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Attention: Terrence Chan & Bryan Benney

Our ref: LTR-NRC-03-61

October 1, 2003

Subject: Inspection of Embedded Flaw Repair of a J-groove Weld

The purpose of this letter is to provide NDE information related to the embedded flaw repair of head penetration J-groove welds.

The NRC staff and Westinghouse met on August 7, 2003 to discuss the embedded flaw repair process, as approved by the NRC on July 3, 2003. The meeting summary issued on Sept. 17, 2003 mentioned the discussion on inspection capabilities, and noted that a demonstration of ultrasonic inspection limitations could be documented.

The attached report, WDI-TJ-013-03, Rev. 1, "NDE Process for CRDM Embedded Flaw Repairs" documents the impracticality of ultrasonic inspection of both the J-groove weld surface and a repair weld of that surface from inside the head. As discussed between Westinghouse and the NRC, alternate inspection techniques will be implemented to provide a practical approach for compliance with the SER inspection requirements. Therefore, this transmittal provides the demonstration discussed in the NRC meeting summary.

Very truly yours,

J. S. Galembush, Acting Manager
Regulatory Compliance and Plant Licensing

Attachment

T010

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WesDyne International **WesDyne International Non-Proprietary**	**DOCUMENT NUMBER & REV:** WDI-TJ-013-03 Rev. 1
COVER SHEET FOR: ☐ DESIGN SPECIFICATION ☐ FUNCTIONAL SPECIFICATION ☐ QUALIFICATION PROCEDURE ☐ FUNCTIONAL TEST PROCEDURE ☐ USERS MANUAL ☐ TRAINING PLAN ☒ TECHNICAL JUSTIFICATION ☐ CALIBRATION PROCEDURE ☐ OTHER	**TITLE:** NDE Process for CRDM Embedded Flaw Repairs **PLANT SITE/PLANT ALPHA:** Generic **KEY WORDS:** RVHP Inspection

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

Originator	**Signature**	**Date**
J. P. Lareau	*Original signed by R. P. Vestovich for*	*10/1/03*
Cognizant Manager	**Signature**	**Date***
D.C. Adamonis	*Original signed by D.C. Adamonis*	*10/1/03*

*Effective/Revised Date

WDF-19.10-2, Rev. 0

WESDYNE INTERNATIONAL

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NDE Process for CRDM Embedded Flaw Repairs

Summary of Changes

Rev. 0	Initial Issue – Sept. 26, 2003
Rev. 1	Changed document from Proprietary to Non-Proprietary

NDE Process for CRDM Embedded Flaw Repairs

1.0 Introduction

The repair method being used for CRDM nozzles with flaws detected on a penetration nozzle outside diameter surface, on the J groove weld inside diameter surface, or on a penetration nozzle inside surface uses a process referred to as the 'Embedded Flaw Repair'. The technical basis for this repair has been documented in WCAP-15987 [Ref. 5.1] that was approved by an NRC SER dated July 3, 2003 [Ref. 5.2].

In this process, Alloy 690 weld metal is deposited over the flaw area thus encapsulating the flaw and isolating it from the PWSCC environment. After the repair, a series of nondestructive examination (NDE) inspections will be performed.

The NDE inspection methods defined for this weld repair process are identified within this document. An assessment/investigation for using an ultrasonic test approach on the weld overlay of J-groove welds was conducted and is also reported herein.

2.0 NDE of J-Groove Weld and Adjacent Penetration Outside Diameter Surface Overlay Repair

Figures 1 and 2 show the typical resultant surface condition obtained from the automated welding process of the embedded flaw repair. These photographs are from practice repair overlays that were performed on a spare reactor vessel head (Jamesport vessel) located in the Westinghouse Waltz Mill facility. They show the overlay repair as applied over the J-groove weld and over a part of the adjacent penetration nozzle OD surface.

The surface is very rough and it consists of a series of 'hills and valleys'. Machining to eliminate the surface roughness has been considered impractical given the dose rates under the head, the access restrictions, the time constraints, and the irregular geometry about the penetration nozzle. This roughness, however, does not impair the primary role of the weld repair, which is to isolate any cracks from the environment.

This surface roughness will impact the type of NDE methods that can be applied – particularly ultrasonics. To determine its impact on an ultrasonic examination (UT), an investigation was conducted on the practice weld overlays. A 2.25 MHz, dual element, 70° refracted longitudinal wave ultrasonic test probe (0.55" by 0.6" casing) was applied to the overlay areas.

It is noted that this same UT probe was applied on PDI dissimilar metal weld practice samples to specifically detect axial planar flaws (0.31" deep by 0.39" long) in very irregular surface areas caused by a pipe fit-up offset and a lack of surface conditioning; these flaws were in the weld (Alloy 182) and fell under the requirements for flaw detection in Appendix VIII, Supplement 10. The small footprint of the probe was intended to reduce the effects of inadequate coupling and reverberations/noise from the rough ID surface of the weld. While successful on the practice samples in an open test environment, this probe failed to detect similar type flaws in blind test samples for the same reasons as larger probes, i.e. inadequate coupling, noise from the rough ID surface of the weld, and irregular probe movement over the rough surface. A smaller footprint probe is considered impractical given an inspection coverage depth of the weld overlay plus 25% of the underlying material.

For the investigation on the weld overlays, the UT system was calibrated using a 1/32" diameter side-drilled hole at 0.4" below the surface in a smooth-surfaced IIW block. This reflector is at approximately 25% of the J-groove weld thickness; the calibrated A-scan display is shown in Figure 3 with the side-drilled response at 82% FSH. The signal-to-noise ratio is about 9:1. The probe was then manipulated manually on various J-groove weld surfaces in the Jamesport head using a scanning sensitivity +6dB above the calibration gain.

Figures 4 through 6 show representative A-scan presentations from various examinations of the J-groove weld area on non-repaired and repaired penetrations.

Figure 4 shows results from a non-repaired J-groove weld inspection which indicates the presence of a distinct 79% response that would be comparable to a 40% response at the calibration gain (note that the instrument gain is at +6 dB above the calibration gain). This signal could be associated with metallurgical reflector or a weld discontinuity. Such signals are to be expected in the coarse dendritic grain structure of the weld and from welds that were inspected in fabrication using ASME Code Section III criteria (PT at defined intervals). If the region were examined after the weld overlay repair and such a signal was observed it may have to be incorrectly interpreted as emanating from PWSCC or a flaw initiated as a result of the repair process. This mis-interpretation would result in unnecessary repairs (which could only be done manually) and an increased dose exposure to repair personnel.

Figures 5 and 6 depict representative results from scans (axial and circumferential, respectively) on overlay repairs covering the J-groove weld. In these examples, the noise associated with the rough surface ranges from 40% to 63% at the calibration gain level. Such responses could mask signals from planar flaws.

Thus the use of ultrasonic inspection techniques for the J-groove weld overlay repair process is considered not practical for the following reasons:

- The rough, irregular surface conditions will cause ultrasonic coupling difficulties limiting the sound energy being transmitted into the test material. This effect will be more pronounced than our demonstrations conducted in accordance with Appendix VIII, Supplement 10 given that the inspection is conducted in an air environment rather than water.
- The rough, irregular surface conditions will create significant noise signals that may mask relevant signals from planar flaws.
- Innocuous responses from metallurgical reflectors (associated with the coarse grained dendritic structure of the J-groove weld as exacerbated by the different dendritic structure of the weld overlay repair) and weld discontinuities remaining from the original head fabrication could be mis-interpreted as PWSCC or flaws emanating as a result of the weld repair process. Repair of the weld overlay as a result of this mis-interpretation would add significant and unnecessary man-rem exposure to the repair personnel.

Additional constraints placed on the use of ultrasonic inspection techniques for the J-groove weld overlay repairs include:

- Access restrictions for getting an UT probe onto the weld overlay surface from below the head.
- Added radiation exposure to personnel implementing the examination.
- Complex surface geometry for scanning the UT probe.
- Ultrasonic examinations from the penetration inner diameter surface have to date been unsuccessful in penetrating the J-groove weld material beyond 0.06". This is an indicator of the significant attenuation associated with the J-groove weld material.

Given these limitations to the use of ultrasonic inspection techniques on the weld overlay surface, the following nondestructive test methods are to be implemented for the embedded flaw repair on J-groove welds (Figure 7):

- Surface examination (PT) of the weld overlay surface consistent with ASME Code requirements.
- Ultrasonic examination (UT) from the penetration nozzle inside diameter surface using techniques demonstrated to the MRP. Such techniques would examine the volume of the penetration plus 0.06" inside the J-groove weld adjacent to the penetration for flaw growth and leak paths.

3.0 NDE of Penetration Outside Diameter Surface and Penetration Inside Diameter Surface Weld Repairs

For penetration outside diameter surface and inside diameter surface embedded flaw weld repairs, the actual weld thickness will be less than for the J-groove weld overlays (two layers vs. three) and the final inner diameter surface will be as-welded (penetration outside diameter surface repair) or machined smooth (penetration inside diameter surface repair).

In the case of the penetration inside diameter surface repair, the surfaces and access to the surfaces are conducive for a machining operation. The resultant smooth ID surface provides an adequate inspection surface for both ultrasonic and eddy current testing. The UT and ECT techniques are to be the same as the demonstrated techniques used for standard CRDM penetration examinations in accordance with NRC Order EA-03-009 [Ref. 5.3]. The detection of artificial OD-initiating planar flaws using this UT approach through an ID surface weld overlay has been demonstrated [Ref. 5.4]. Westinghouse is currently working with EPRI and ENTERGY to fabricate a blind mockup that will have two inlay repairs and a number of EDM notches using the cold isostatic pressure (CIP) method. These simulated flaws will be on the ID and OD surfaces representing both axial and circumferential orientations. The inspection results from this mockup will be reported separately when available.

In the case of the penetration outside diameter surface repair, the relatively smooth as-fabricated ID surface provides a sufficient surface for applying the demonstrated volumetric UT techniques satisfying EA-03-009 requirements. The use of the standard demonstrated UT inspection process from the penetration nozzle bore was confirmed as being capable of inspecting the volume underneath a repair. Ultrasonic data, taken at an operating plant, was reviewed where four OD overlay repairs were performed in May 2003. In these penetration nozzles, OD axial flaws were detected below the J groove weld. There were a total of five flaws with measurable depths. The UT depth measurements before and after the overlay were compared. The RMS value for the depth measurement repeatability uncertainty for these five flaws was 0.031", which is within the accuracy tolerance for the ultrasonic tip diffraction technique. A surface examination (PT) of the weld repair surface is also to be applied.

The inspection coverage for the penetration ID and OD surface embedded flaw weld repairs is shown in Figure 8.

4.0 Conclusions

The following conclusions can be offered:

- Ultrasonic testing of the J-groove embedded flaw repair volumes is not considered practical given the rough and irregular surface conditions, the ultrasonic energy attenuation associated with the welds (J-groove fabrication and weld overlay), the potential mis-interpretation of the inspection results, the personnel radiation exposure, the access to the surfaces and the complex geometry of the weld repair.
- Penetrant examination of the J-groove weld and penetration OD repair surfaces is to be performed.
- Ultrasonic examination of the penetration tube volume on a penetration having a J-groove weld repair is capable of detecting flaw growth and leak paths.
- Penetration ID surface-applied ultrasonic and eddy current examinations of penetration ID repair areas using previously demonstrated approaches to satisfy NRC Order EA-03-009 are considered adequate for detecting flaw growth.
- Penetration D surface-applied ultrasonic examinations of penetration OD repair areas using previously demonstrated approaches to satisfy NRC Order EA-03-009 are considered adequate for detecting flaw growth.

5.0 References

5.1 Westinghouse Electric Company Topical Report WCAP-15987-P, *Technical Basis for the Embedded Flaw Process for Repair of Recator Vessel Head Penetrations*, Revision 2.

5.2 NRC Letter, *Acceptance for Referencing – Topical Report WCAP-15987-P, Revision 2, "Technical Basis for the Embedded Flaw Process for Repair of Reactor Vessel Head Penetrations"*, TAC No. MB8997, Project 700 (including Safety Evaluation by the Office of Nuclear Reactor Regulation).

5.3 NRC Order EA-03-009, *Issuance of Order Establishing Interim Inspection Requirements for Reactor Pressure Vessel Heads at Pressurized Water Reactors*, February 11, 2003.

5.4 Westinghouse Presentation, *Embedded Flaw Repair SER Discussion and Comments*, Warren Bamford and Jack Lareau, August 7, 2003.

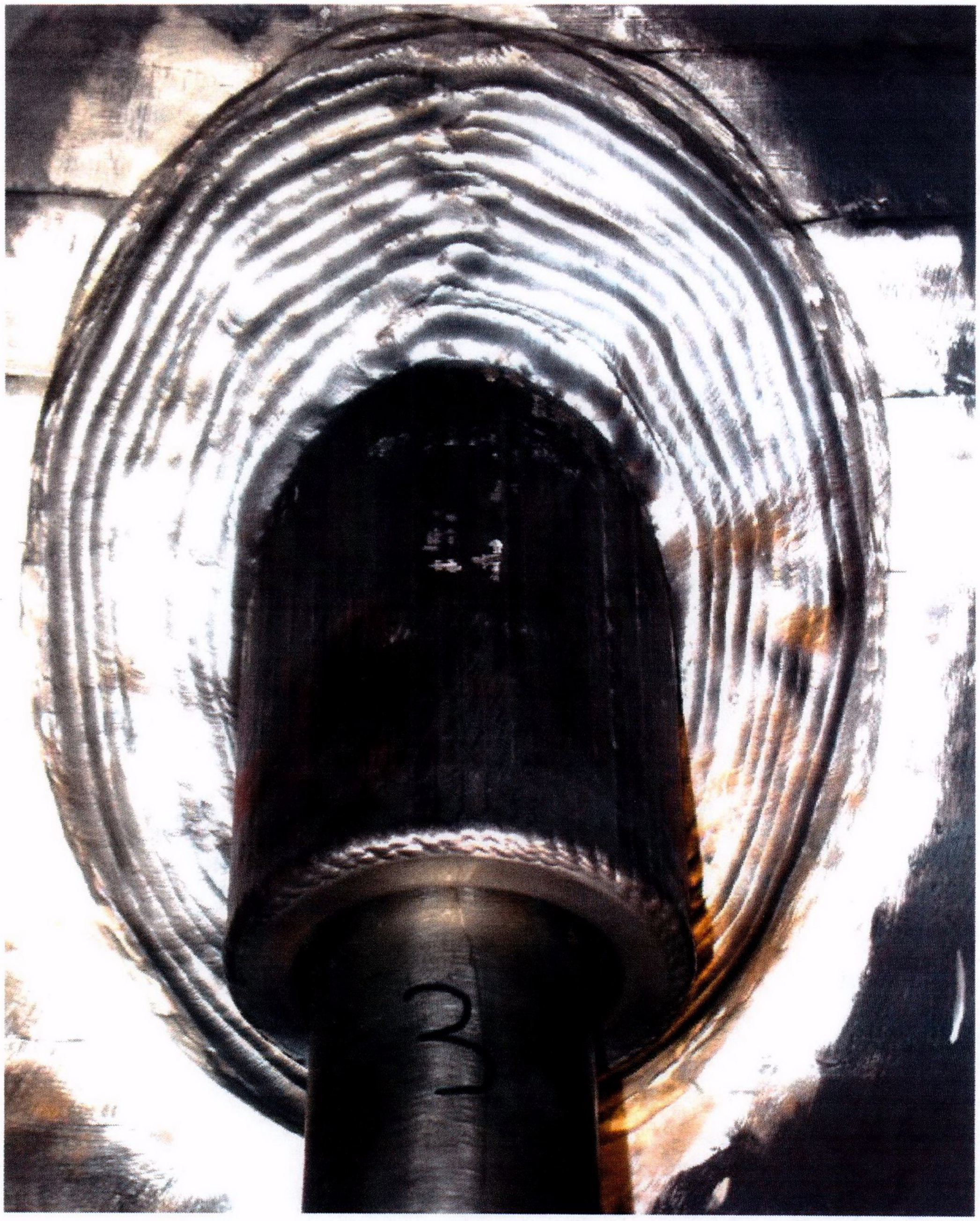

Figure 1: Weld Overlay Repair on J-Groove Weld and Nozzle OD in the Jamesport Head Depicting the Rough As Welded Surface Condition over the J-Groove Weld

C01

Figure 2: Weld Overlay Repair on another J -Groove Weld and Nozzle OD in the Jamesport Head Depicting the Rough As Welded Surface Condition over the J Groove Weld

C02

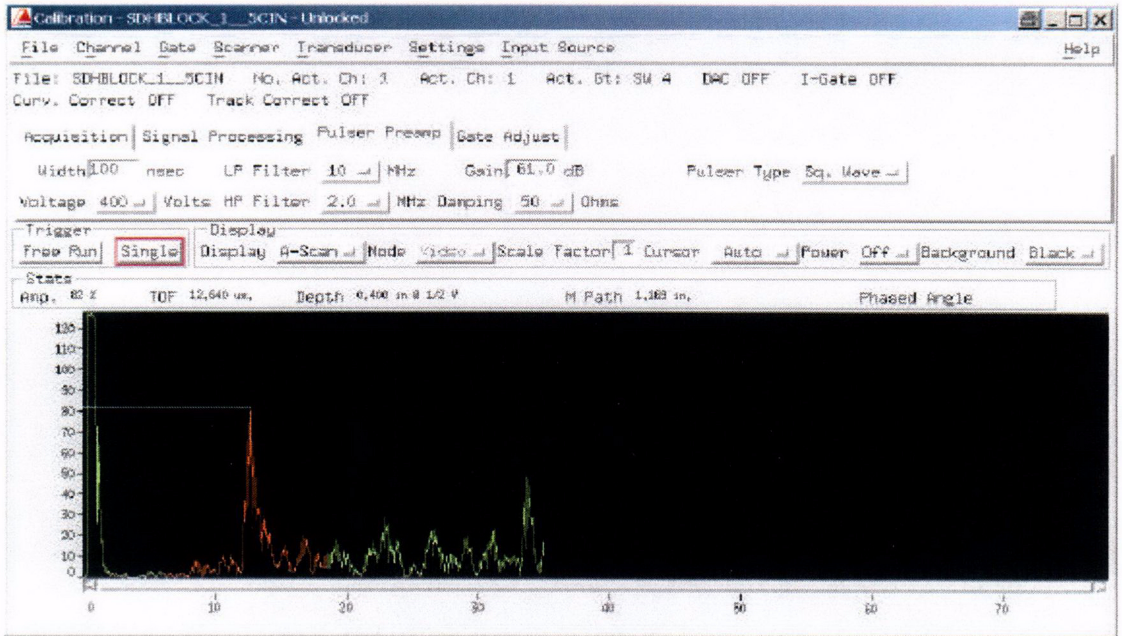

Figure 3: **Calibration Response for the 2.25 MHz, Dual Element 70-degree Refracted Longitudinal Wave Transducer (1/32" diameter side drilled hole set to 82% FSH response)**

C03

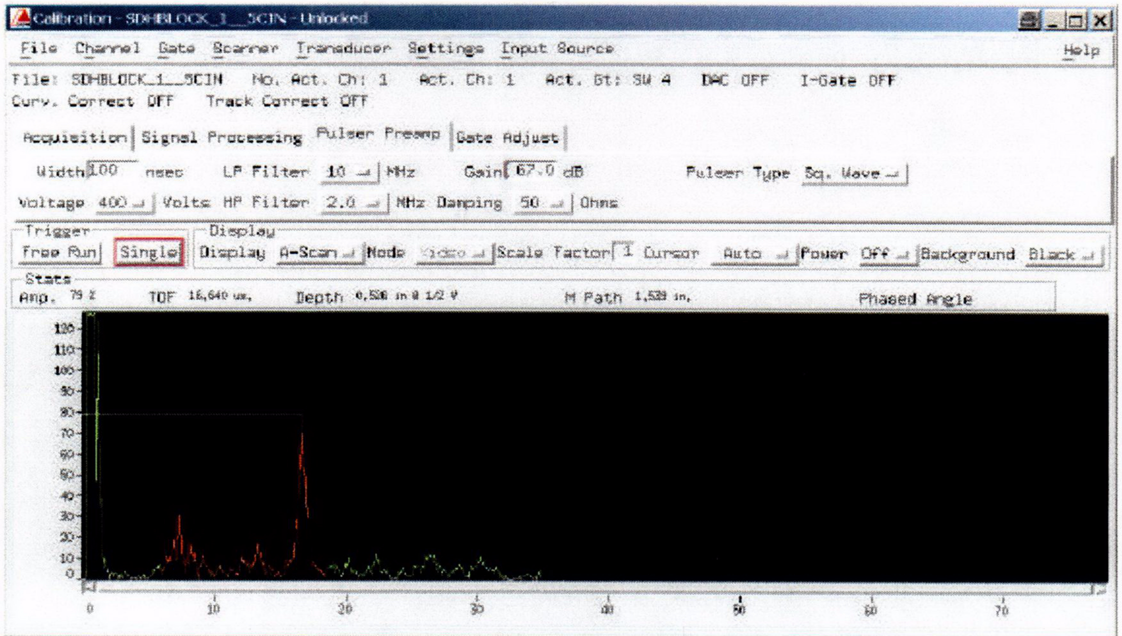

Figure 4: **Axial Scan Results from a Non-Repaired J-Groove Weld Depicting Distinct Reflector in the Weld (79% FSH response, approx. 40% FSH response at calibration gain)**

C04

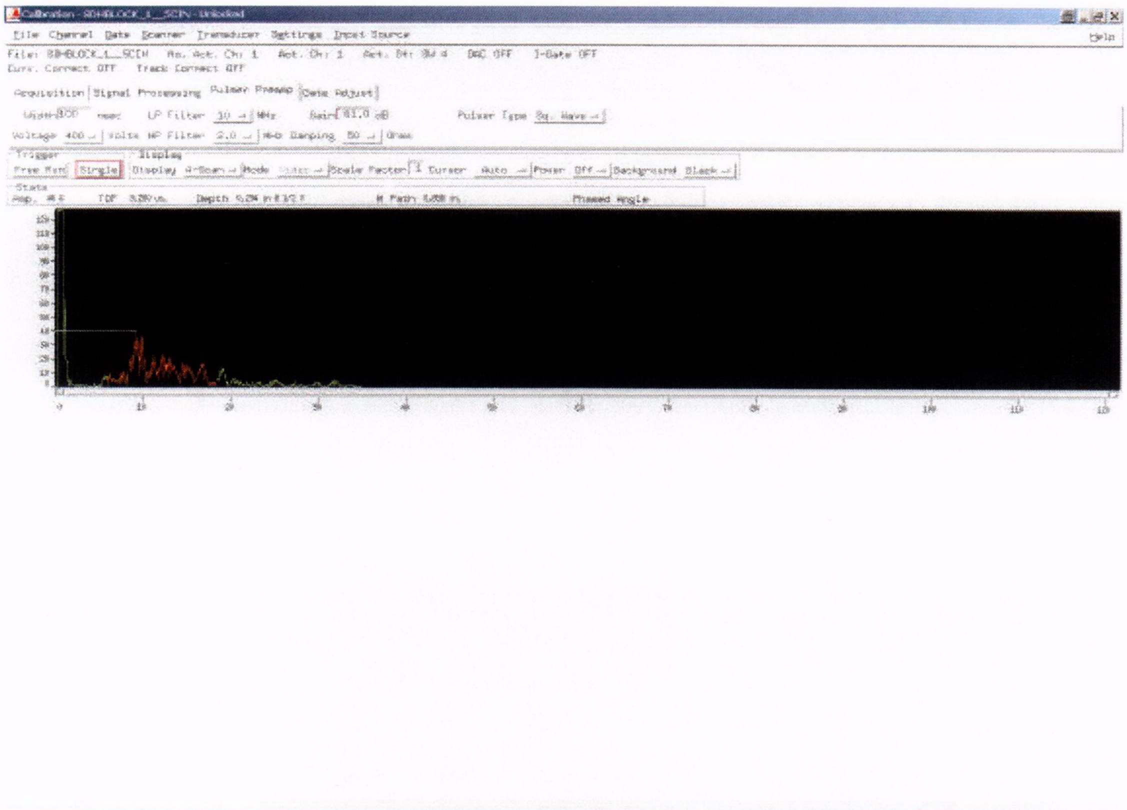

Figure 5: **Axial Scan on a Weld Overlay Surface Depicting the High Noise Background from the Irregular Surface (background noise from the irregular coupling surface is nominally 50% of the calibration response)**

C05

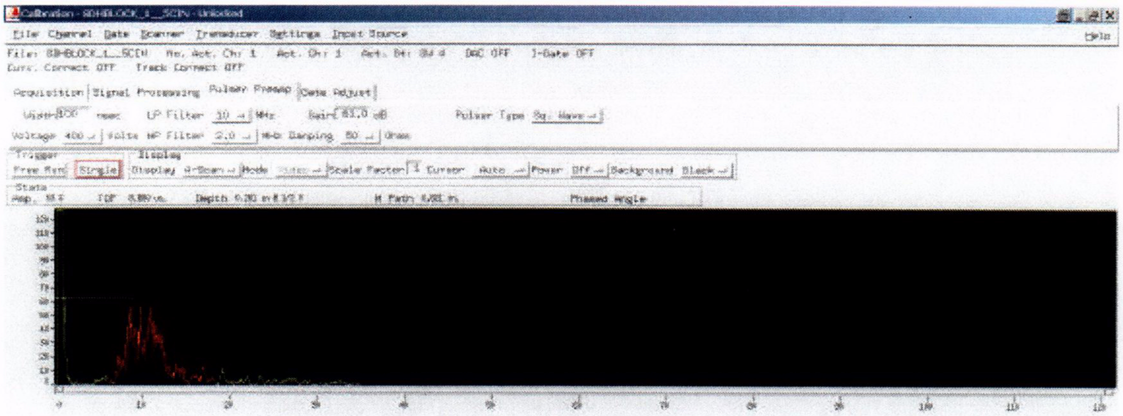

Figure 6: Circumferential Scan On a Weld Overlay Surface Depicting High Noise Level from the Irregular Surface (background noise from the irregular coupling surface exceeds 50% of calibration response)

C06

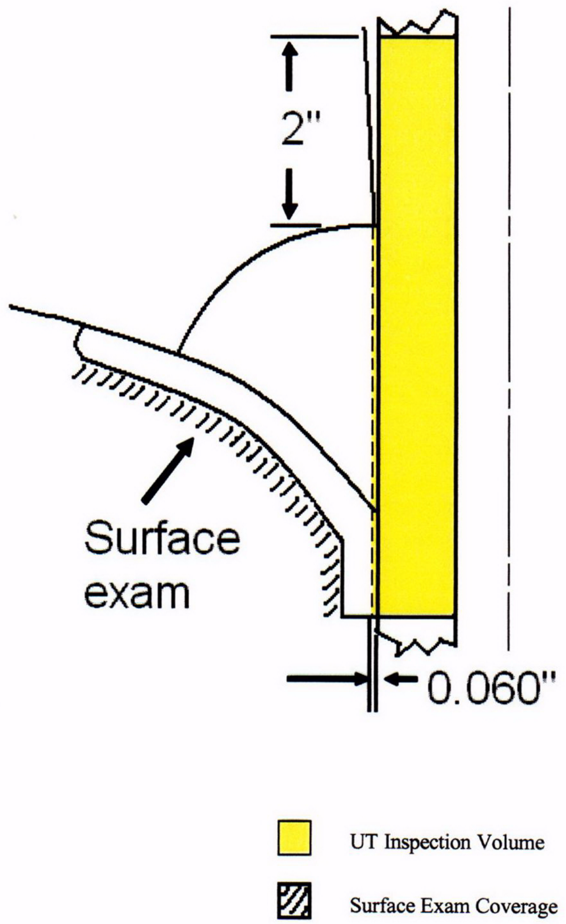

Figure 7: NDE Examinations and Coverage Associated with the J-Groove Weld and Adjacent Penetration Outside Diameter Surface Embedded Flaw Repair

C07

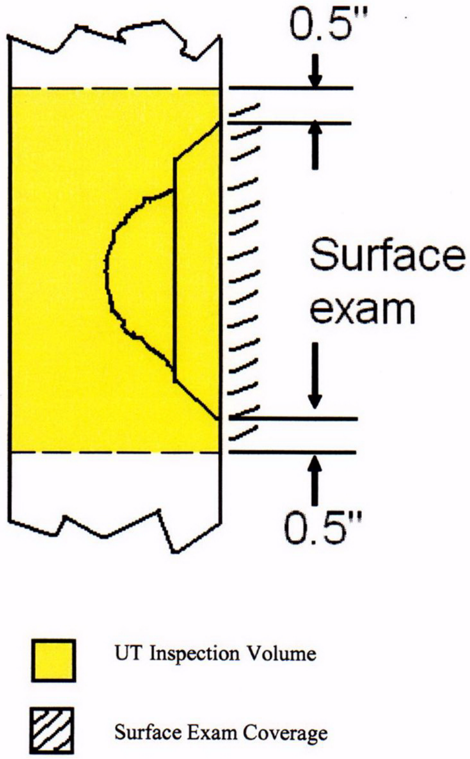

Figure 8: NDE Examinations and Coverage Associated with Penetration Inside Diameter Surface and Penetration Outside Diameter Surface Embedded Flaw Repair (surface examination is PT for OD repair and ET for ID repair)

C08