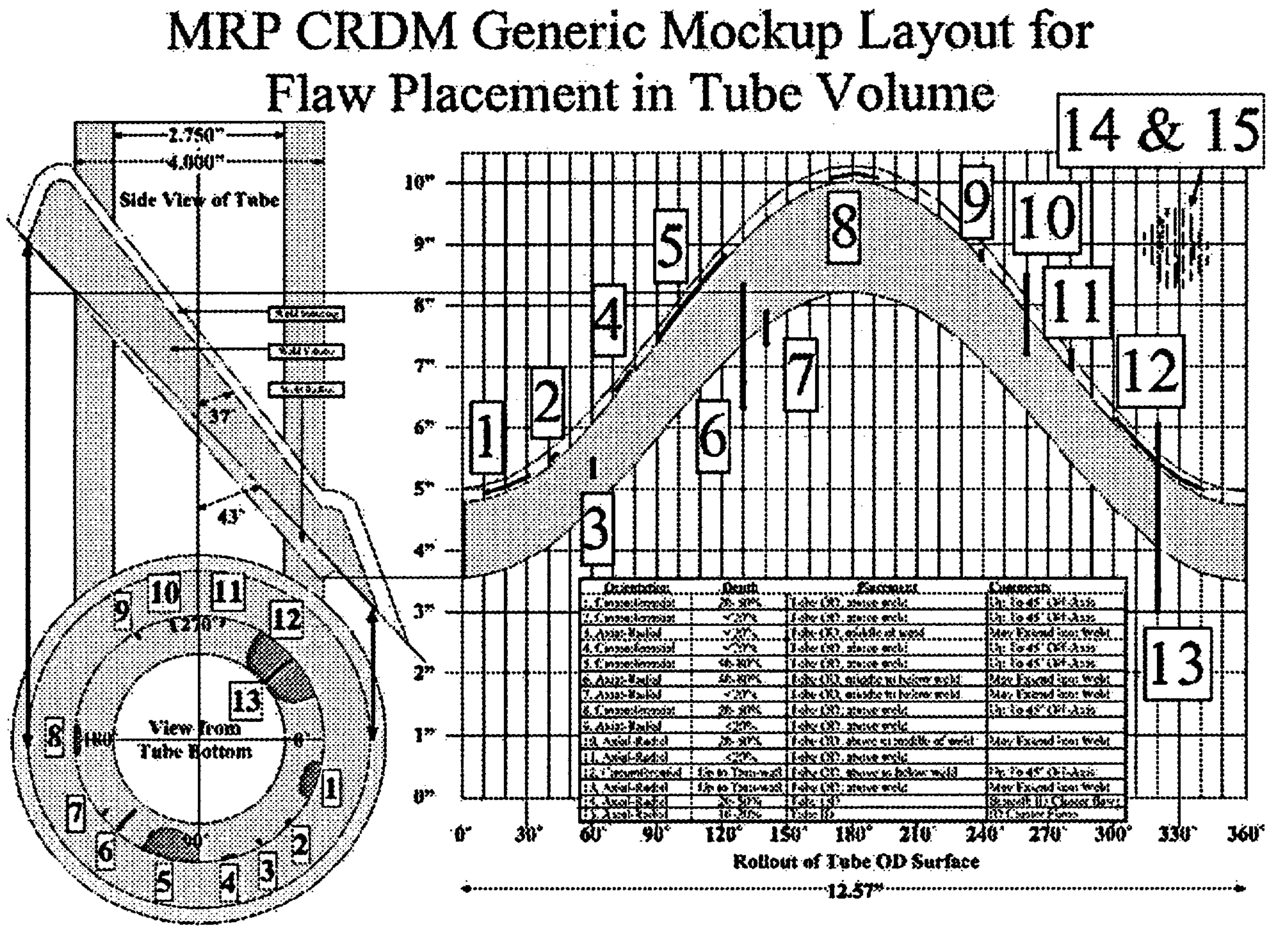


Figure 1. Illustration of the orientation and placement of flaws in the tube mock-up.

Although not indicated in Figure 1, in some cases the individual flaws are comprised of multiple parallel and/or branching flaws. This configuration more closely represents flaws found in head penetrations in the field. Figure 2 shows an example of some of the flaws implanted in the mock-up.

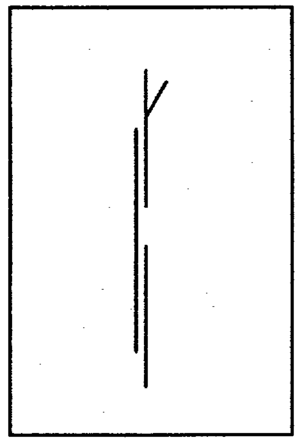


Figure 2. Example of implanted flaw configuration.

Figure 4 shows a comparison of a CIP flaw and an OD-initiated PWSCC flaw located in a tube stub end from Oconee Nuclear Plant, Unit 3. The flaws are shown at the same magnification. The PWSCC flaw shown represents the more challenging type of flaw to detect, an isolated, shallow flaw, with limited or no branching. Detection of flaws of this type, positioned over the attachment weld in the RVHP tube, relies on detection of the diffracted signal from the tip of the flaw. Lack of a back-wall reflection can make detection in this location more difficult. As discussed, CIP flaws have been demonstrated to deliver tip responses representative of PWSCC. Figure 5 shows a cross-section of a field-removed PWSCC flaw in the Alloy-182 attachment weld.

Weld Flaw Mock-Up
A weld flaw mock-up (designated "K") is full-scale, fabricated using production materials and contains CIP flaws to evaluate both UT techniques applied from the ID of the tube, and surface methods applied on the wetted surface of the weld. A generic description of the flaw locations and sizes is provided in the illustration below.

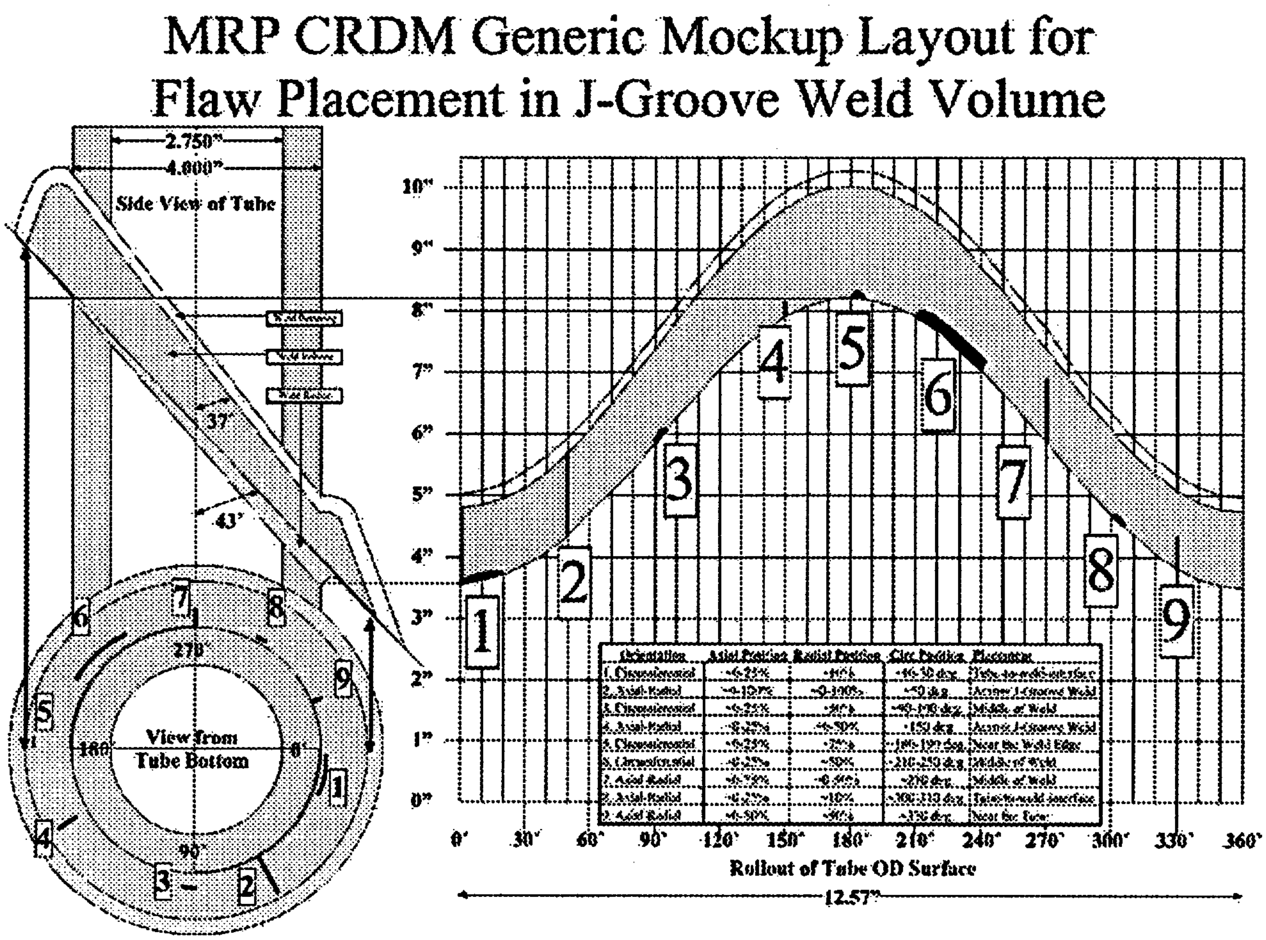


Figure 3 - Illustration of the orientation and placement of flaws in the weld mock-up.

Figure 5 shows a cross-section of a field-removed PWSCC flaw in the Alloy-182 attachment weld. The wetted surface of the weld is at the upper left-hand corner of the photo. Note that the crack width is very small at the wetted surface and widens significantly as it propagates toward the weld/tube interface on the lower right-hand corner of the photo.

CIP flaws are used in the attachment weld mock-up to evaluate UT techniques applied from the ID surface of the tube. Procedures have been proposed to examine a short distance past the tube/weld interface. As can be seen in Figures 1, 2, 3, and 4, CIP flaws and/or multiple CIP flaws can be used to simulate weld flaw morphology for evaluating tip diffraction UT techniques applied from the ID surface the penetration tube.

Mock-up "K" contains CIP flaws at various locations in the weld (i.e. weld/tube interface, center of weld, weld/head interface) and will quantify the ability of equipment to detect flaws at various orientations and locations in the examination volume.

Phase II Demonstration Process

WesDyne has demonstrated blade-probe and open-tube UT techniques for the tube volume and tube-to-weld interface. ET of the wetted surface of the attachment weld has also been demonstrated.

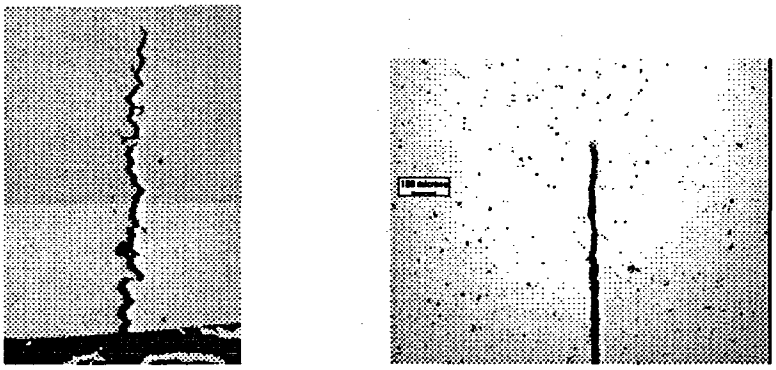


Figure 4 - Shallow flaws in: Oconee RVHP Alloy-600 tube material (left), and CIP flaw (right).

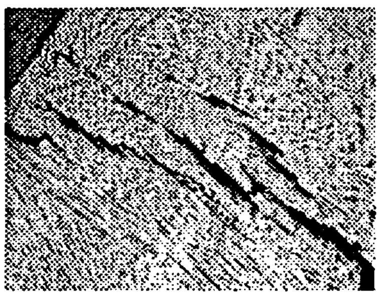


Figure 5 - Typical PWSCC flaw in Oconee RVHP attachment weld.

WesDyne Demonstration Status

WesDyne demonstration activities began on Tuesday August 28, 2002. WesDyne finalized analysis of data collected on the Entergy/MRP practice mock-up. This data was reviewed as part of the readiness review process established by the MRP demonstration protocol. Demonstration of WesDyne equipment and procedures was conducted at their Windsor, CT facility during the period of August 26 to September 11. WesDyne personnel involved were Jack Lareau (UT/ET), Russ Devlin (UT), Mark Kirby (ET), Joshua Whiting (UT), Fred Whytsel (UT/ET), and Joel Johnson (UT/ET).

Open-tube and blade probe UT and ET equipment and procedures were demonstrated. WesDyne procedures addressed inspection of the RVHP tube and weld-to-tube interface from the inside surface of the tube during this phase of the demonstration.

Procedure Demonstrated

WesDyne used one UT procedure (WDI-UT-010, Revision-3 [DRAFT]) with an additional UT analysis guide (WDI-UT-013, Revision 1 [DRAFT]).

They also used two ET procedures (WDI-ET-003, Revision-3 [DRAFT] and WDI-ET-008, Revision-0 [DRAFT]) with an additional ET analysis guide (WDI-ET-004, Revision 1 [DRAFT]).

Mock-ups employed during the demonstration were:

Entergy mockup "H"
97-01 mock-up "A" for ID initiated flaws
Tube mock-up "J"
Weld mock-up "K"
Cluster flaw mock-up "O"

WesDyne Demonstration Sequence

To maintain validity of the blind demonstration, data was again collected and evaluated in a predetermined order (i.e. blade-probe UT TOFD was collected before open-tube UT data and coarse increment scans were performed before fine increment scans). Data collection and analysis were performed and the results submitted to the PDA before proceeding to the next probe or finer scan increment. Therefore, subsequent data would not influence previous results.

The open-tube and blade probes also contain ET coils. The ET data was reviewed with the UT data to assist in characterizing the detected flaws.

Data collection, analysis, and results were performed in the order shown below:

PCS24 TOFD Blade Probe with UT beam axially-oriented-for-circumferential-flaws (AOCF) and ET (Detection/Characterization scans)

1.5 degree
1.0 degree

PCS24 TOFD Blade Probe with UT beam circumferentially-oriented-for-axial-flaws (COAF) (Characterization scan only)

1.0 degree

PCS18 TOFD Blade Probe with UT AOCF (Initially for Characterization scan only for the PCS24, but data was later analyzed on November 11, 2002 for Detection/Characterization scan)

1.0 degree

PCS18 TOFD Blade Probe with UT COAF (Characterization scan only)

1.0 degree

0 Degree Blade Probe UT (Characterization scan only)

1.0 degree

ET Blade Probe (Characterization scan)

1.0 degree

Open-Tube Probe UT AOCF/COAF/0 deg/ET (Detection/Characterization scans)

2.0 degree
1.5 degree

Initial Review of WesDyne UT Detection Results
WesDyne was informed that:

- circumferential components of flaws were not being reported in the correct orientation,
- that the written procedure did not contain definitive criteria on flaw detection in the near-surface region, and
- additional viewing perspectives were required to achieve adequate detection.

1) Significant axial flaws were being reported as being circumferentially oriented with the open-tube.
   - If the analyst identifies an area of interest, the minimum set of viewing perspectives should improve the ability to correctly orient the indication.
   - The procedure should require a minimum set of required viewing perspectives.

2) Tube flaws with large through-wall dimension were being undersized.
   - Disturbance of surrounding material (grain) noise is a major discriminate in flaw characterization and sizing.
   - The procedure should provide guidance on the use of material noise disturbance.

Additions to the procedure were discussed and incorporated. Appropriate portions of the data were then re-analyzed. WesDyne agreed to provide a revised procedure upon completion of the demonstration activity.

WesDyne UT Detection Results After Procedure Revision
Table 2 summarizes WesDyne detection results after incorporation of procedure revisions mentioned above. Analysis of the Circ Blade PCS18 data @ 1.0 degree scan index increment was conducted November 8, 2002 by Josh Whiting at the request of Entergy.

Table 2 - WesDyne detection results.

	WesDyne Detection Results Including Missed Flaws and False Calls See Flaw Table 4 and drawing for description of flaw types "A" through "O"					
WesDyne UT Techniques	**A, B, & C** ID Axial Flaws	**G, H, & I** ID Circumferential Flaws	**D, E, & F** OD Axial Flaws	**J, K, & L** OD Circumferential Flaws	**M, N, & O** Weld Flaws (Note 4)	**Cluster Flaws** OD Flaws under shallow (< 3 mm deep) ID Cluster Flaws
"Circ Blade" (PCS24 TOFD UT AOCF /ET) (Note 1)	5%-86% TWE detected (Note 3)	11%-49% TWE detected	12%-100% TWE detected 2 flaws < 10% TWE	15%-100% TWE detected	No implanted flaws detected 4 false	100% detection of ID & OD

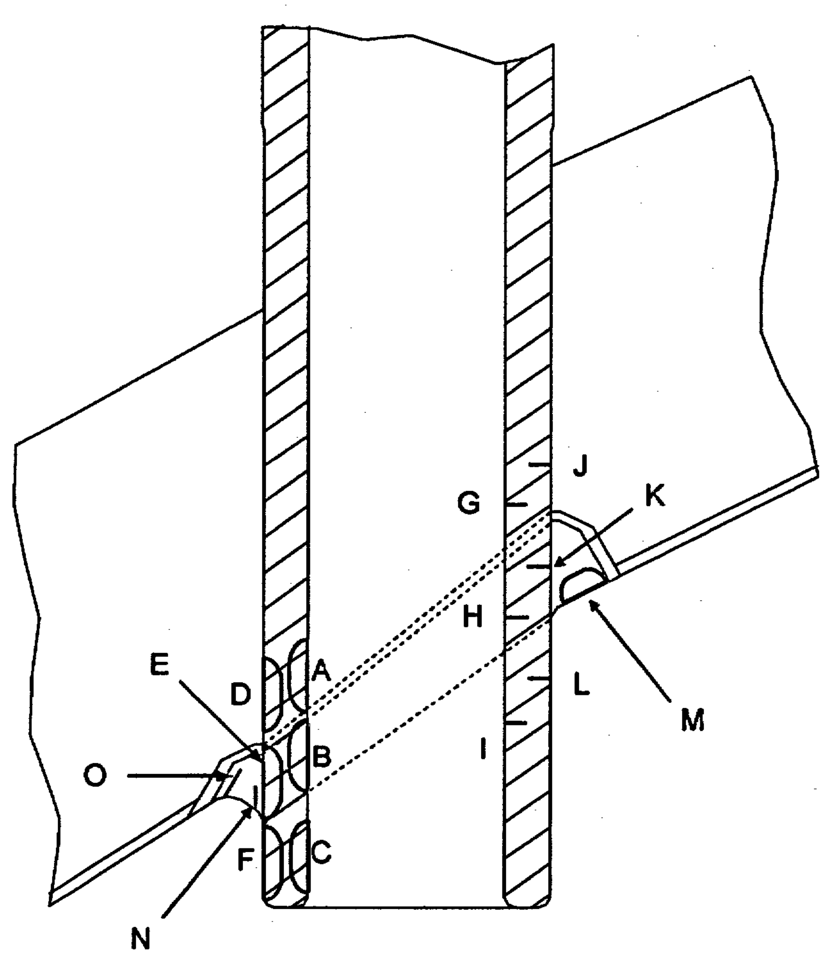
1.5 degree scan increment			missed: 1-D type flaw, 1-EF type flaw		calls: MN type flaws (Note 5)	
"Circ Blade" (PCS24 TOFD UT AOCF /ET) (Note 1) **1.0 degree scan increment**	5%-86% TWE detected	11%-49% TWE detected	12%-100% TWE detected 2 flaws < 10% TWE missed: 1-D type flaw, 1-EF type flaw	15%-100% TWE detected	Data not reviewed	100% detection of ID & OD
"Open-Tube" (PCS24 TOFD UT AOCF/COAF/ 0 Deg/ET) (Note 2) **2 degree scan increment**	5%-86% TWE detected	11%-49% TWE detected	10%-100% TWE detected Orientation of flaws < 40% TWE inconsistent 1 D type flaw <8% TWE missed	15%-100% TWE detected 2 false calls: 16% TWE KL type flaws	**1 M type flaw, 100% to triple-point detected** **2 M type flaws < 75% to triple-point missed** **2 false calls: M type flaws** **(Note 5)**	100% detection of ID & OD
"Circ Blade" (PCS18 TOFD UT AOCF) (Note 6) **1.0 degree scan increment**	11%-86% TWE detected 3 flaws < 11% TWE missed: 2-B type flaws, 1-C type flaw	11%-49% TWE detected	16%-100% TWE detected 4 flaws < 13% TWE missed: 2-D type flaws, 1-E type flaw, 1-EF type flaw	15%-100% TWE detected 2 false calls: < 14% TWE K type flaws (Note 5)	Data not reviewed	100% detection of ID & OD

Notes:	(1) PCS24 TOFD UT AOCF/ET (Axially Oriented for Circumferential Flaws) used for detection and sizing of flaws. PCS24 UT COAF (Circumferentially Oriented for Axial Flaws), PCS18 UT COAF/AOCF, & Zero degree probes used for sizing only. (2) PCS24 UT AOCF/COAF/0 deg/ET open-tube probe used for detection and sizing of flaws. PCS18 UT AOCF/COAF open-tube probe used for sizing only. (3) Through-wall-extent (TWE) of flaw depth in the tube thickness. (4) WesDyne only interrogated the first 0.1" of the tube-to-weld-interface for detection of flaws. **(5) Appears to be a welding defect at the tube-to-weld-interface.** (6) PCS18 TOFD UT AOCF used for detection and sizing of flaws.

Table 4 – Flaw Designations

Flaw Type/Location Designations

Flaw Designation	Flaw Description	Contained in Mockups
A	ID Axial Above the Weld	Yes
B	ID Axial Over the Weld	Yes
C	ID Axial Below the Weld	Yes
D	OD Axial Above the Weld	Yes
E	OD Axial Over the Weld	Yes
F	OD Axial Below the Weld	Yes
G	ID Circumferential Above the Weld	N/A (Note 1)
H	ID Circumferential Over the Weld	N/A (Note 1)
I	ID Circumferential Below the Weld	Yes
J	OD Circumferential Above the Weld	Yes
K	OD Circumferential Over the Weld	Yes
L	OD Circumferential Below the Weld	Yes
M	Axial/Radial @ Wetted Surface of the J-Groove Weld	Yes
N	Circumferential/Axial (reference to tube) on Wetted Surface near interface of tube to J-Groove Weld	Yes
O	Circumferential/Axial (referenced to tube) on Wetted Surface near Head (clad) to J-Groove Weld	Yes
Notes:	(1) Presence of back-wall does not influence detection and analysis of ID surface initiated flaws to the degree that it affects OD surface initiated flaws	


J
G
K
H
L
M
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D
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O
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Enclosure 4

2CAN080302

WesDyne Report WDI-TJ-006-03, Rev 01,
UT of Interference Fit Samples for Leak Path
(Non-proprietary)

WESDYNE INTERNATIONAL

Title:				
Ultrasonic Testing of Interference Fit Samples for Leak Path Detection				
Key Words: Vessel head penetrations, UT , Wastage	**Date:** 07/22/03	**Document Number:** WDI-TJ-006-03 NP	**Revision:** 2	**Plant:**

WesDyne International LLC Non-Proprietary Class 3

Author(s): R. Devlin	Cognizant Manager: Vin LaDuca						
31 July 03 FOR R. DEVLIN	7/31/03 for V.L.						
Customer	Required		Yes		No		Date

SUMMARY

An evaluation was performed to determine the detection capabilities of the existing CRDM penetration ID UT techniques to detect simulated wastage of the carbon steel behind a RPVH penetration.

The inspection technique involves monitoring the backwall signal of the CRDM sleeve. In the shrink fit area some of the energy that is normally reflected back to the transducer would be transferred into the RPV head thus reducing the backwall signal amplitude in the shrink fit area. In an area with erosion of the head material behind the sleeve (leak path) the signal response from the sleeve backwall signal will increase.

Two techniques described below were capable of clearly detecting the [a,c,e] [a,c,e] in the carbon steel sleeve with a shrink fit.

The best results were achieved using a [a,c,e] [a,c,e] The backwall signal amplitude difference between the shrink fit and the grooves was up to [a,c,e] giving the ability to detect areas of erosion on the head in the range of [a,c,e] wide and above.

The [a,c,e] probe monitoring the backwall signal from the longitudinal wave also produced good results. Monitoring the first backwall signal amplitude difference between the shrink fit area and the grooves produced a difference in signal amplitude between [a,c,e] [a,c,e] giving the ability to detect areas of erosion on the head in the range of [a,c,e] wide and above. The technique requires that the backwall signal be reduced to a range that it can be monitored. Two methods may be used to reduce the TOFD backwall signal. [a,c,e]

[a,c,e]

1. Introduction

The purpose of this test sequence was to determine the feasibility of using one of the existing inspection techniques now in service for inspecting CRDM RPV head penetrations as a method for detecting leak paths in the RPV head material.
The CRDM penetration above the J weld has a manufactured shrink fit as it passes through the head. It is expected that in the area of the shrink fit some of the ultrasonic energy will pass into the head producing a reduced signal response. An area of erosion on the ID of the head penetration that is normally in contact with the OD of the CRDM would produce a gap in the shrink fit section and might be detectable with ultrasonic inspection techniques.

2. Equipment:

All of the testing was performed with a standard IntraSpect 4 channel data acquisition system configured as it would be used in the field to perform head penetration inspections. This consisted of a Data Acquisition Subsystem (DAS) [a,c,e]
[a,c,e]
A 7010 Open housing scanner was used to manipulate the probes in the test samples.
A 50' umbilical cable with triax data lines were used to connect the scanner to the DAS.
The probe modules used consisted of a standard open housing [a,c,e] probe module set with [a,c,e] a combo [a,c,e] blade probe with [a,c,e]
[a,c,e]

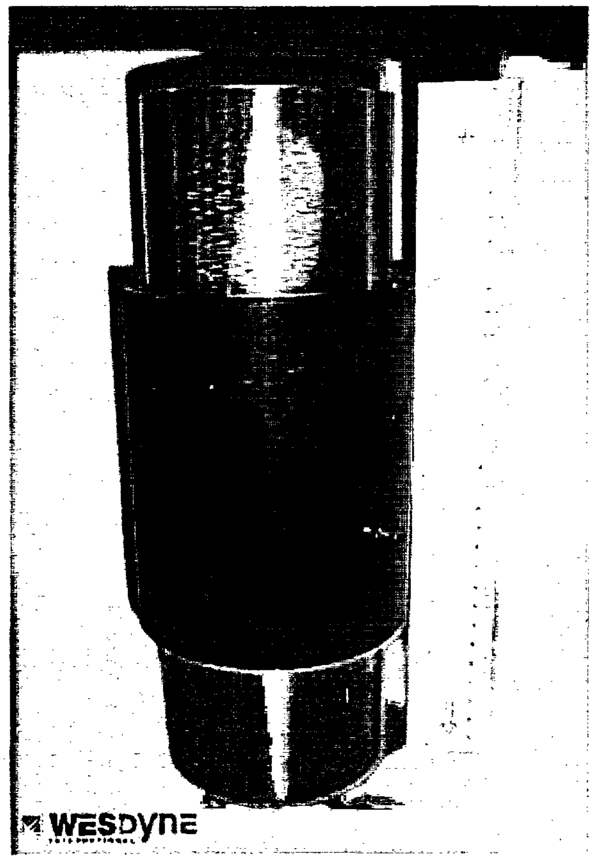
Test Sample's: Two test samples were manufactured for use in this testing.

Sample 1: Interference Fit

The first sample was manufactured from a 12" section of CRDM penetration material with a 2.71" ID diameter and a .720" wall. A 6" long section of carbon steel sleeve was shrunk on to the penetration with a 2 mil. diametrical shrink fit. The interference fit (shrink fit) area was 5" long. The remaining 1" was machined to be 3 mil diametrically oversized simulating the counter bore in the RPV head. The sleeve was heated in an oven and then assembled over the center of the CRDM penetration. The shrunk on sleeve had four machined artifacts consisting of [a,c,e]

[a,c,e]

Sample 2: Slip Fit
The second sample was manufactured from a 12" section of CRDM penetration material with a 2.71" ID and a .720" wall. A 6" long section of carbon steel sleeve was machined to provide a slip fit from 0.0 to +.5 mils on the CRDM penetration. The sleeve was slipped over the center of the CRDM penetration. The sleeve had the same four machined artifacts describes in sample # 1.



Test Sample # 1

3. **Data:**

Each test sample was scanned using the open housing probe set and the blade probe. The subsequent images present the results of the data that was acquired.

a,c,e

This probe generated the best results producing discernable signal responses from [a,c,e] the wide groove, approx. [a,c,e] differentiation between the shrink fit area and the defects. This probe setup produced the highest difference between the signal from the shrink fit area and the non shrink areas on the sample. The striping noted in the shrink fit area determined to be caused by the machining process used on the sleeve. The machining of the sleeve was done on a lathe which is less rigid than the actual manufacturing process. The horizontal striping does not occur in the actual RPV heads.

a,c,e

[ ]

This probe generated good results producing discernable signal responses from the [a,c,e] wide groove, approx.[a,c,e]
amplitude differentiation between the shrink fit area and the defects.

a,c,e
[

]

This probe generated good results producing discernable signal responses from the [ ]a,c,e wide groove, approx. [ ]a,c,e
amplitude differentiation between the shrink fit area and the defects.

a,c,e

[ ]

The results from this probe was fair, producing discernable signal responses from the [ ][a,c,e] wide groove and the [ ][a,c,e] amplitude differentiation between the shrink fit area and the defects.

a,c,e

This scan demonstrates the effect of water in the grooves and side drilled holes. Water in the grooves did not show any change in the signal responses received from the dry sample test.
Ultrasonic couplant had to be used in the holes and did show a reduction in the signal amplitude when compared to the dry sample test.

a,c,e

[ ]

a,c,e

This test was performed by[ ]so that a multiple backwall signal could be monitored. The inspection sensitivity was left at normal levels.

This probe generated poor results producing no discernable signal responses from the holes. The [a,c,e] wide groove can be detected but the surrounding noise level would make it hard to call unless its location was already known .

a,c,e

This test was performed by dropping the [a,c,e] down to a level that the backwall signal could be monitored (L-Wave and Shear Wave). The sensitivity was reduced by [a,c,e]feature of the IntraSpect system.

This probe generated good results producing discernable signal responses from the [a,c,e] wide groove, [a,c,e] differentiation between the shrink fit area and the defects. This test produced the best results on the [a,c,e] diameter hole.

a,c,e

[ ]

This test was performed by dropping the [a,c,e] backwall sensitivity down to a level that the backwall signal could be monitored (L-Wave and Shear Wave). The sensitivity was reduced by [ ] feature of the IntraSpect system.

This Test generated poor results producing no discernable signal responses from the grooves or holes. This result was caused by a large area of the signal being in saturation. The scan was performed a number of times adjusting the DAC level but to date a good scan of the second backwall has not been achieved. The time required to setup and maintain the signals in the desired range using this technique could be prohibitive.

a,c,e

This probe provided fair results producing discernable signal responses from the [ ]a,c,e wide groove, and the [ ]a,c,e amplitude differentiation between the shrink fit area and the defects detected.

a,c,e

This test generated poor results producing no discernable signal responses from the carbon steel sleeve or the defects in the sleeve. The results of this test indicates that an erosion area would not be detected in a non shrink fit (slip fit) section of a penetration using the ultrasonic techniques tested.

a,c,e

This test generated poor results producing no discernable signal responses from the carbon steel sleeve or the defects in the sleeve. The results of this test indicates that an erosion area would not be detected in a non shrink fit (slip fit) section of a penetration using the ultrasonic techniques tested.

4. Conclusions

It has been demonstrated, based on the data acquired to date, that an erosion area in the RPV head can be detected using ultrasonic inspection techniques.

The best results were achieved using a [ ]a,c,e probe monitoring the backwall signal from the CRDM penetration. The backwall signal amplitude difference between the shrink fit and the grooves was up to [ ]a,c,e giving the ability to detect areas of erosion on the head in the range of [ ]a,c,e and above.

The results acquired on the [ ]a,c,e probe monitoring the backwall signal from the longitudinal wave also produced good results. Monitoring [ ]a,c,e produced a difference in signal amplitude between [ ]a,c,e giving the ability to detect areas of erosion on the head in the range of [ ]a,c,e wide and above. The technique requires that the backwall signal be reduced to a range that can be monitored. The inspection sensitivity required for defect detection and sizing using the TOFD probe normally produces a saturated backwall signal. [ ]a,c,e

The results acquired on the [ ]a,c,e signal from the CRDM penetration could be used but again the results are not as good as the [ ]a,c,e The signal amplitude difference between the shrink fit and the grooves was in the [ ]a,c,e range.

An added inspection of the shrink fit area will require retooling of the 7010 OHS in some cases to allow for a longer stroke to accommodate the extended inspection area.

Water in the grooves did not affect the signal response from the groove. Ultrasonic couplant placed in the holes did reduce the signal amplitude [ ]a,c,e below the backwall amplitude in the shrink fit area.

None of the techniques described in this test sequence were capable of detecting any of the artifacts in the slip fit sample.