Performance Demonstration Initiative (PDI)

Guideline for Ultrasonic Examination of Corrosion Resistant Cladding (CRC)

PDI-GL-002

Randy Linden
CRC Users Group Chairman

Guy M. Bratton
PDI Steering Committee Chairman

Revision A, Date (Draft Rev. B)

ATTACHMENT 3

Performance Demonstration Initiative (PDI)
Guideline for Ultrasonic Examination of Corrosion Resistant Cladding (CRC)

1.0 SCOPE

1.1 The objective of this guideline is to establish a consistent process for selecting appropriate procedures, personnel, and equipment for ultrasonic examination of austenitic piping welds containing corrosion resistant cladding.

2.0 REFERENCES

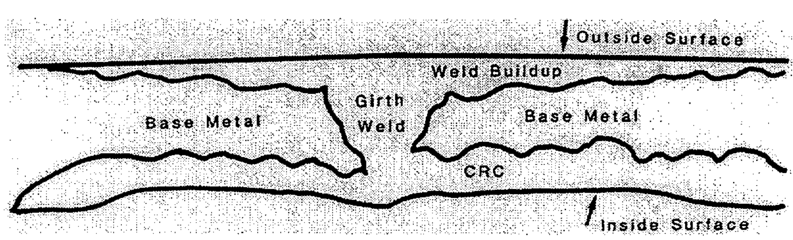
2.1 ASME Boiler & Pressure Vessel Code, Section XI, Appendix VIII, 1995 Edition including 1996 Addenda.

2.2 EPRI Report NP-4891-LD, "Examination of Corrosion Resistant Clad Weldments, Dated October, 1986

3.0 BACKGROUND

3.1 Corrosion Resistant Cladding (CRC) – The term "Cladding", typically refers to the layer(s) of austenitic weld material applied to the inside of ferritic materials to protect them from a corrosive environment, such as borated reactor water. CRC refers to layer(s) of austenitic weld metal applied to the inside of a small number of austenitic pipe welds in Boiling Water Reactors to mitigate IGSCC. It is typically applied as an inlay and is therefore part of the design pressure retaining boundary.

Because of radial shrink from the welding process, the outside of the pipe often received supplemental weld material. An example of this type of configuration is illustrated below.



3.2 This guideline was developed because examination requirements for piping welds containing CRC are not specifically addressed by ASME

Section XI. In particular, the current qualification requirements in Appendix VIII are considered inappropriate for several reasons:

3.2.1 The additional weld metal in the examination volume is beyond the scope of Supplement 2.

3.2.2 Supplement 10, which addresses dissimilar metal welds is also inappropriate since CRC is not a dissimilar metal weld and doesn't possess similar technical complications

3.2.3 While a moderate amount of weld metal on the outside surface can be treated as a wide weld crown, extensive weld metal provides additional technical complications similar to those inherent in examining weld overlays. Supplement 11, which governs requirements for weld overlays only addresses examination of the overlay and the outer 25% of the wall thickness. It doesn't address examination of the lower 1/3 of the weld volume and is also inappropriate.

3.3 Other considerations include the relatively small number of welds, the fact that CRC is an approved mitigation activity for IGSCC, and the uniqueness of the various configurations. These factors make an extensive qualification program inappropriate. A better course of action is to utilize the current qualification programs to the extent practical and augment the qualification with site specific requirements. This is similar to the current PDI program for bolting where the range can be extended with an onsite demonstration.

3.4 Once applied, CRC is considered part of the parent material. The examination volume remains as before. For example, the lower 1/3 t of the closing weld, plus 1/4 inch on either side of the closing weld as identified in Figure IWB-2500-8.

4.0 QUALIFICATION REQUIREMENTS

4.1 Personnel Requirements

4.1.1 Personnel shall have a current PDI Supplement 2 IGSCC Qualification for the task at hand (e.g., detection, length or depth sizing, single side access, etc.). This assures personnel are knowledgeable in IGSCC characteristics.

4.1.2 Personnel shall be knowledgeable in the use of refracted longitudinal waves as evidenced by current or previous qualification in IGSCC flaw sizing, weld overlay, etc.

4.2 Equipment/Procedures

4.2.1 The combination of personnel, procedure, and equipment shall demonstrate the capability to locate appropriate reflectors in a representative mock-up of the CRC weld.

5.0 RECORDS

5.1 It is expected that typical personnel and calibration records will provide adequate evidence of personnel and equipment qualification. If calibration is performed on other than the qualification reference reflectors in a representative mock up, the procedure qualification must be documented in accordance with site specific requirements.

Contact	Plant	DSM?	Procedure	Technique	Mockups	Reflector	# of CRC	Size and thickness
Chuck Wirtz	Perry	Yes	Separate	RL	Yes	10% notch	50	12" NPS x 0.575" t
								16" NPS x 0.951" t
								20" NPS x Sch. 100
								22" NPS x 0.948" t
								22" NPS x 1.078" t
								24" NPS x 1.346" t
Mike A. Cross	GrandGulf	Yes	Separate	RL	Yes	0%notch/cr	2	4"x.521"
						10%notch	20	12"x.625"
						10%notch	17	24"x1.310"
Don Welch	WNP-2	No	Same	SW & RL	No	N/A	2	24" sweep-o-let x 8"
							2	24" sweep-o-let x12"
							2	12" reducer to 12" pipe
							8	12" sweep-o-let to 12" pipe
							10	12" pipe to 12" SE
Marc A. Brooks	Fermi 2	No	Same	Supp. RL	Yes	racks/notche	8	12" sweep to pipe
							2	12" reducer to pipe
							10	12" pipe to SE
Tim Oldfield	NMP-1	No	Same	SW	Yes	None	10	10" pipe .594" t
							12	12" pipe .688" t
Wayne Denlinger	ope Cree	No	Separate	RL	Yes	Cracks	20	12" pipe .696" t
						Cracks	4	20" pipe 1.13" t
						Cracks	22	28" pipe 1.014" t
Randy T. Linden	SSES- 1	No	Same	RL	Yes	Cracks	20	12' Pipe .688" t
	1 & 2				No	N/A	4	28" pipe 1.076" t
Mirza M. Baig	Clinton-1	No	Separate	RL	Yes	10%Notch	4	16" Pipe 0.844 t
					Yes	10%Notch	24	20" Pipe 1.031t
					No	N/A	2	4" Pipe 0.37t
					No	N/A	1	18" Pipe 1.000t
						TOTAL	256	
DRAFT - Info Only								

From: O'Regan, Patrick
Sent: Thursday, March 01, 2001 8:07 AM
To: Gothard, Mike
Cc: 'Linden, Randy'
Subject: RE: Risk Vs CRC

Guys,

Provided the CRC piping falls into Generic Letter 88-01 category A , from a RI-ISI perspective, this piping is considered resistant to IGSCC. I haven't seen any cases yet where CRC was not considered category A. For Class 1 piping in BWRs, typically the only other type of degradation we've found (not widespread) is susceptibility to thermal fatigue.

From a risk perspective, provided there is not any other potential mechanism, then this piping typically falls into what we call risk category 4. That is, high consequence if it fails (e.g. loss of coolant accident) but very low failure potential. We tend to sample ten percent of these locations. Some of it has fallen into risk category six which get zero volumetric exam but continued leakage testing. See attached. Given the all (most) of this piping the NRC has been resistant in RI-ISI space to allow zero inspections.

Keep in mind that RI-ISI is a risk-informed application versus risk-based. It's a subtle but important difference. Risk-based would probably tell you to do nothing (if you're not susceptible to IGSCC, FAC, thermal fatigue or MIC). While risk-informed would tell you it's probably a good idea to do some reduced number of sampling.

I'm not exactly sure where you trying to go but I hope the above helps.

I'm on the road now but if you would like to talk in more detail maybe we can hook up on Monday.

Thanks, PJO'R

<<File: risk matrix.ppt>>

From: Gothard, Mike
Sent: Wednesday, February 28, 2001 9:15 AM
To: O'Regan, Patrick
Cc: 'Linden, Randy'
Subject: Risk Vs CRC

Patrick,

Corrosion Resistant Cladding (CRC) was applied to the inside surface of austenitic piping welds on BWR's to mitigate IGSCC by protecting the sensitized weld from the corrosive environment formed by the reactor coolant. Along with Randy Linden, of PP&L, I've been working with the PDI-CRC users Group (an informal organization of BWR utilities with CRC) and the NRC to establish a guidelines document for qualification of Ultrasonic examination personnel to examine these welds in accordance with ASME Section XI Code Rules.

A key item of discussion with the NRC is the level of risk associated with these welds and I was wondering if you had anything published or otherwise "official" that could be used to support an assessment of low risk. Everyone, including the NRC, feels that these are low risk welds and one utility has said that CRC welds "fall out" when doing a risk based analysis, but I am looking for something a little more generic. I can be reached at the EPRI NDE Center (704) 547-6131. Randy can be reached at PP&L (570) 542-3671. Thanks in advance for your help.

Michael E. Gothard
RPV, Project Manager
EPRI NDE Center
1300 W. T. Harris Blvd
Charlotte, NC 28262
(704) 547-6131, fax 6028

RISK EVALUATION

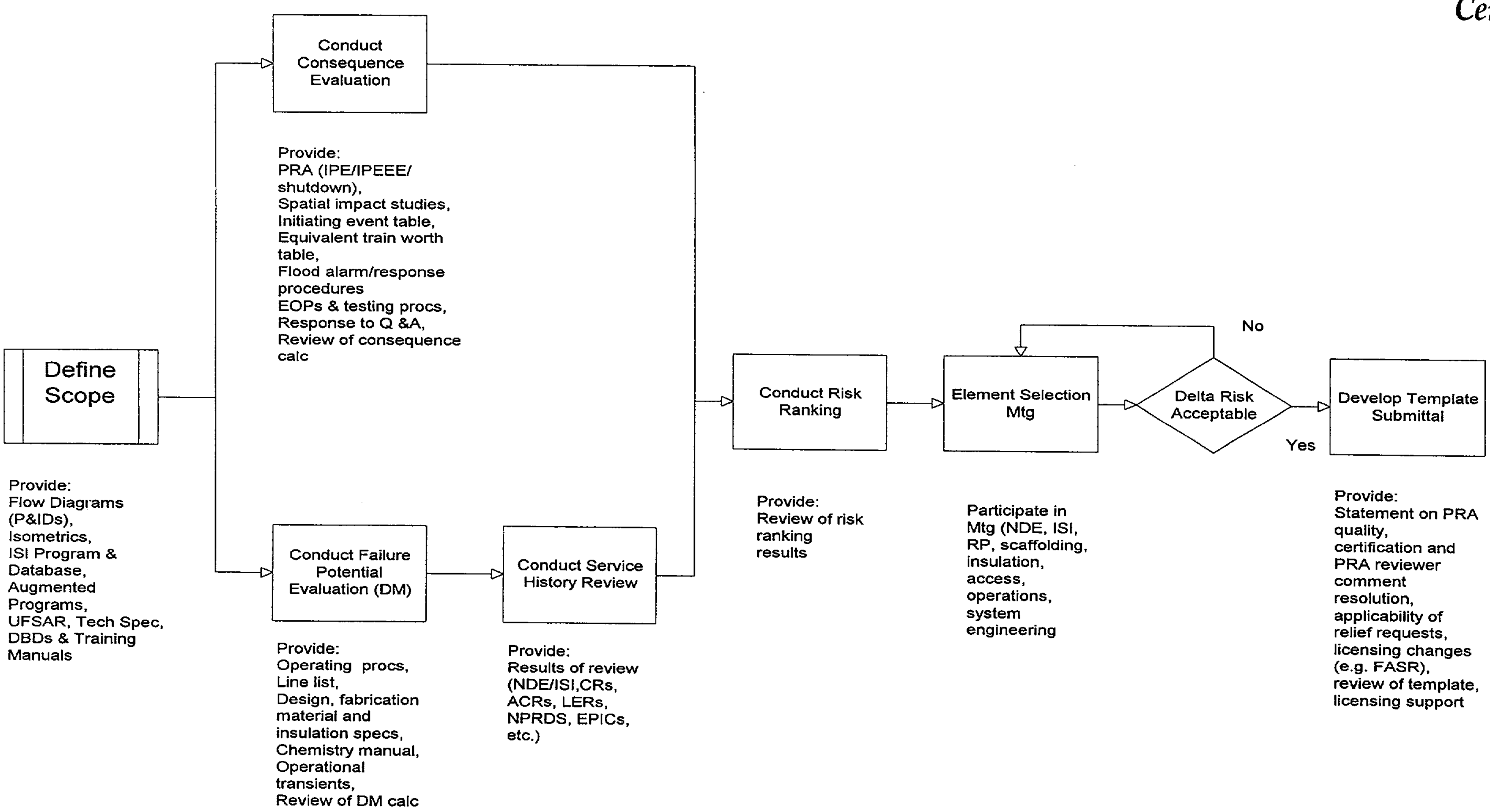
EPRI NDE Center

Consequence Evaluation

Failure Potential Assessment ***(Degradation Mechanism)***

DEGRADATION CATEGORY Pipe Rupture Potential	CONSEQUENCE CATEGORY CCDP and CLERP Potential: NONE	LOW	MEDIUM	HIGH
HIGH	LOW (Cat. 7)	MEDIUM (Cat. 5)	HIGH (Cat. 3)	HIGH (Cat. 1)
MEDIUM	LOW (Cat. 7)	LOW (Cat. 6)	MEDIUM (Cat. 5)	HIGH (Cat. 2)
LOW	LOW (Cat. 7)	LOW (Cat. 7)	LOW (Cat. 6)	MEDIUM (Cat. 4)

RI-ISI Process



Define Scope — Provide: Flow Diagrams (P&IDs), Isometrics, ISI Program & Database, Augmented Programs, UFSAR, Tech Spec, DBDs & Training Manuals

Conduct Consequence Evaluation — Provide: PRA (IPE/IPEEE/ shutdown), Spatial impact studies, Initiating event table, Equivalent train worth table, Flood alarm/response procedures EOPs & testing procs, Response to Q &A, Review of consequence calc

Conduct Failure Potential Evaluation (DM) — Provide: Operating procs, Line list, Design, fabrication material and insulation specs, Chemistry manual, Operational transients, Review of DM calc

Conduct Service History Review — Provide: Results of review (NDE/ISI,CRs, ACRs, LERs, NPRDS, EPICs, etc.)

Conduct Risk Ranking — Provide: Review of risk ranking results

Element Selection Mtg — Participate in Mtg (NDE, ISI, RP, scaffolding, insulation, access, operations, system engineering

Develop Template Submittal — Provide: Statement on PRA quality, certification and PRA reviewer comment resolution, applicability of relief requests, licensing changes (e.g. FASR), review of template, licensing support

Performance Demonstration Initiative (PDI)

Proposed Supplement 10 (Dissimilar Metal Weld) Configurations for **Outside** Surface Qualification

Presented By: Carl Latiolais

EPRI NDE Center

ATTACHMENT 4

Disclaimer

- The following configurations were selected by EPRI based research funded by PDI and the NDE Center Steering Committee. Final acceptance has not been obtained from the respective steering committees and modifications may be made to the proposal during the acceptance process

Sample Selection Basis

- Basis for sample selection will be based on the following;
  - Number of occurrences
  - Documented failures in field
  - Perceived degree of difficulty
  - Data evaluated on recently purchased samples

Sample Selection Basis

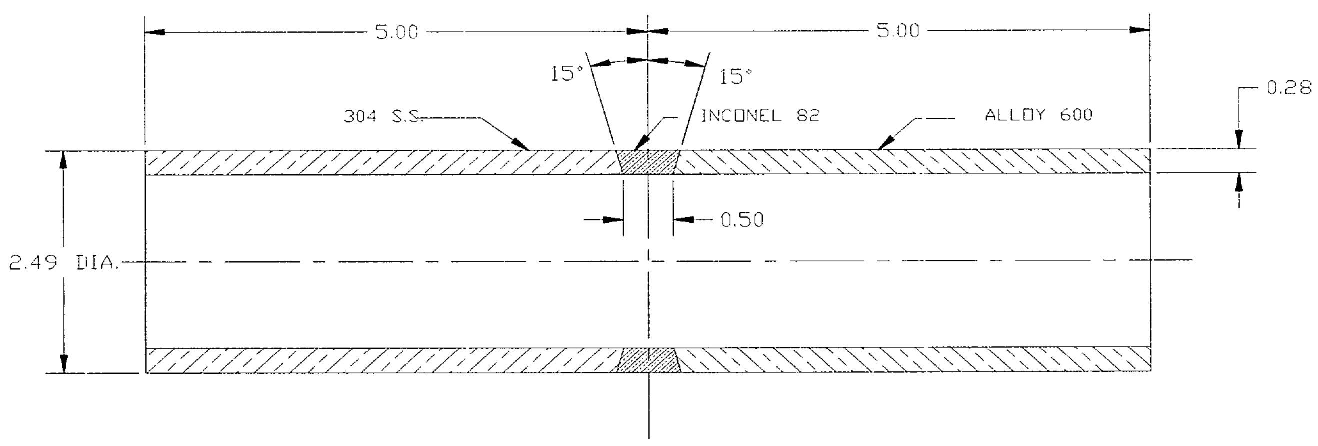
- Test Set will not cover every configuration that exists in field, but will be a cross cut of configurations
  - Site Specific Samples may be Required to Expand the Procedure and Candidate Qualifications. Details of this proposed approach will be covered in a separate presentation
- **All of the following dimensions are approximate values**

Small Category

- Small
  - Minimum Diameter - **2.49" OD, 1.93 ID**
  - Maximum Diameter - **5.36" OD, 3.36 ID**
  - Minimum Thickness - **0.28"**
  - Maximum Thickness - **1.0"**
- Systems
  - Pressurizer Spray Safety and Relief (PWR)
  - Jet Pump Instrumentation (BWR)
  - Stand by Liquid Control (BWR)

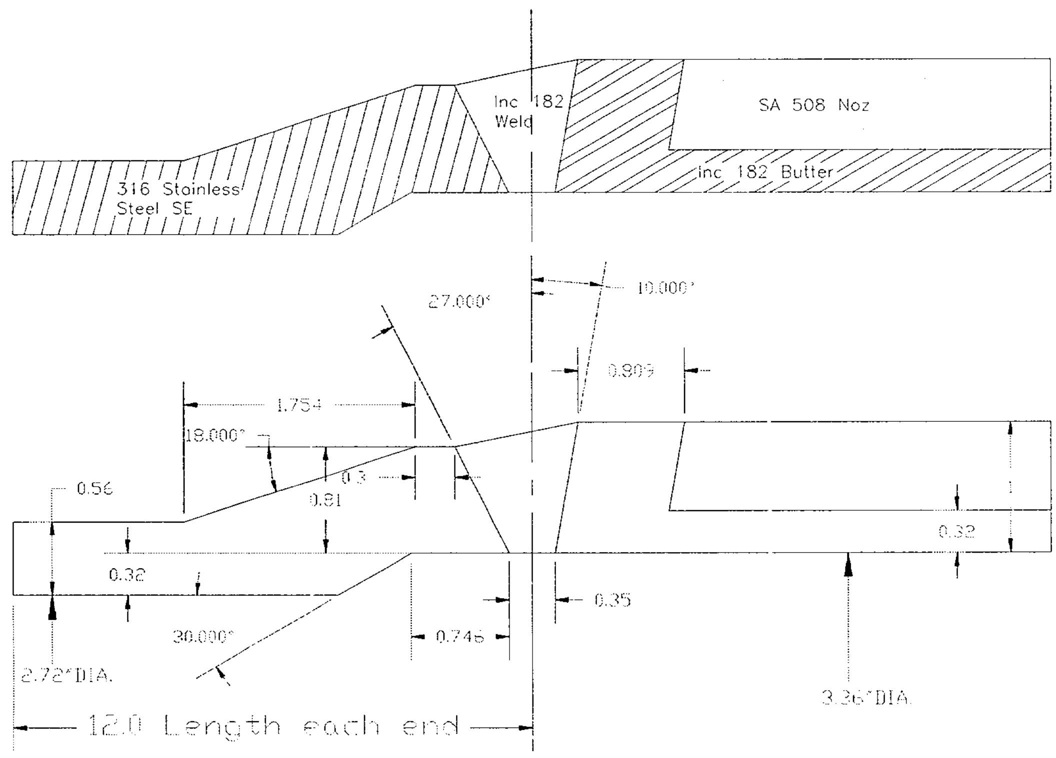
Small Category

STANDBY LIQUID CONTROL PIPE



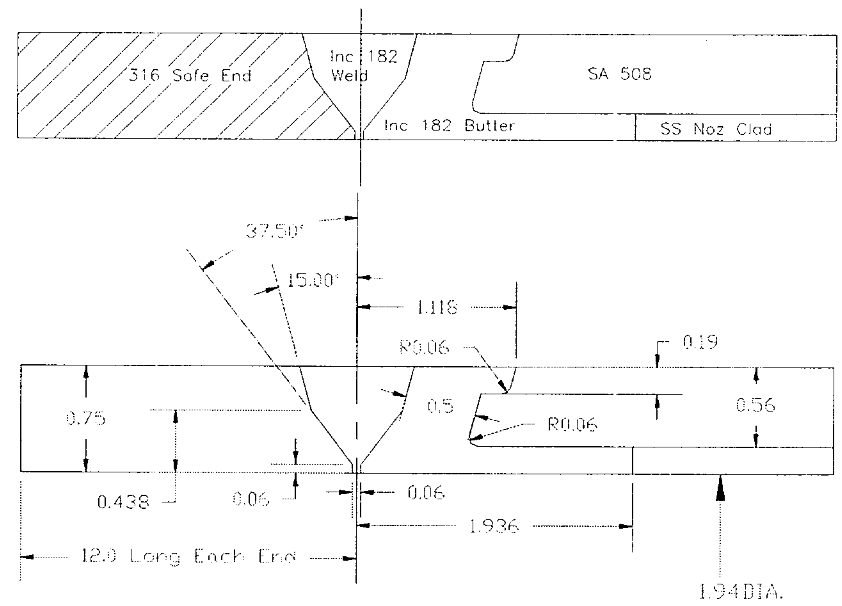
Small Category

4" PRESSURIZER SPRAY NOZZLE TO SAFE END



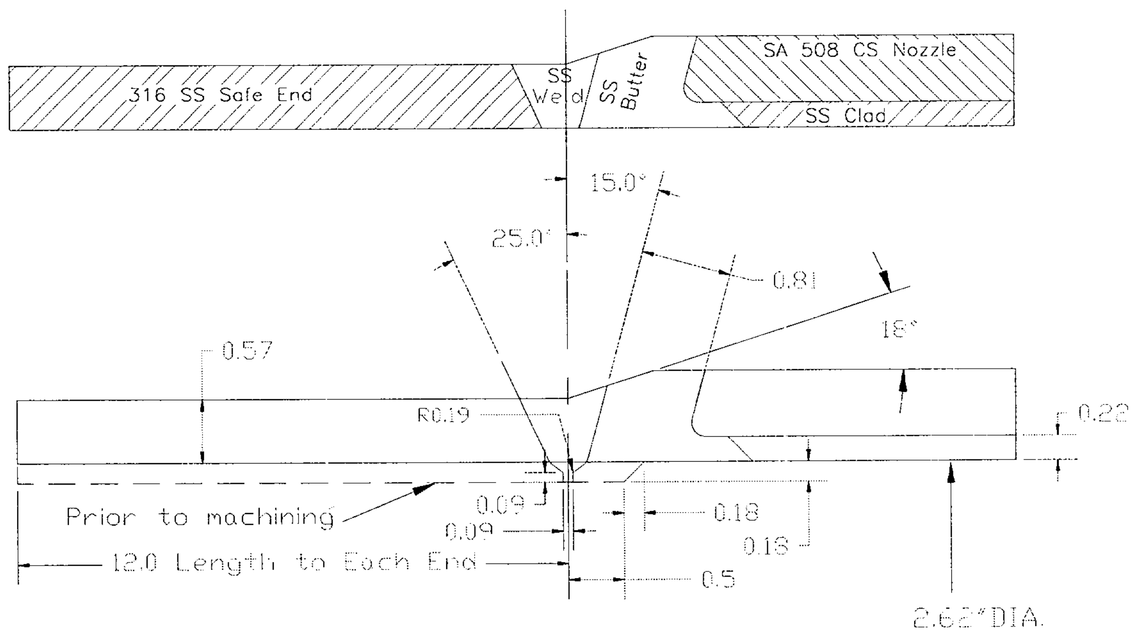
Small Category

4" CRD & JET PUMP RETURN NTSE



Small Category

4" PWR PRESS. SPRAY NOZZLE TO SAFE END
(TYPICAL FEATUTRES)

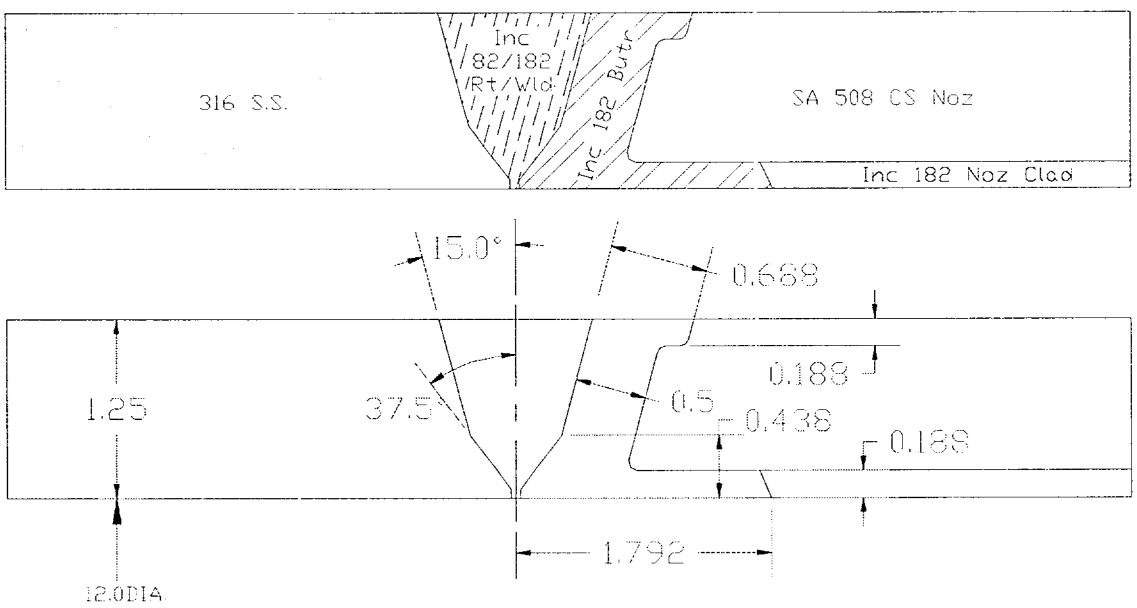


Medium Category

- Medium
  - Minimum Diameter - **12.75”OD, 10.13” ID**
  - Maximum Diameter - **14.5” OD, 12.0 ID**
  - Minimum Thickness - **1.125”**
  - Maximum Thickness - **1.31”**
- Systems
  - N2 Recirculation (BWR)
  - Feedwater, Core Spray (BWR)
  - Safety Injection, Pressurizer Surge (PWR)

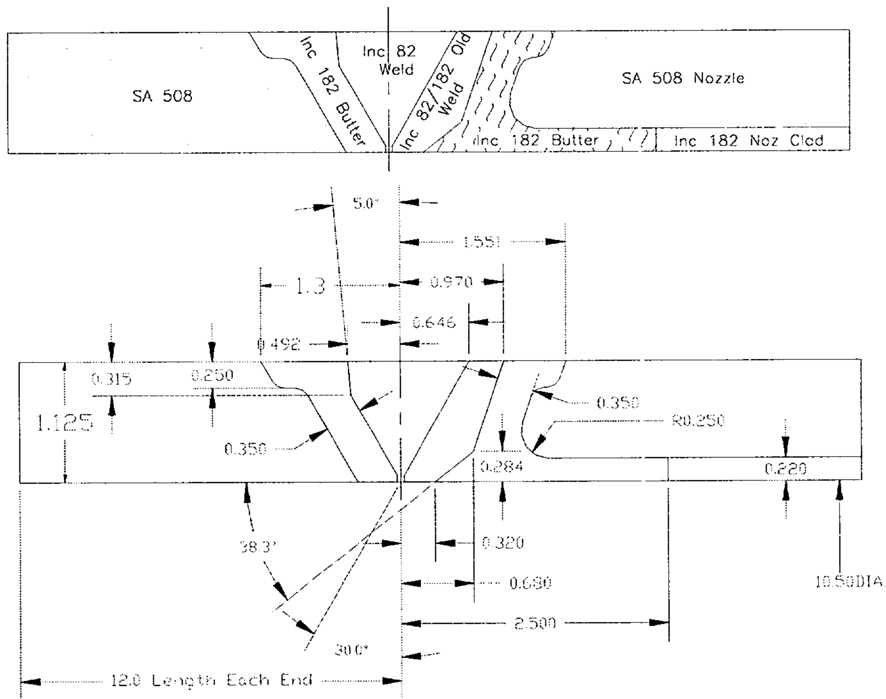
Medium Category

12"BWR STANDARD N2 NOZZLE TO SAFE END



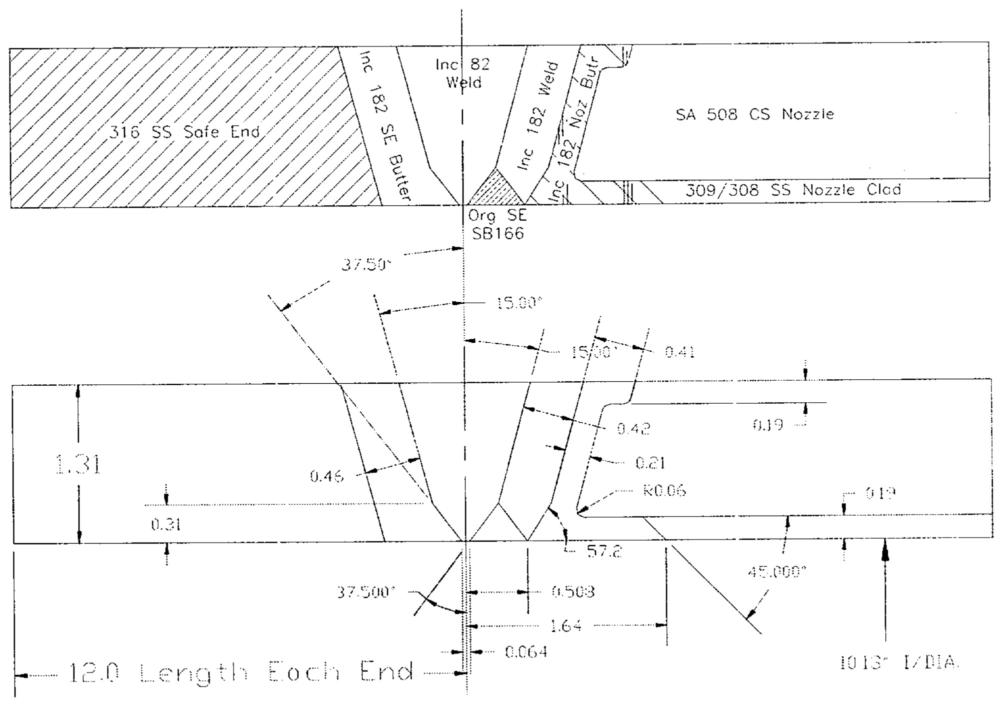
Medium Category

12" BWR N4,N5&N6 (FEEDWATER/CORE SPRAY) NOZZLE
TO REPLACEMENT SAFE-END



Medium Category

12" BWR N2 NOZZLE TO REPLACEMENT SAFE END

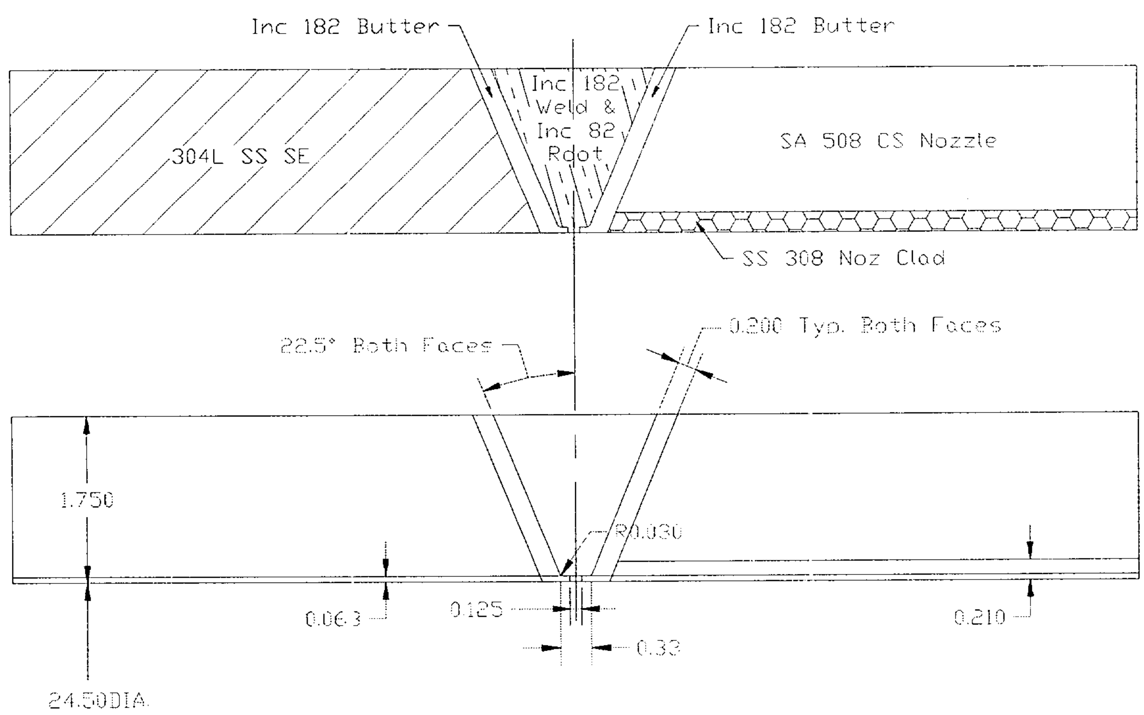


Large Category

- Large
  - Minimum Diameter - **18.35"OD, 13.57" ID**
  - Maximum Diameter - **41" OD, 31" ID**
  - Minimum Thickness - **1.75"**
  - Maximum Thickness - **5.2"**
- Systems
  - N1 Recirculation (BWR)
  - Pressurizer Surge (PWR)
  - Inlet and Outlet Recirculation Piping (PWR)

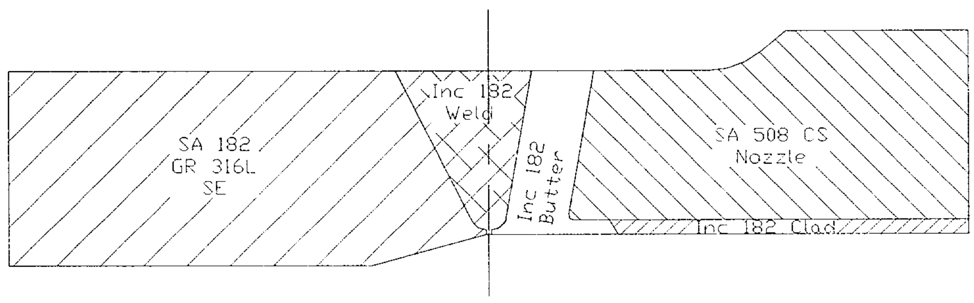
Large Category

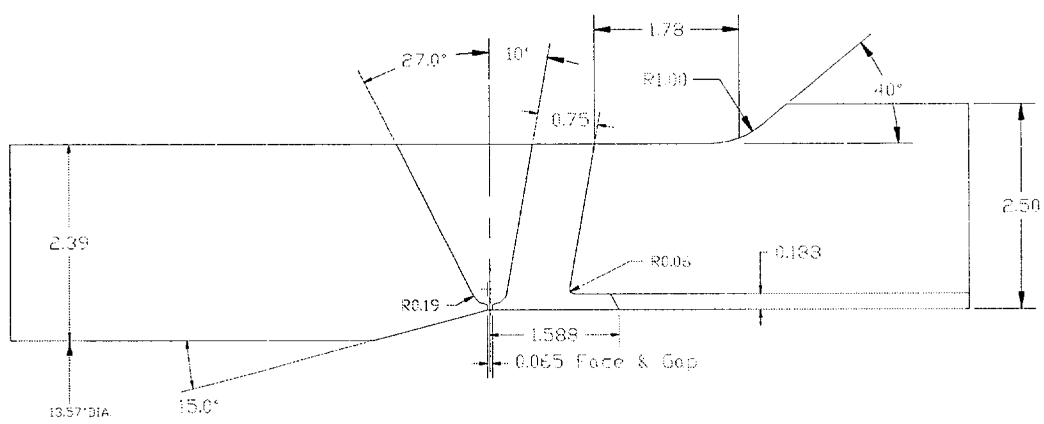
28" BWR N1 RECIRC. OUTLET NOZZLE TO SAFE END



Large Category

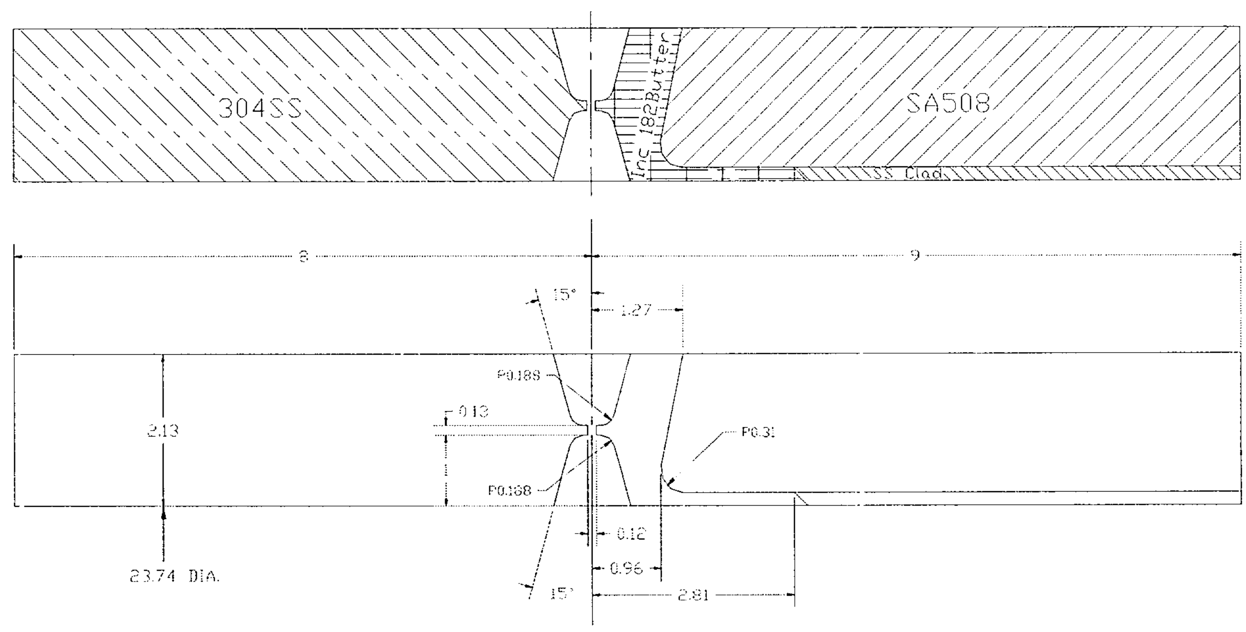
18" PWR PRESSURIZER SURGE NOZZLE TO SAFE END



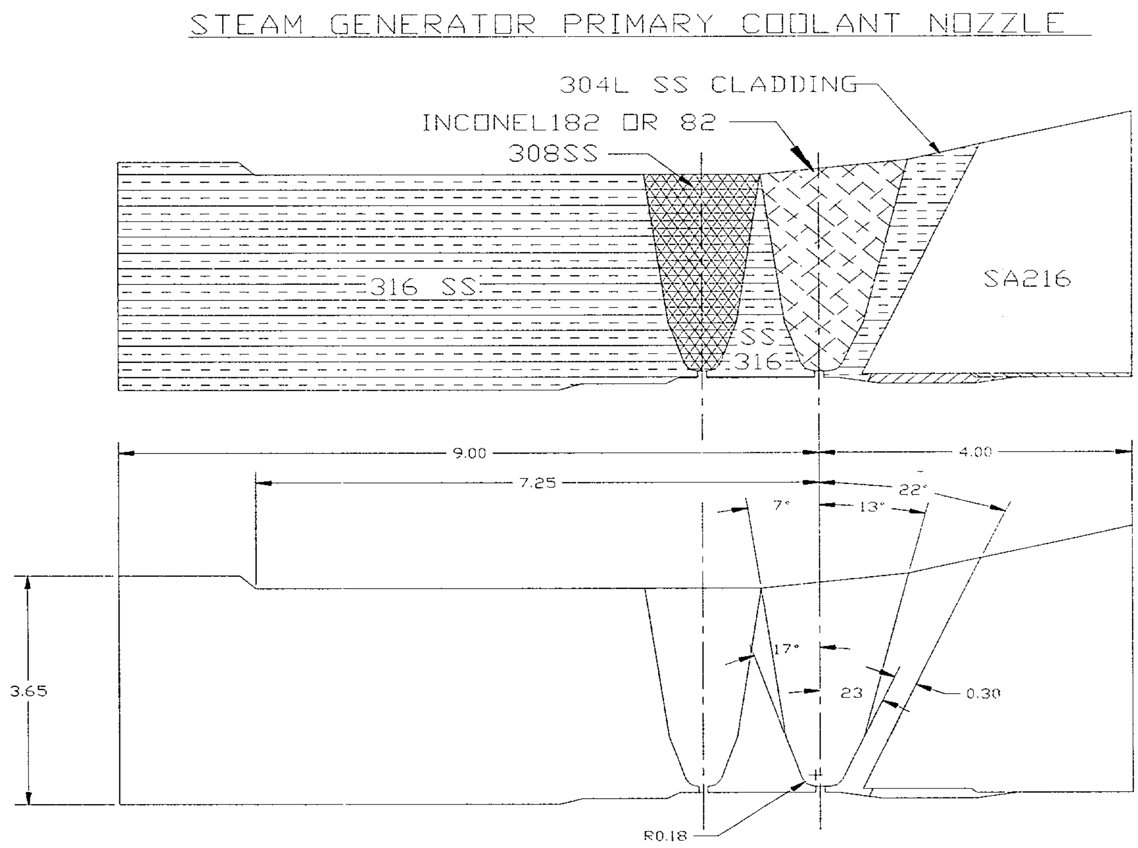


Large Category

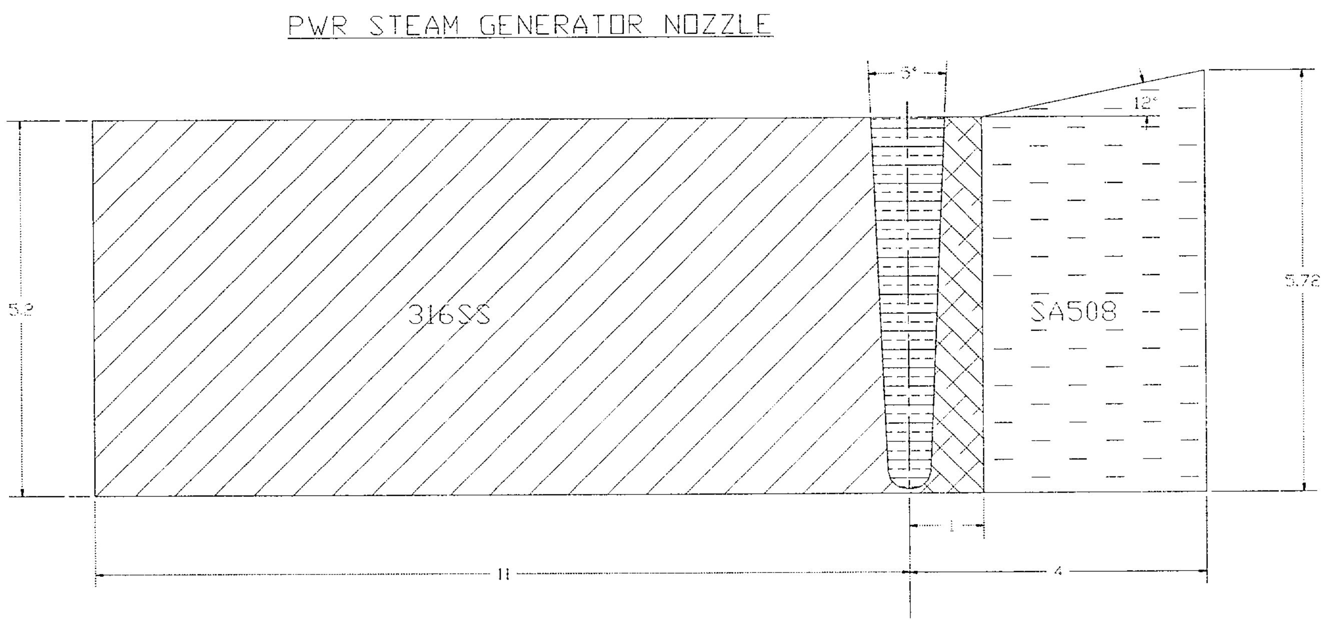
28"BWR N1 OUTLET NOZZLE TO SAFE END



Large Category



Large Category



Test Administration

- Plans are to limit access during testing to only from the safe-end side
  - Greater than 90% of field configurations are limited to access from safe-end side only
  - Successful candidates would be qualified for examination from both sides (Nozzle/safe-end)

Maximum Ranges Covered by Test Set

- When code tolerances are applied the PDI test sets will cover the following ranges
  - Minimum Diameter - **2.24" OD**
  - Maximum Diameter - **Unlimited**
  - Minimum Thickness - **0.21"**
  - Maximum Thickness - **6.5"**

Flaw Types

- Currently PDI plans to use the In-Situ process for the majority of the flaws
- Efforts underway to evaluate alternative flaw implantation processes utilizing HIP (Hot Isostatic Pressure) bonding
- Field data is being reviewed and the responses compared to fabricated defects and the techniques

Geometry

- Test sets will include some representative geometry, but will not cover all situations.
- Site specific mock-ups may have to be used to expand procedure qualifications to specific configurations

Welding Processes

- Samples will be fabricated in similar fashion as the field components (e.g. welding type, weld direction, repair processes)
- Samples will include weld repair areas with and without flaws associated with them

Summary

- PDI is working diligently to develop technically justifiable cost affective program to meet the requirements of Supplement 10 of Appendix VIII
- PDI welcomes the NRC subject matter experts to review and provide input into its development

Performance Demonstration Initiative (PDI)

Proposed Sample Configurations for Supplements 2, 3 and 10 Qualifications Scanned from the **Inside** Surface

Presented By: Carl Latiolais

EPRI NDE Center

ATTACHMENT 5

Disclaimer

- The following configurations were selected by EPRI based research funded by PDI, MRP and the NDE Center Steering Committee. Final acceptance has not been obtained from the respective steering committees and modifications may be made to the proposal during the acceptance process

Sample Selection Basis

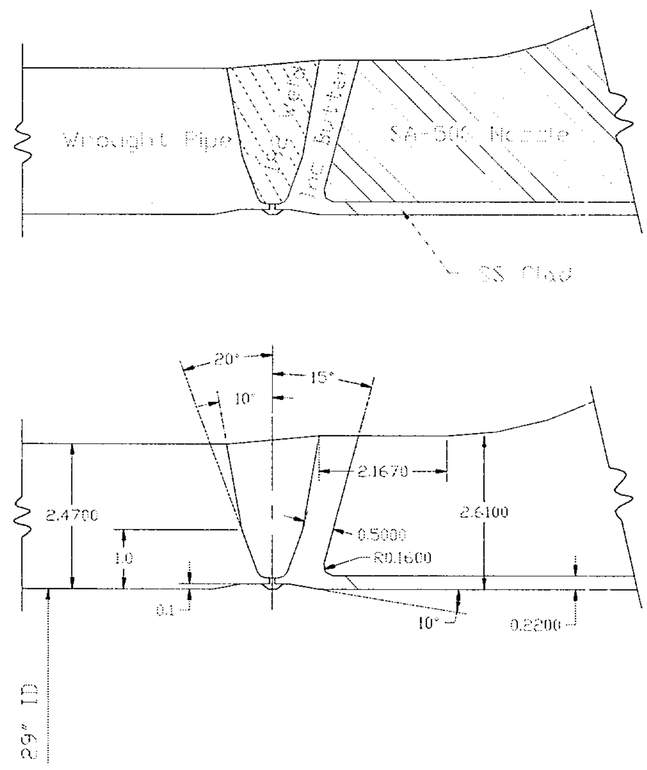
- Basis for sample selection will be based on the following;
  - Number of occurrences
  - Experience gained from recent documented failures (Ringhals, VC Summer)
  - Vendor and utility participation in design
  - EPRI personnel experience gained from support of spring examinations funded by MRP
  - Perceived degree of difficulty
  - Data evaluated on recently purchased samples

Standard Test Set

- Will be a combined Supplement 2,3 and 10 qualification specifically designed for inside surface qualifications
  - New code supplement (Supplement XX) will be developed to address this combined approach
- Candidate organizations requesting qualification will be tested on the following configurations

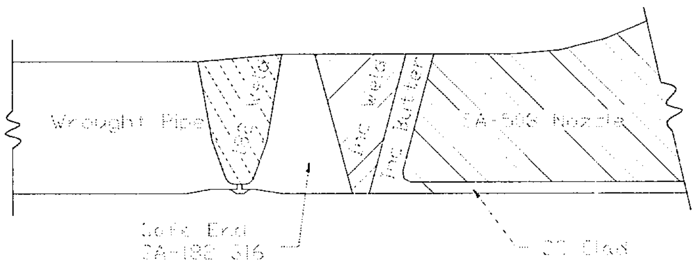
Sample Configurations Standard Test

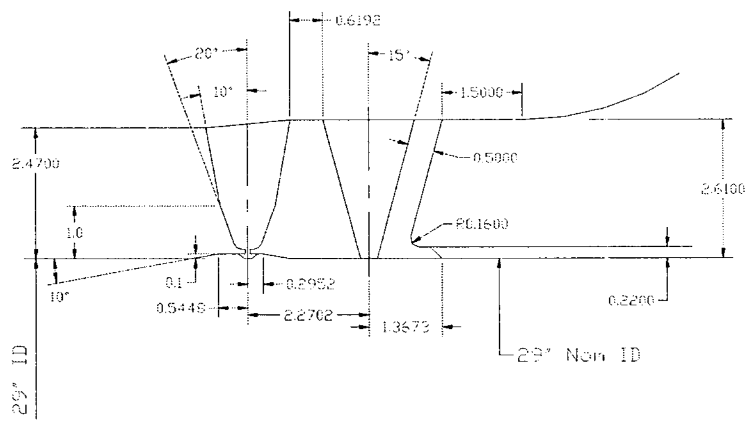
Outlet Field Weld Configuration



Sample Configurations Standard Test

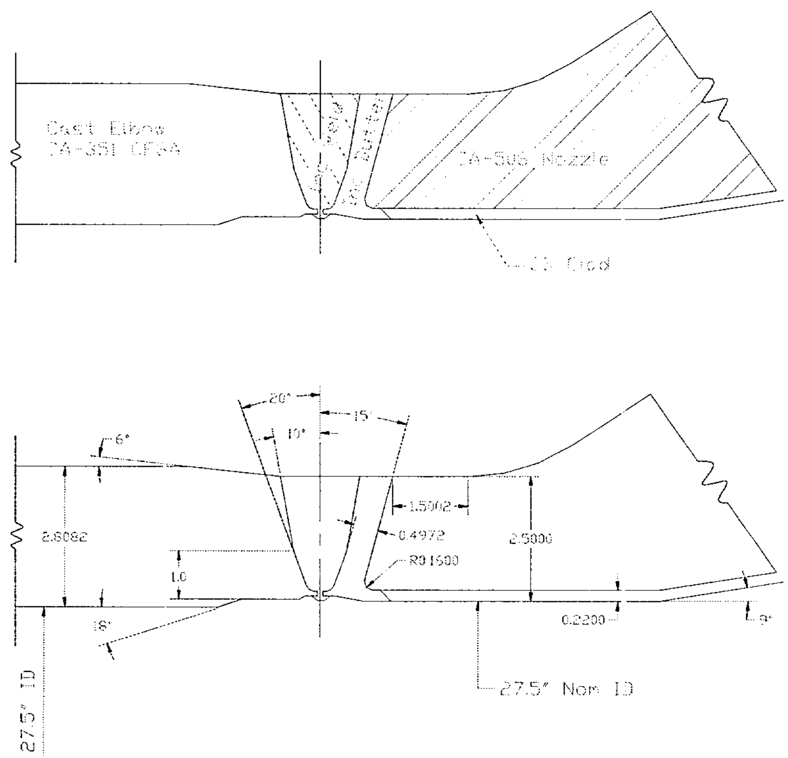
Outlet Shop Weld Configuration





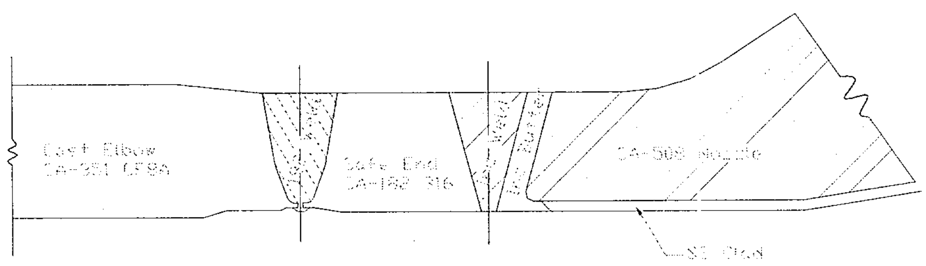
Sample Configurations Standard Test

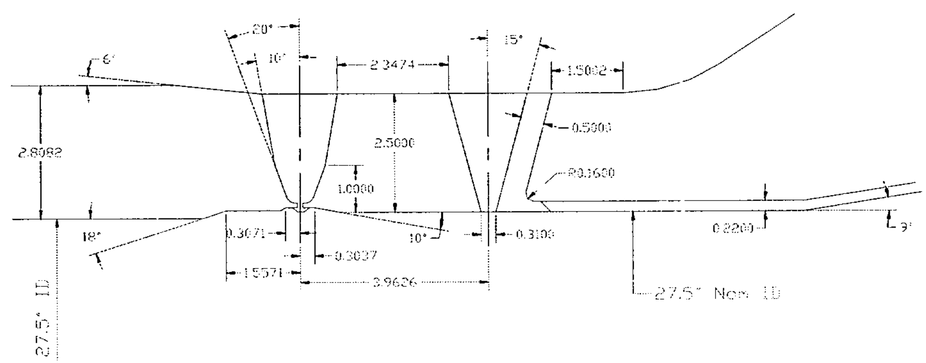
Inlet Field Weld Configuration



Sample Configurations Standard Test

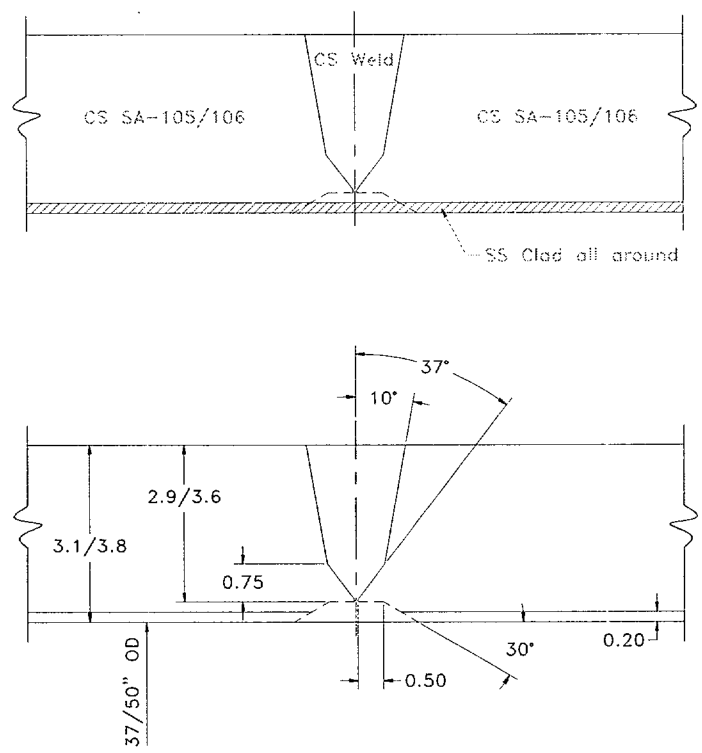
Inlet Shop Weld Configuration





Sample Configurations Standard Test

Typical PDI 525/526 CS Pipe Weld Joint Configuration

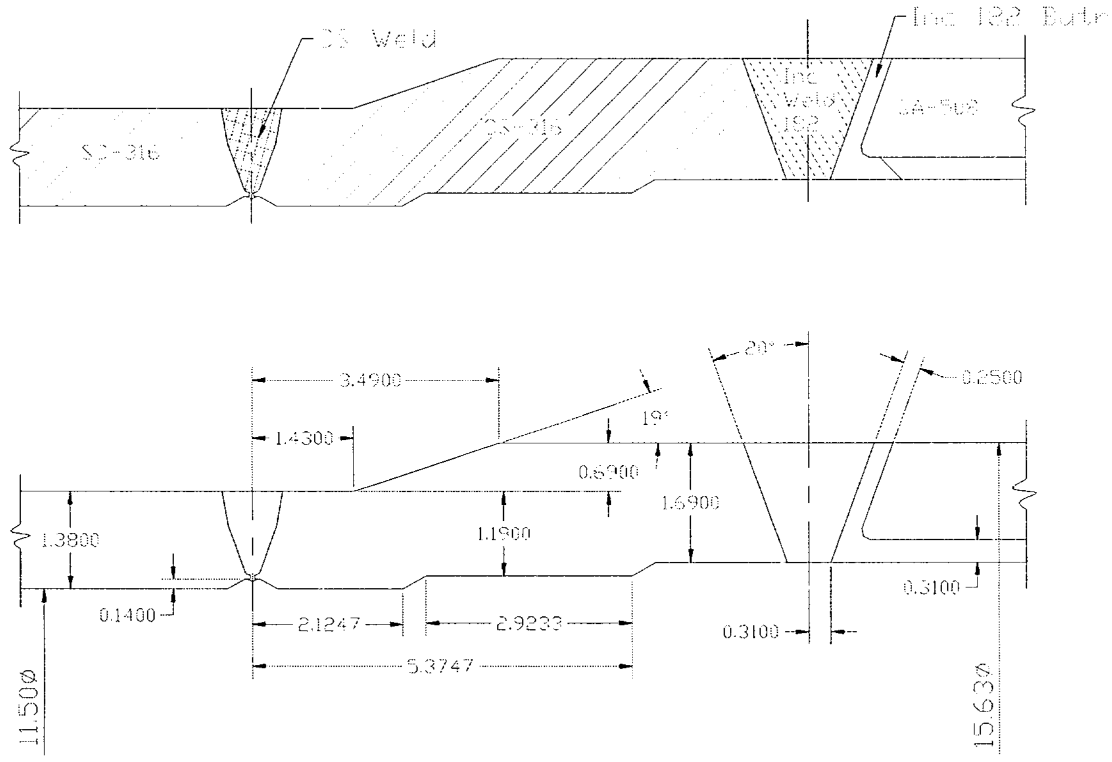


Add-Ons

- Candidate Organizations that perform specialized examinations on these smaller configurations will be required to expand their qualification to cover these configurations.
  - Both personnel and procedures must be qualified on standard set prior to attempting add-on

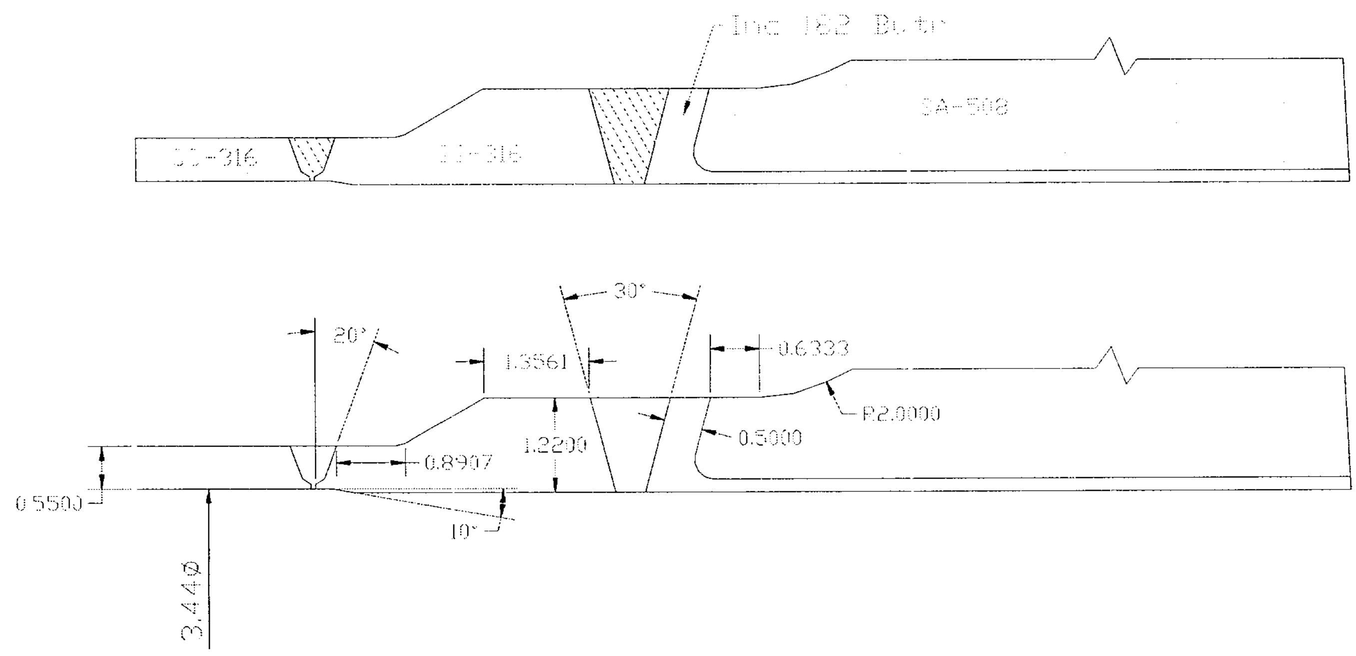
Add-On Configurations

Typical PWR Core Flood Weld Configuration



Add-On Configurations

Typical PWR Safety Injection Nozzle Configuration



Test Administration

- All examinations shall be performed from inside surface
- Mock-ups will be full 360 degree segments containing actual geometry (counterbore, exposed roots, tapers, cladding, localized grinding and simulated repair areas)
- Candidates will be required to use their actual delivery head to collect data during qualification
  - Actual scanner may be different for that used in field

Flaw Types

- Currently PDI plans to use the In-Situ process for the majority of the flaws
- Efforts underway to evaluate alternative flaw implantation processes utilizing HIP (Hot Isostatic Pressure) bonding
- Field data, where available, is being reviewed and the responses compared to fabricated defects and the techniques

Welding Processes

- Samples will be fabricated in similar fashion as the field components (e.g. welding type, weld direction, repair processes)
- Samples will include weld repair areas with and without flaws associated with them

Limitations

- The flaws/samples are being designed specifically to qualify procedures and personnel for ultrasonic examination and may not be appropriate for qualification of other methods
- Samples will not contain outside surface breaking flaws

Summary

- PDI in coordination with MRP is working diligently to develop technically justifiable cost affective program to meet the requirements of Supplement 10 of Appendix VIII
- PDI/MRP welcomes the NRC subject matter experts to review and provide input into its development

Proposed Criteria for Expansion of Supplement 10 Qualifications Utilizing Site Specific Mock-Ups

Prepared by: Carl Latiolais and Jeff Landrum
ERPI NDE Center
Presented by: Carl Latiolais

ATTACHMENT 6

Disclaimer

- The following configurations were selected by EPRI based research funded by PDI and the NDE Center Steering Committee. Final acceptance has not been obtained from the respective steering committees and modifications may be made to the proposal during the acceptance process

Sample Selection

- Supplement 10 of Section XI states

“ *The specimen test set shall include examples of the following fabrication conditions:*

  - *Geometric conditions that normally require discrimination from flaws (e.g., counterbore or weld root conditions, cladding, weld buttering, remnants of previous welds, adjacent welds in close proximity);*
  - *typical limited scanning surface conditions (e.g; diametrical shrink, single side access due to nozzle and safe end external tapers).”*

Sample Selection

- The PDI Supplement 10 program will meet all of the aforementioned criteria
- The code does not require demonstrations on all configurations that exist in the plants
- PDI realizes that the samples selected for the test set need to document the procedures capability over its range of applicability

PDI Approach

- Perform survey to assess the population of configuration that exist
- Perform research to determine what are the essential variables with regards to sample selection and limit them
- Design test set that contains key attributes while limiting the size of the test (unique configurations would not be addressed)

PDI Approach

- Survey Results
  - Conservative estimates would indicate that thousands of different configurations exist and that not every configuration can be covered
  - Research would have to be done to limit the scope of the demonstration

PDI Approach

- Research
  - Mock-ups were fabricated in an effort to determine the essential variables in sample selection
  - A cross cut of the existing configurations were selected

PDI Approach

- Sample selection criteria
  - Code required criteria
  - Failure history
  - Number of occurrences in population
  - Experience gained from EPRI staff in support of dissimilar metal weld examinations
  - Vendor and utility participation
  - Perceived degree of difficulty

PDI Approach

- Results of research
  - Safe-end material and nozzle material have very little affect on sensitivity of examination (508, 316, 304 or Alloy 600)
    - Greater affects noted if beam is initiated on top of weld material verses base material
  - Orientation of flaw has much greater affect than base material type
  - External or internal tapers which preclude the proper angle from reaching the examination volume has significant affect

PDI Approach

- Results of research cont;
  - Procedure parameters (e.g., instrument settings, search unit selection and other essential parameters) did not vary greatly and can be defined in a criteria based procedure
    - Not many options to choose from
  - Site Specific Mock-Ups will be required, but can be limited in number for some configurations

Site Specific Mock-ups

- If a licensee makes a determination that their configuration is outside the range of the demonstration
  - Perform evaluation on feasibility of the examination and determine if a meaningful examination can be performed with qualified ultrasonics
  - Obtain site specific mock-up and attempt expansion of procedure
  - Perform alternative examinations (e.g., Radiography)

Mock-Up Requirements

- Site Specific Mock-Ups
  - When are they required?
  - How many flaws are required?
  - What type of flaws can be used?
  - What size flaws are needed?
  - Where do they need to be located?
  - What are the demonstration requirements?
  - Do both procedure and personnel capabilities need to demonstrated?
  - What constitutes an acceptable demonstration?
  - How are the demonstrations documented?
  - What happens if adequate results cannot be obtained?

Mock-Up Requirements

- When are site specific mock-ups required ?
    - When external tapers precludes coverage of the examination volume with the procedurally defined angles due to scanning surface configuration
    - When presence of adjacent weld requires the beam to initiate wholly in austenitic weld material (excluding circumferential scans)
        - Only if sample does not been included in qualification test
    - When the scanning surface has been cladded either with corrosive resistant cladding or with weld build up (excluding normal nozzle cladding present on most welds)
    - When it required to examine a weld outside of the demonstrated thickness or diameter ranges

Mock-Up Requirements

- How many flaws are required?
  - A sufficient number of flaws should be included in the mock-up to demonstrate that coverage can be achieved
    - Areas that cannot be physically covered will be claimed as a limitation

Mock-Up Requirements

- What type of flaws can be used?
  - Notches, alternative flaws or cracks can be used for this demonstration
    - Basis; The procedure and techniques have been previously qualified prior to this demonstration on cracks. This exercise is merely a transfer of the procedure to site specific configurations

Mock-Up Requirements

- What size flaws are needed?
  - The size of the flaws shall be dictated either by IWB-3500 or by IWB-3600 criteria
    - There may be inherent limitations on the size of the detectable flaws which will be defined by the PDI demonstration program (Not all flaws sizes may be detectable)

Mock-Up Requirements

- Where do they need to be located?
  - In areas that are known to be susceptible to cracking (e.g., weld, butter, heat affected zone)

Mock-Up Requirements

- What are the demonstration requirements?
  - The demonstration will be conducted in an open format and witnessed by the site ANII and licensee
    - Basis; The procedure and the personnel have already gone through a performance demonstration and this is merely a transfer of the technology to a site specific configuration

Mock-Up Requirements

- Do both procedure and personnel capabilities need to demonstrated?
  - The procedure is the only item that needs to be demonstrated, but the personnel performing the examination must be made familiar with the data collection and analysis process determined during the demonstration

Mock-Up Requirements

- What constitutes an acceptable demonstration?
  - A signal response from the flaw of at least 2 to 1 signal to noise ratio for detection

Mock-Up Requirements

- How are the results to be documented?
  - A report will be generated on site with sufficient detail to document the capability of the procedure.
    - ANII signature
  - Essential parameters established during demonstration shall be documented and added to the site specific procedure for that specific configuration

Mock-Up Requirements

- What happens if adequate results cannot be obtained?
  - Alternative examinations can be performed (e.g., radiography)
  - Best effort examination documenting the limitations coupled with a relief request
  - Licensee documents limitations and declares the weld un-inspectable and seeks relief

Summary

- PDI believes that the steps outlined in this presentation will allow for a consistent approach in the expansion of Supplement 10 procedure qualifications to site specific configurations

Fabrication of Flaws for Weld Overlay Examination Samples Utilizing Hot Iso-Static Pressure (HIP)

Prepared by: Carl Latiolais, Robert Smilie and Ron Ervine

Presented by: Carl Latiolais EPRI NDE Center

ATTACHMENT 7

Goals

- To develop flaws that provide a realistic ultrasonic response in weld overlaid components
- To develop flaws in which the dimensions are known
- To develop flaws that can be implanted in precise locations in an already fabricated component.
- Avoid complex welding operations which could cause unrealistic ultrasonic responses

Goals

- To develop a flaw that could be implanted in samples with other intentional flaws without damaging or affecting their dimensions or responses

First Application

- Implant axial flaws in previously weld overlaid austenitic piping welds

Trials

- 8 flaws have been fabricated in weld overlaid components
- All samples have been scanned ultrasonically and their responses evaluated
- Multiple sections have been taken and their dimensions compared to available samples with laboratory grown IGSCC and In-Situ flaws

Trials

- Process control sheets have been utilized to control all manufacturing processes in accordance with EPRI's Quality Assurance Program

Requirements of Test

- Tip diameter of flaws must be equal to or less than 0.002"
  - Basis for dimension
    - PISC Study
    - ASME Code Case

Results

- Initial Tests
  - The majority of the flaws had a tip diameter of less than 0.002" but several flaws had tip diameter slightly larger
  - The responses from these flaws were good and it would be most difficult to determine ultrasonically which flaw had the larger tip diameter.

01972 Sample 2A	1	Slanted Circ flaw along HAZ with 0.002" mica	0.002	0.0006	-0.0014
01972 Sample 2B	1	Slanted Circ flaw along HAZ with 0.002" mica	0.002	0.0017	-0.0003
01972 Sample 4C	1	Slanted Circ flaw along HAZ with 0.002" mica	0.002	0.0005	-0.0015
10976 Sample 12-B-1B	1	Radial axial flaw into WOR	0.002	0.0015	-0.0005
10977 Sample 12-B-1B	2	Radial axial flaw into WOR	0.002	0.0005	-0.0015
315/025 Flaw 1	K	Radial Axial Flaw	0.002	0.0003	-0.0017
315/025 Flaw 1	L	Radial Axial Flaw	0.002	0.0001	-0.0019
315/025 Flaw 1	M	Radial Axial Flaw	0.002	0.0001	-0.0019
315/025 Flaw 3	D	Slanted Circ flaw along HAZ	0.002	0.0019	-0.0001
315/025 Flaw 3	E	Slanted Circ flaw along HAZ	0.002	0.0003	-0.0017
315/025 Flaw 3	F	Slanted Circ flaw along HAZ	0.002	0.0017	-0.0003
315/025 Flaw 4	G	Radial Axial Flaw	0.002	0.0043	0.0023
315/025 Flaw 4	H	Radial Axial Flaw	0.002	0.0014	-0.0006
315/025 Flaw 4	J	Radial Axial Flaw	0.002	0.0001	-0.0019
315/025 Flaw 2	A	Slanted Circ flaw along HAZ	0.002	<.0001	
315/025 Flaw 2	B	Slanted Circ flaw along HAZ	0.002	<.0001	
315/025 Flaw 2	C	Slanted Circ flaw along HAZ	0.002	<.0001	

Summary

- The initial trials were quite successful and it is believed that the process will prove to be an effective way to produce a realistic flaw for performance demonstrations
- Additional tests are underway to improve the process and to ensure that the minimum diameter is achieved repeatedly

PDI Overlay Program Status

Presented by: Carl Latiolais
EPRI NDE Center

ATTACHMENT 8

Program Development

- PDA has drafted code case was submitted during ASME December meeting which includes required changes and has been approved by Sub-group NDE
- Fabrication program put on fast track and well underway

Fabrication Activities

- January RFP issued
- March Samples Ordered
- Phase 1 (Implant In-Situ Flaws)
  - 4.0" and 6.0" samples delivered 6/4/01
  - 28.0" sample to be delivered by 6/15/01

Fabrication Activities

- Phase 2 (Implant HIP Bonded Flaws)
  - Prepping of samples and EDM process underway on 4.0" and 6.0" samples
  - Phase 3 (Fingerprinting,Document Review, Database design)
    - Fingerprinting of samples that do not have HIP flaws are underway
    - Database developed to store sample information

Demonstration Program

- Testing protocol being developed and included in quality instructions
- Manual Generic Overlay procedure being revised to incorporate new sizes
- Grading database being developed to allow storing of results

Demonstration Program

- Testing scheduled to start late August

CHARACTERIZATION OF AN INDICATION IDENTIFIED IN A RE-CIRCULATION NOZZLE-TO-SAFE-END WELD

Background: PNNL under contract by the NRC performed a review of acoustical data from a UT examination of a field repaired dissimilar metal weld that contained an imbedded base metal wedge. The UT examination identified an indication in the vicinity of the wedge. The wedge is in an area of the weld that was repaired. The review consisted of comparing the UT responses from the re-circulation nozzle-to-safe-end field weld (identified as N2B) with UT responses from a similar configured welds with known cracks and fabricated cracks.

Objective: The approach was to evaluate the UT responses (images) for evidence that the indication is either benign or an active degradation (a crack) condition and to develop a characterization of the indication using UT images from cracked and non-crack welds as a guide. The weld materials and configurations were all similar.

Observations: A pre-service repair was identified in the vicinity of the indication. The indication was aligned with the repair and was the same length as the repair. Figure 1 shows a sketch of the weld in question. From the sketch, the coordinates of the repair are -2.6 inches to +7.2 inches and the length coordinates of the indication are -3 inches to +8 inches.

The maintenance history of the re-circulation nozzle to safe-end field weld show that the original, furnace-sensitized, safe-end was removed from the component in 1975 for preventive maintenance. To protect the metallurgical integrity of the nozzle during the replacement of the safe-end, a portion of the original safe-end was left with the nozzle buttering. This was done to avoid altering the heat-treatment of the nozzle. Figure 2 shows a photograph of the nozzle-to-safe-end weld N2B with visual evidence of the repair. Figure 3 shows a pictorial sketch of the nominal nozzle-to-safe-end weld configuration with the location of the fragment (wedge) from the original safe-end.

Data Sets: A large amount of data was available on blank-state responses, artificial cracked responses, and field-cracked responses to develop a characterization of the indication. The available data included 60 degree refracted longitudinal, 45 degree refracted longitudinal, and 45 degree shear transducers with 1-MHZ and 2-MHZ center frequencies. The insonification consisted of all four directions: from the safe-end side, from the nozzle side, and in the two circumferential directions around the pipe. The quality of the data was determined to be high quality and relevant to the objective.

Images of blank material were examined to establish the responses that form the baseline against which the detection of degradation must be performed. These responses included clad noise, weld noise, weld configuration interfaces, fabrication flaws, and base metal responses. The images of blank material were generated using representative transducers, electronics, and weld configuration.

Images of artificially implanted fatigue cracks were used to establish the responses from multifaceted discontinuities of various sizes in the representative weld configuration. Images were generated using representative transducers and electronics. Responses were measured from fatigue cracks as small as 0.3 inches through-wall.

Inspection data for the field weld were available for the years 1992, 1995, 1999, and 2001. However, only data from the 2001 inspection was reviewed in the time allotted. This data was shown to be of high quality and directly comparable to the images of blank material and artificial cracks in the mockups available at EPRI.

Other field data containing known weld cracks from similar components at other nuclear plants available. The weld configurations were different but UT responses were shown to be useful for the weld and flaw characterization. Their image quality were sufficient for establishing relevant field weld responses.

Image Quality: The image quality of the data reviewed was determined, in part, by the transducer properties, the step sizes in the raster scan, the dynamic range of the electronics, the calibration information, and the ability of the large data sets to define the baseline for detection of degradation. Transducer properties determine image resolution and sizing performance. The dual-element transducers used had crystal sizes of 10 x 14 mm. An estimate of the resolution that is possible with this kind of transducer is half the crystal size (5 to 7 mm). Measurement of image resolution was not available in the data sets.

Scans of the blank state, artificial cracks, and the field conditions were performed using a 1-mm step size and 2-mm increment. These small step sizes, available in all the images, took full advantage of the resolving power of the transducers.

The dynamic range of 70 dB was achieved using a logarithmic amplifier and an 8-bit digitizer. All of this dynamic range was useful in the imaging of the component. The low responses from the configuration of the weld played an important role in the characterization.

Calibration was performed and reported. However, the responses in the images from the various data sets were not directly available in dB relative to the reference reflector.

Characterization: The characterization of the N2B indication as a benign condition was determined in a number of ways. The images of blank material showed that the entire configuration of the weld was illuminated except for possibly some limited portions of the inner surface. The location of the reflectors, especially in the images of thermal fatigue cracks in the EPRI mockups, was insensitive to surface connectedness in important parts of the image. The nominal geometry of the weld was well known but not all of the dimensions of the pre-service repair. Because the images were shown to be high quality and because the inspections from 1992, 1995, 1999, and 2001 showed a stable indication, the indication cannot be characterized as active degradation, although it needs to be noted that only the data from the inspection in 2001 was refviewed. For the prior inspection years, the review relied upon the description provided by the EPRI staff. The EPRI staff concluded that there were no changes in characterization from the earlier ISI data.

Because the indication in N2B was co-located in length with the pre-service repair, it makes sense to consider the indication is more strongly associated with the repair than with the fragment of the original safe-end. The fragment of the original safe-end should give a response all the way around the pipe.

Figure 4 shows a response analysis using a portion of the available data. All of the Figure 4 responses obtained by inspections and analyzed by EPRI staff with PNNL oversite are from discrete reflectors in the data sets. The low response from the indication in weld N2B is consistent with a small, embedded fabrication flaw, abnormal microstructure, or small surface-connected discontinuity.

Figure 5 shows the ultrasonic image of blank nozzle to safe-end weld. The weld configuration is shown in the side view as a line drawing. From the figure, the change from base metal to butter weld material is easily identified. Some evidence is given of a response by the original safe-end material. This response, however, is from the material because there are no flaws or weld repairs in the blank weldment.

Figure 6 shows the ultrasonic image of an indication in nozzle to safe-end weld N2B. The co-location of the indication with the fragment of the original safe-end is shown in that the energy appears to come from the middle of the fragment of the original safe-end. The dimensions of the pre-service repair are not shown in the figure.

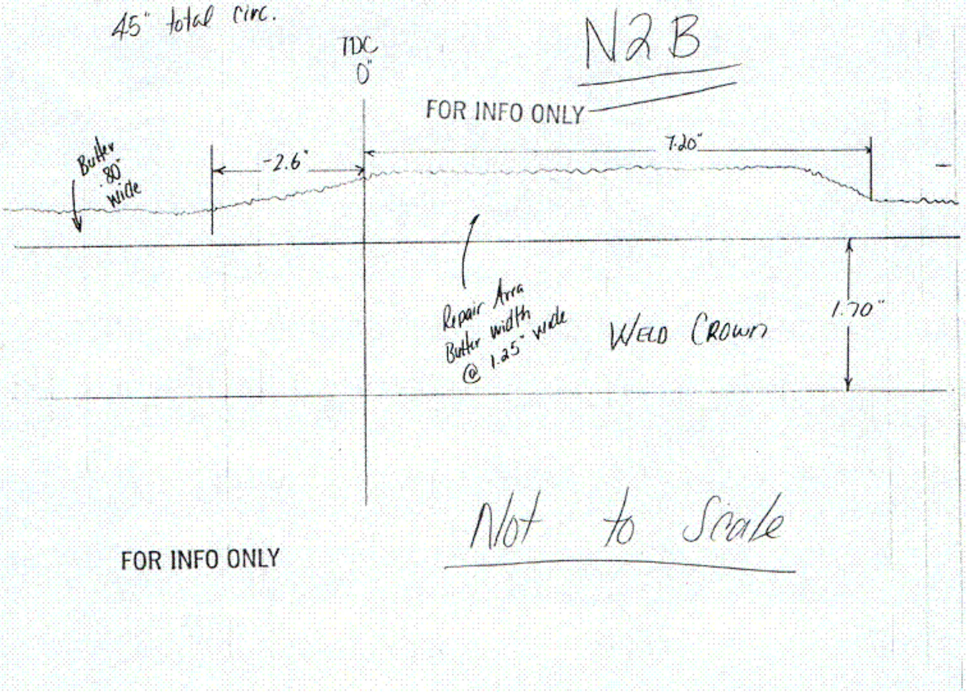
Figure 7 shows the ultrasonic indication of fatigue crack Flaw B in the EPRI mockup. Flaw B is a circumferential crack, 2.7 inches long, and 0.58 inches through-wall. The tip signal from this thermal fatigue crack gives a good measure of the through-wall dimension. The through-wall size is good evidence of degradation (cracking) of the material.

Conclusions: The quality of the images analyzed was high and useful in the characterization, especially for the field data from real cracks at operating plants. The value and reliability of NDE data has been greatly improved and we have achieved NDE data re-use for characterization.

The data sets show that the indication in weld N2B is consistent with a benign condition. The benign condition is most likely a fabrication condition or shallow, stable, surface-connected metallurgical discontinuity associated with the pre-service repair. Fabrication conditions for the pre-service repair include embedded lack of fusion and possibly anomalous microstructure. Considerable data show that long, embedded, and benign lack of fusion exists in repair metal. Anomalous microstructure (interface conditions where elastic properties change across a fusion surface) is postulated but more information is needed for substantiation of the condition and its ultrasonic responses.

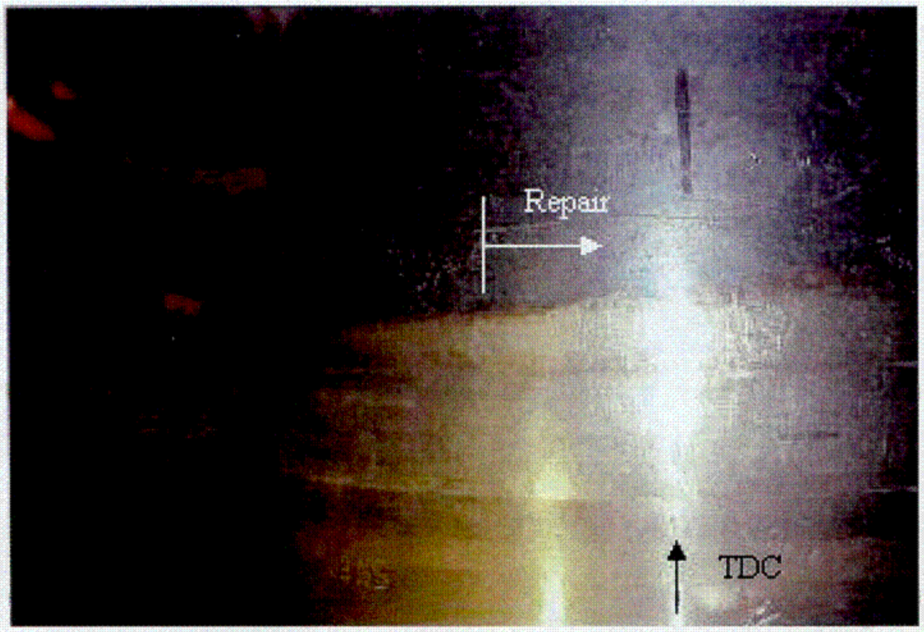
A shallow, stable, surface-connected discontinuity, less than 0.3 inches though-wall, remains a possible explanation, through slim, for the response in the images that were reviewed. The 0.3 inch value was selected because al thermal fatigue crack of this size was not detectable in one of the EPRI mockups. Because the high-quality images from the four inspections recorded from 1992 to present show a stable condition, it follows that the component is not degrading.

In summary, the data support the position that the indication in weld N2B is a benign condition. The most likely explanation for the indication, based on all the evidence (including length alignment with a repair), is (1) embedded lack of fusion, (2) is anomalous microstructure (this is based, in part, on the low response of the indication), and (3) a small stable surface-connected discontinuity (this is based on the inability of the images to confirm or deny surface a surface connection).



Color Slide

Figure 1. Sketch of pre-service repair to nozzle to safe-end weld N2B showing location and dimensions of the repair. The repair starts at -2.6 inches from top-dead-center and extends to +7.2 inches.



Color Slide

Figure 2. Photograph of nozzle to safe end weld N2B showing pre-service repair on nozzle side of weld.

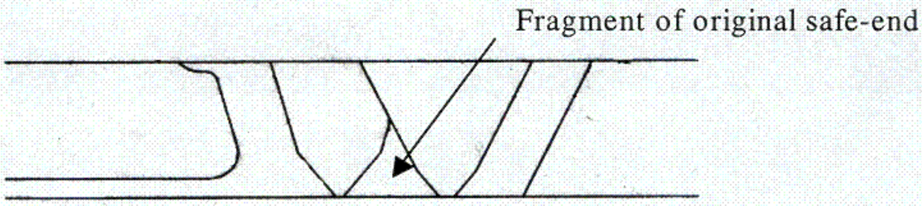


Figure 3. Nominal weld configuration for nozzle to safe-end weld N2B. This drawing shows the fragment of the original safe-end that remains in the component.

Color slide

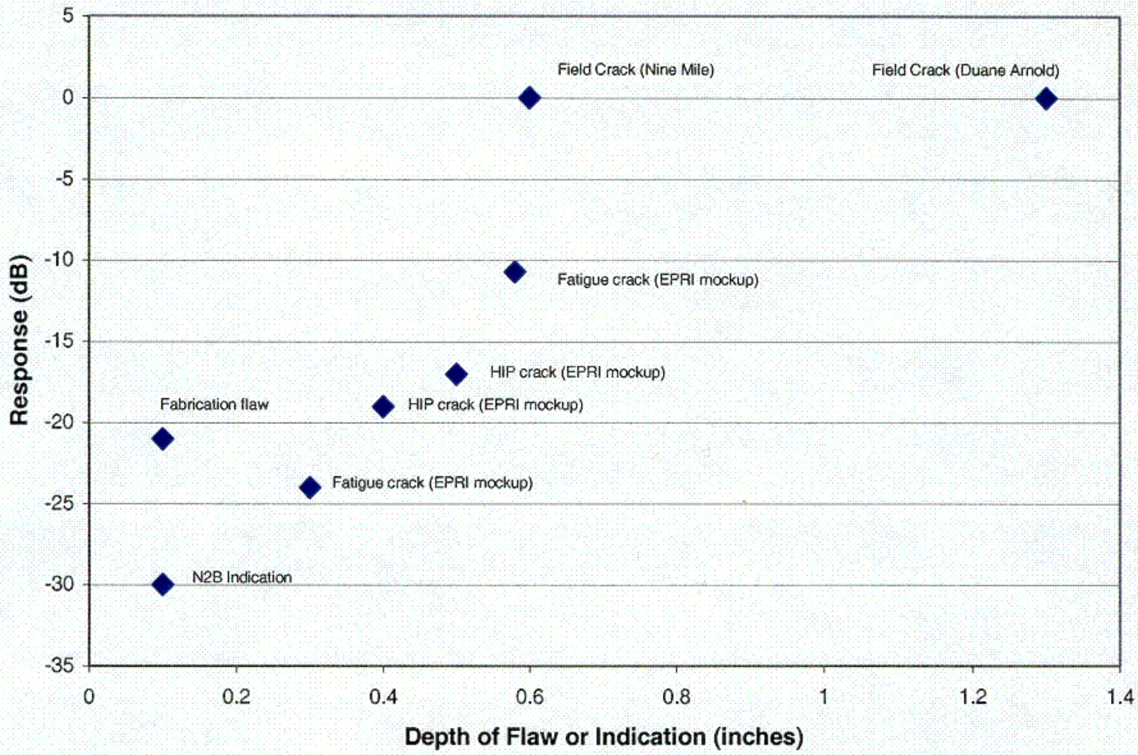


Figure 4. Responses of field cracks, mockup cracks, and N2B weld indications. Response does not predict crack size but the chart does support the characterization of the N2B indication as a benign condition. The EPRI Flaw B is located at -10dB, 0.6 inches.

C02

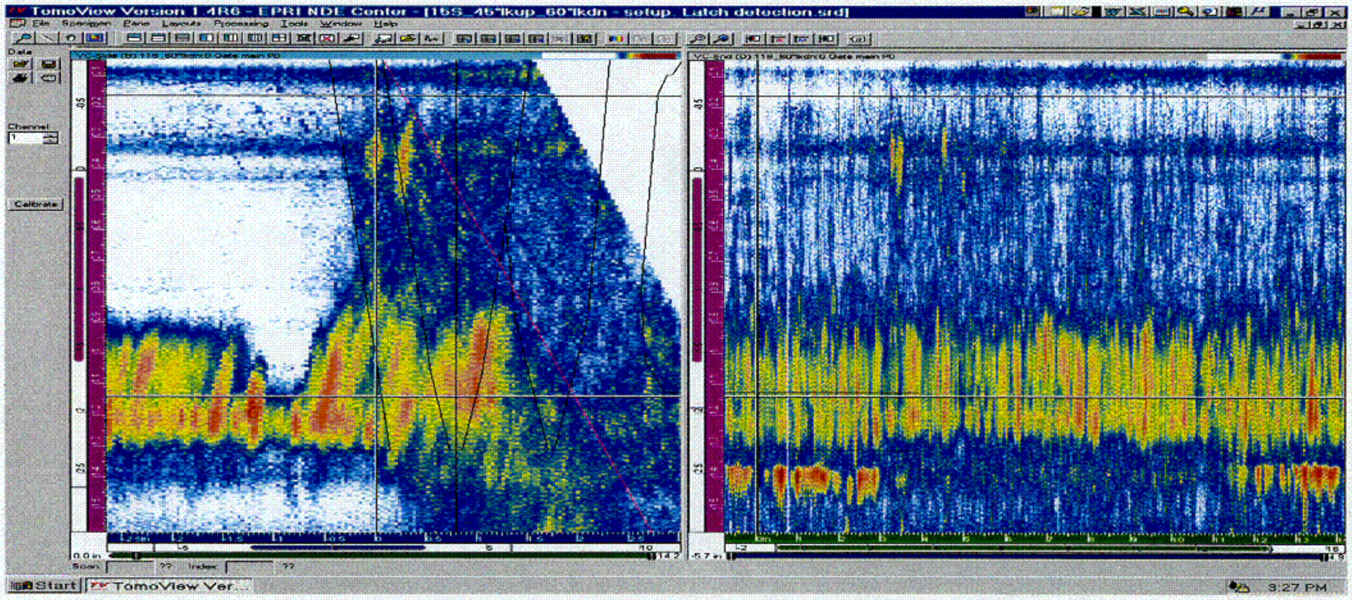
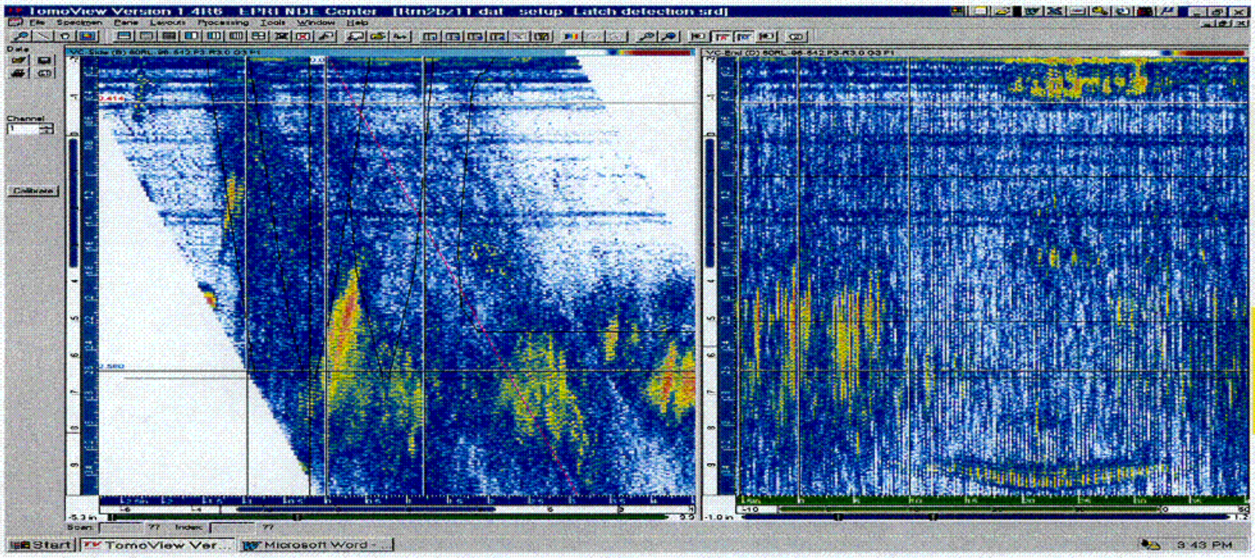


Figure 5. Ultrasonic image of blank nozzle to safe-end weld. Weld configuration is shown in the side view as a line drawing on the left. The other view is a B-scan end view.



Color Slide

Figure 6. Ultrasonic image of indication in nozzle to safe-end weld N2B. The co-location of the indication with the fragment of the original safe-end is shown.

C03

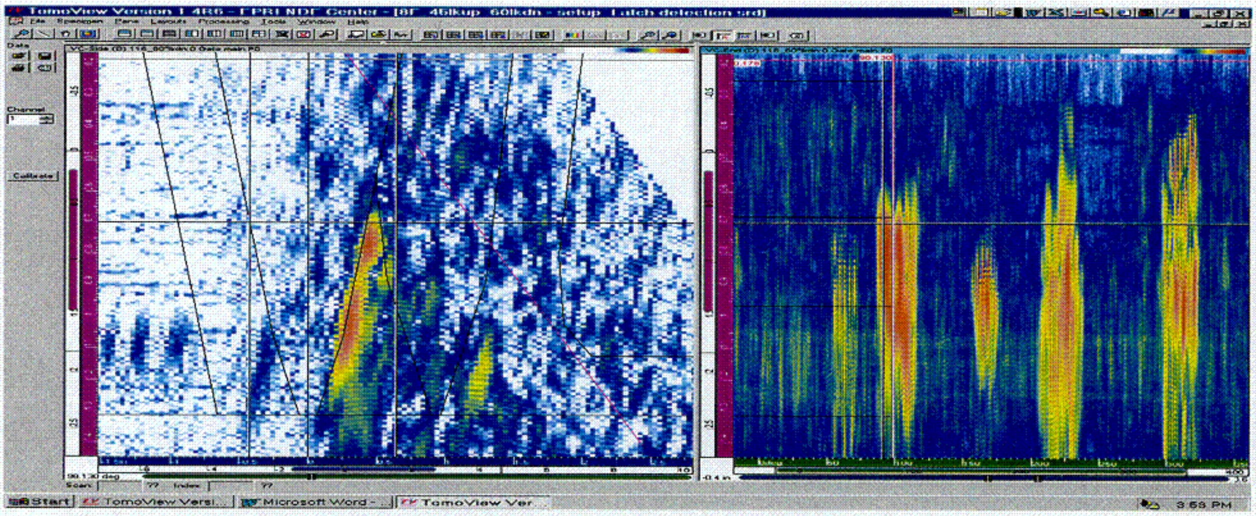


Figure 7. Ultrasonic indication of fatigue crack Flaw B in EPRI mockup. Flaw B is a circumferential crack, 2.7 inches long, and 0.58 inches through-wall. Flaw B is located where the position lines cross in the right hand figure.

color slide

C04