



ELECTRIC POWER
RESEARCH INSTITUTE

Inspection Experience and Welding Guidance for Alloy 600 Welds and Overlays

NRC/PDI Meeting – May 2007

Carl Latiolais

Program Manager, Appendix VIII
Performance Demonstration



Objectives

- Background
- Planned applications
- Examination goals
- Ultrasonic techniques
- Reported indications
- Examination history
- Flaw evaluation criteria
- Ultrasonic technique limitations
- Alloy 52 weld overlay guidance document
- Summary

Background

- To date ~18 PWR units have applied Alloy 52 Inconel overlays to 1 or more of their Alloy 600 butt welds
- Plants that performed overlays in 2005/2006
 - Byron (2 Units)
 - Davis-Besse
 - Millstone
 - Wolf Creek
 - STP
 - Beaver Valley
 - Sequoyah
 - McGuire (2 Units)
 - Oconee
 - SONGS (2 Units)
 - DC Cook (2 Units)
 - Vogtle
 - Comanche Peak
 - Farely

Planned Applications

- 22 PWR units are planning to apply pre-emptive overlays to one or more Alloy 600 butt welds in 2007
 - 11 in the spring
 - 11 in the fall
- 9 additional PWR units are scheduled in Spring of 2008

Examination Goals

- Overlay Examination
 - Performed after initial application of overlay only
 - Workmanship standard
 - Purpose of examination
 - Assure quality of the overlay itself
 - No unacceptable welding flaws
 - Bonded to original base material
 - Assure no conditions would affect the examination of the upper 25% of the original base material

Examination Goals

- Inservice Examination
 - Performed directly after application of overlay (PSI)
 - Subsequent examinations dictated by relief request commitments and MRP-139 requirements
 - Purpose of examination
 - Detect and size any flaws that may have propagated into the outer 25% of the original base material
 - Critical attribute
 - Assure no propagation into overlay
 - No new flaws appear

Ultrasonic Technique

- Same techniques used since early 1980's for standard overlays
- No marked increase in sensitivity
- Application of these techniques on the complex configurations requires a great deal of planning
 - Scan plan development
 - Takes time and is quite complex
 - Specialized search units
 - Must be qualified
 - Long delivery time
 - Specialized calibration blocks
- Phased array techniques have been qualified that have simplified process to some degree

Reported Indications

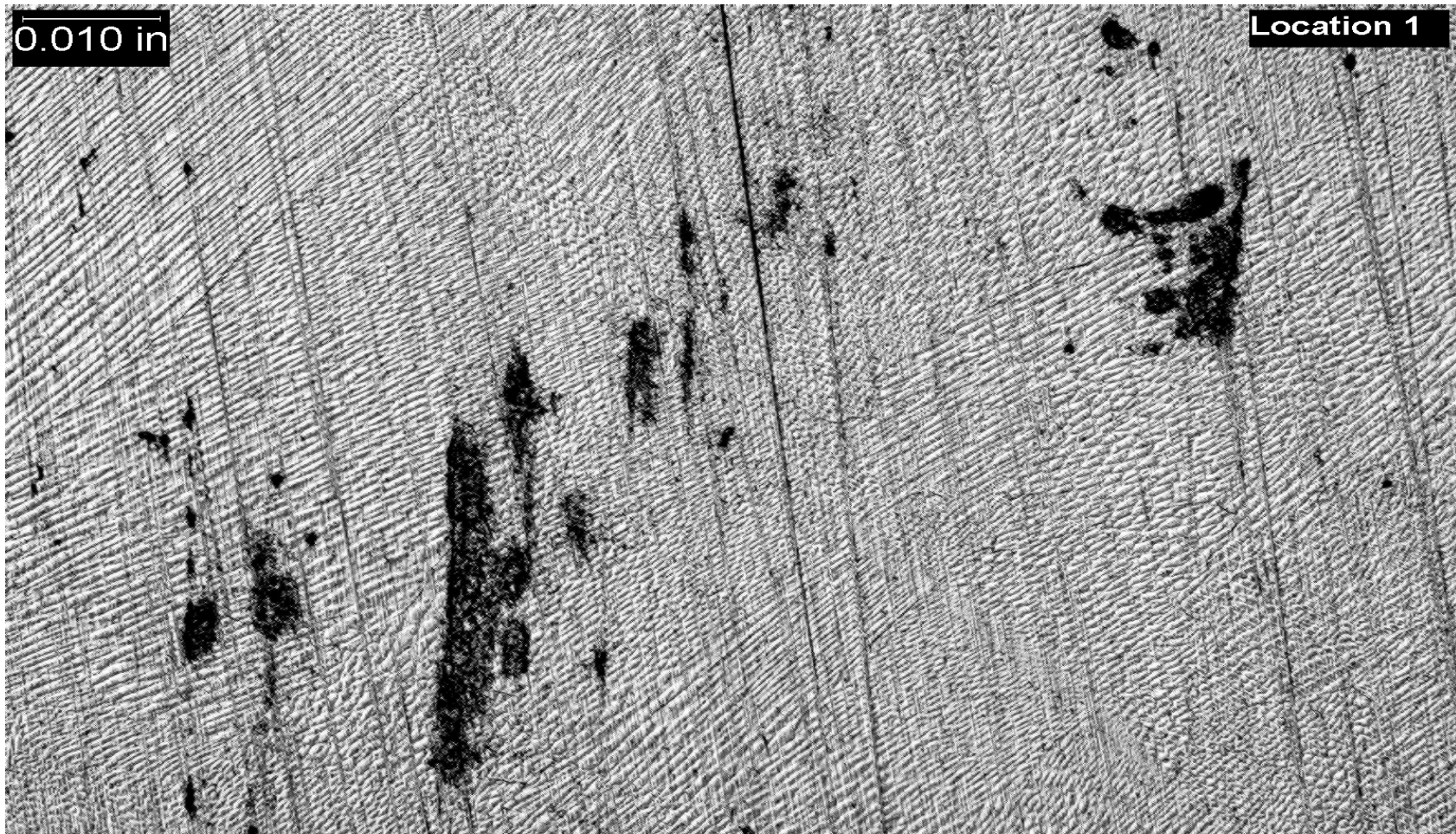
- Types of flaws detected to date in most recent applications of overlays
 - Inter-bead lack of fusion (laminar and planar)
 - Lack of bond (laminar)
 - High concentrations of solidification defects

Examination History

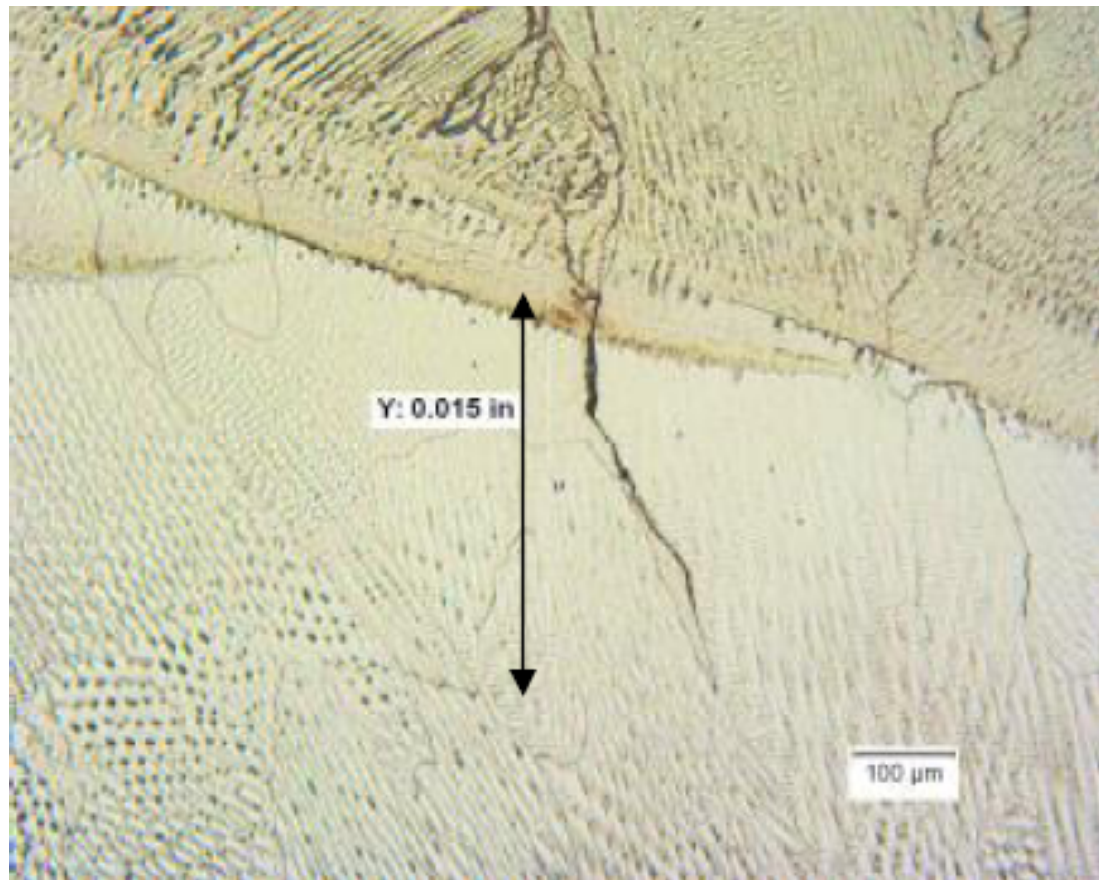
- Hope Creek (1 weld) *
- Perry (1 weld) *
- Duane Arnold (4 welds) *
- Nine Mile (1 weld) *
- TMI (1 weld) *
- Pilgrim (1 weld)
- PPL (2 welds)
- Calvert Cliffs (2 welds)
- Hope Creek (1 weld)*
- Millstone (1 weld)
- San Onofre (8 welds) *
- DC Cook (12 welds)*
- Wolf Creek (6 welds)*
- Beaver Valley (6 welds)*
- Byron (12 welds)*
- STP (1 weld)
- McGuire (12 welds)
- Oconee (6 welds)
- Sequoyah (6 welds)
- Davis Besse (1 weld)
- Vogtle*
- Farley
- Comanche Peak (6 welds)

***Indicates applications that experienced problems with unintentional defects that had to be evaluated in 52 material**

Flaw Evaluations – oxide and nitride



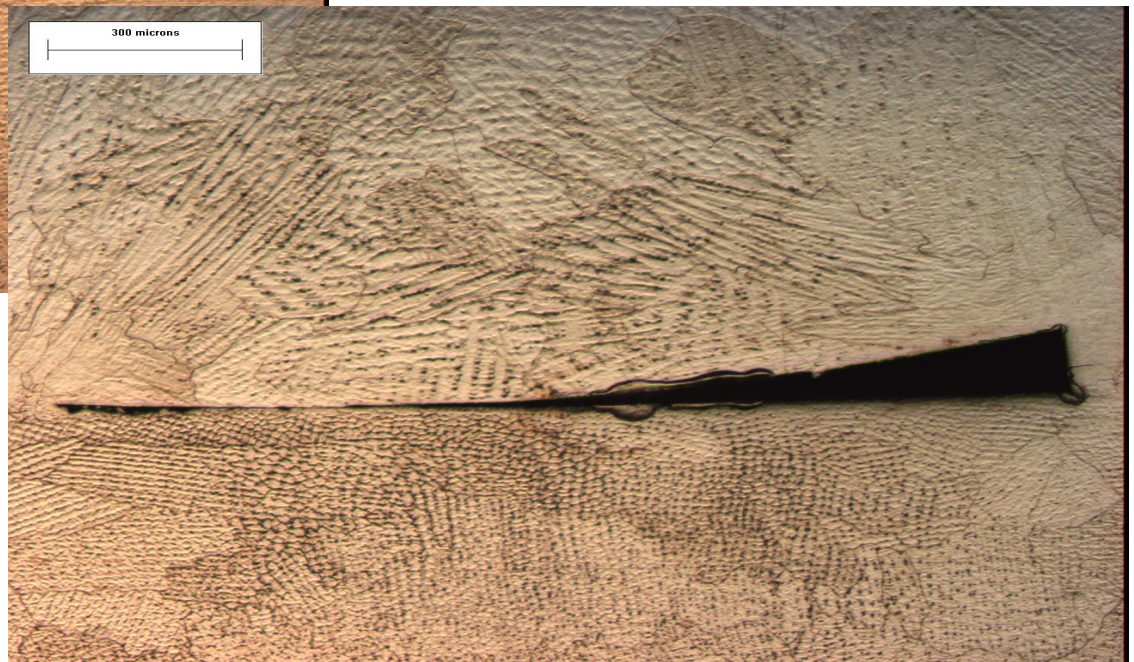
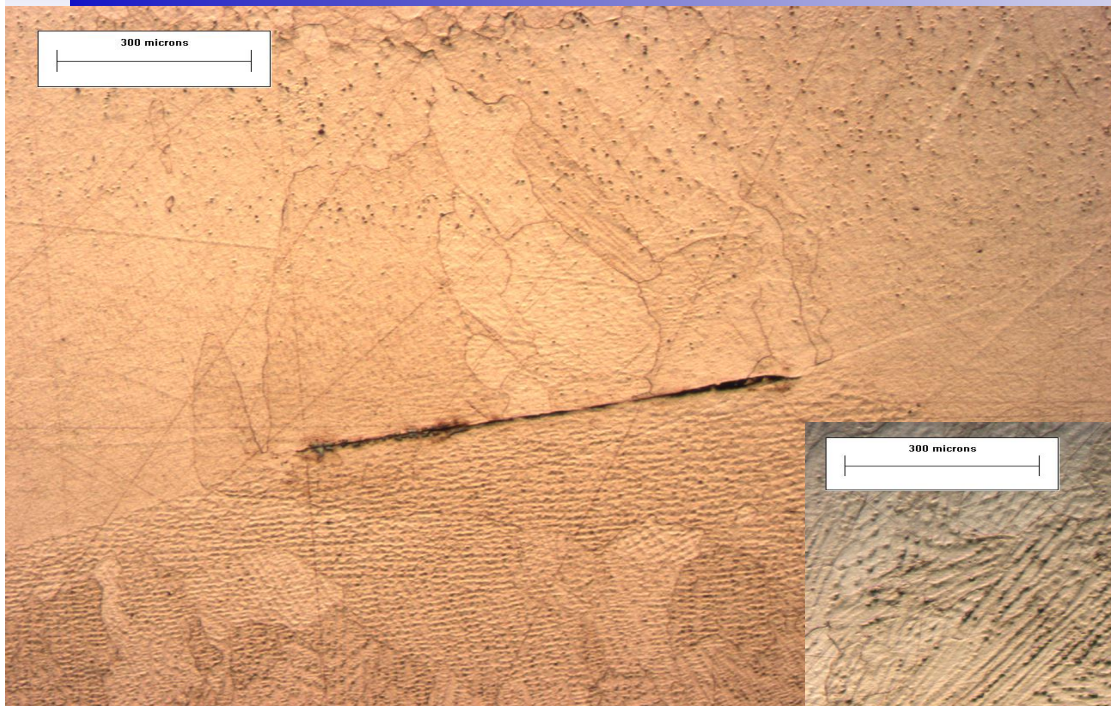
Flaw Evaluations - DDC



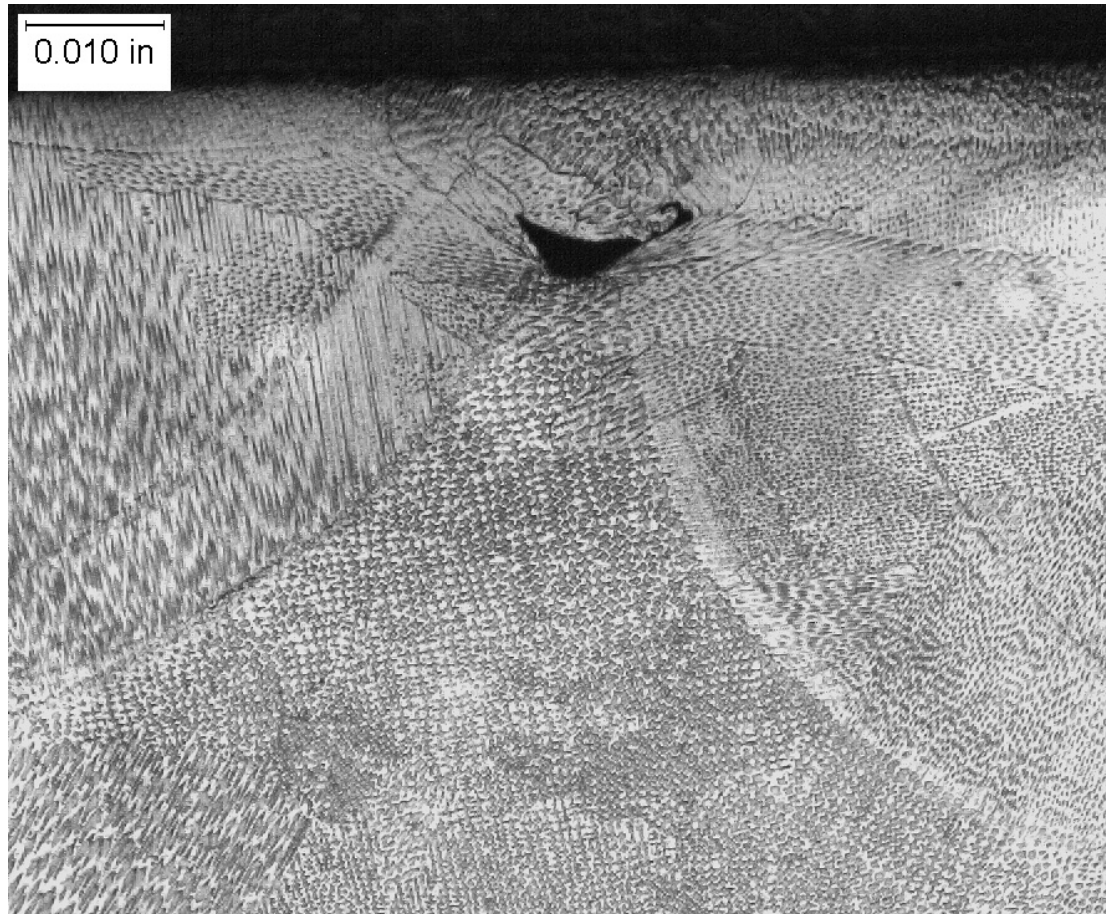
Flaw Evaluations – Hot Cracking



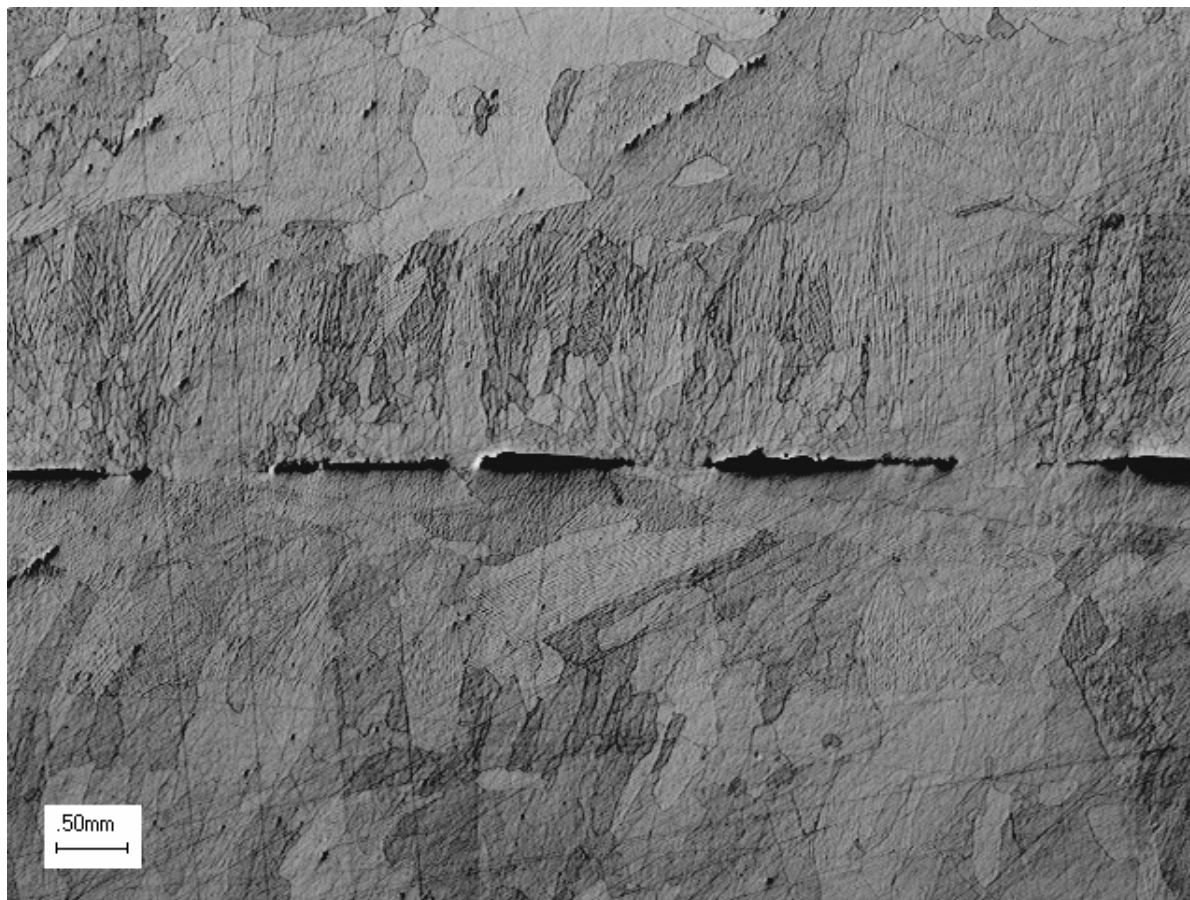
Flaw Evaluations – LOB



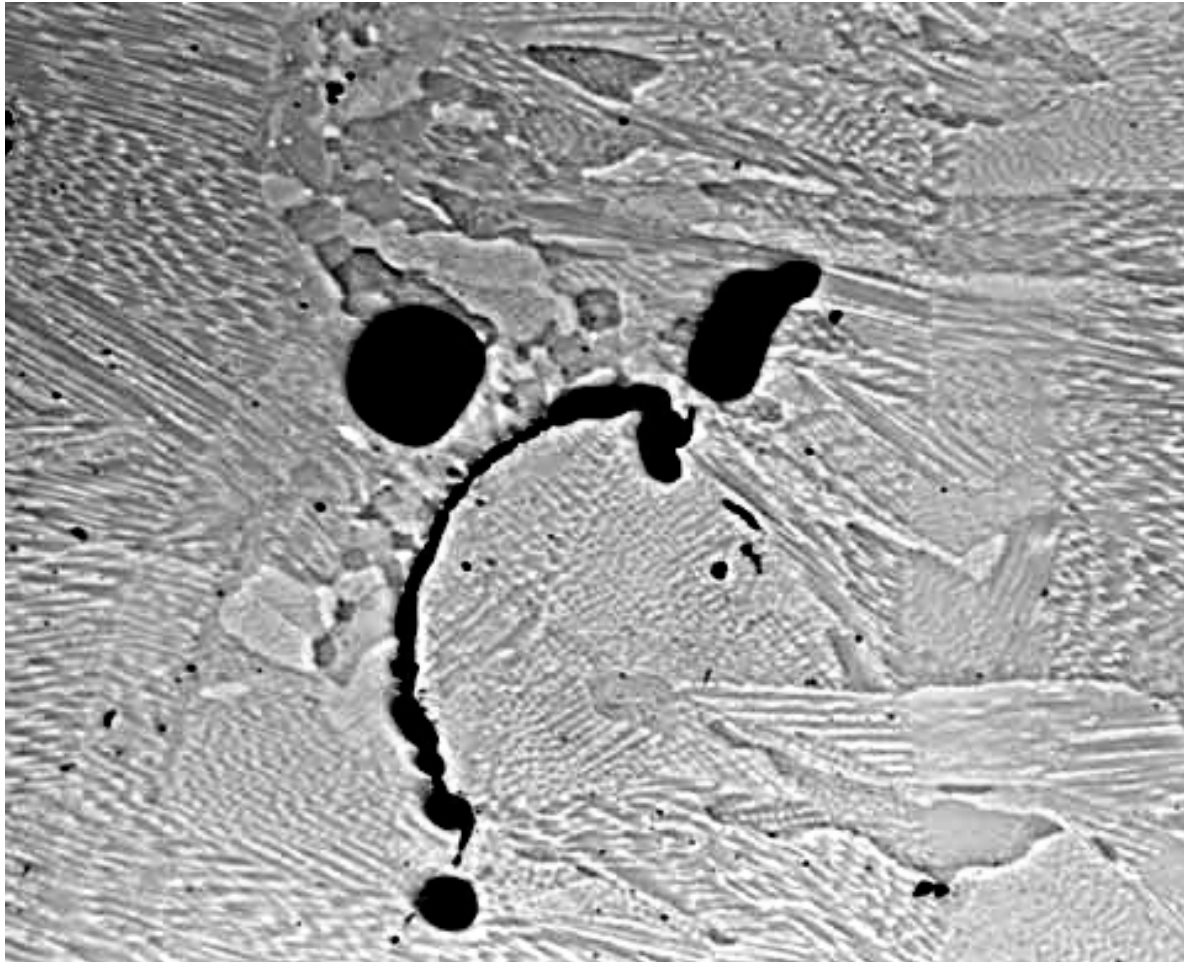
Flaw Evaluations – LOF



Flaw Evaluations – Floaters



Flaw Evaluations – Porosity



Flaw Evaluations

- Currently a multi-level evaluation must be performed on any flaw that is detected during examination
- These evaluations are quite complex and time consuming
 - Must consider
 - Real planar flaws
 - Postulated planar flaws
 - Laminar flaws
 - Loss of coverage due to laminar flaw

Flaw Evaluations

- Currently a multi level evaluation must be performed on any flaw that is detected during examination
- These evaluations are quite complex and time consuming
- New requirements included in CC-740-1 make this evaluation even more complex and perhaps are unrealistic

Flaw Evaluations (Appendix Q)

Section	Requirement
Q-4100 (c)	The weld overlay itself shall be ultrasonically examined to assure adequate bond fusion (i.e., adequate bond) with the base metal and to detect welding flaws such as interbead lack of fusion, inclusions, or cracks. Planar flaws shall meet the preservice examination standards of Table IWB-3514-2.
Q-4100 (c) (1)	Laminar flaws shall meet the acceptance standards of Table IWB-3514-3.
Q-4100 (c) (2)	The reduction in coverage of the inservice examination (Figure 2) volume, due to laminar flaws, shall be less than 10%. The dimensions of the uninspectable volume are dependent on the coverage achieved with the angle beam examination of the overlay.

Flaw Evaluations (Appendix Q)

Section	Requirement
Q-4100 (c) (3)	Any uninspectable volume in the weld overlay shall be assumed to contain the largest radial planar flaw that could exist within that volume. This assumed (postulated) flaw shall meet the inservice examination standards of IWB-3514-2. Alternatively, the assumed flaw shall be evaluated and shall meet the requirements of IWB-3640, IWC-3640, or IWD-3640, as applicable. Both axial and circumferential planar flaws shall be assumed.
Q-4100 (c) (4)	As an alternative to (3), radiography in accordance with the Construction Code shall be used to examine the uninspectable volume. The radiographic acceptance criteria of the Construction Code shall apply.

Flaw Evaluations (Code Case N-740-1)

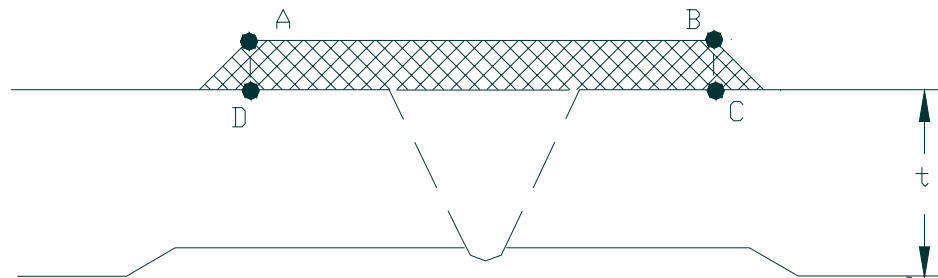
UnderlinedText New in 740-1

Appendix Q and Case N-504-3	Proposed Code Case N-740 -1
Appendix Q states that "Planar flaws shall meet the preservice examination standards of Table IWB-3514-2. "	Planar flaws shall meet the preservice examination standards of Table IWB-3514-2. In applying the acceptance standards, wall thickness "tw" shall be the thickness of the weld overlay.
Appendix Q states that "The acceptance standards of Table IWB-3514-3 shall apply for laminar flaws provided the reduction in coverage of the <u>ISI volume</u> is less than 10%".	Laminar flaws shall meet the acceptance standards of Table IWB-3514-3 with the additional limitation that the total laminar flaw shall not exceed 10% of the weld surface area and that no linear dimension of the laminar flaw area exceeds 3.0 inches (76mm) or 10% of the nominal pipe circumference, which ever is greater.
Appendix Q states that "The acceptance standards of Table IWB-3514-3 shall apply for laminar flaws provided the reduction in coverage of the <u>ISI volume</u> Figure 2 is less than 10%".	The reduction in coverage of the examination volume, <u>A-B-C-D in Figure 1(a) (overlay volume)</u> due to laminar flaws shall be less than 10%. The uninspectable volume, is the <u>volumen in the weld overlay underneath the laminar flaws for which coverage cannot be achieved with the angle beam examination.</u>

Flaw Evaluations (Proposed Code Case N-740-1)

Appendix Q and Case N-504-3	Proposed Code Case N-740-1
<p><i>Appendix Q states that “Any uninspectable volume in the weld overlay shall be assumed to contain the largest radial planar flaw that could exist within that volume. This assumed (postulated) flaw shall meet the inservice examination standards of IWB-3514-2. Alternatively, the assumed flaw shall be evaluated and shall meet the requirements of IWB-3640, IWC-3640, or IWD-3640, as applicable. Both axial and circumferential planar flaws shall be assumed. “</i></p>	<p>Any uninspectable volume in the weld overlay shall be assumed to contain the largest radial planar flaw that could exist within that volume. This assumed flaw shall meet the inservice examination standards of Table IWB-3514-2. Alternately, the assumed flaw shall be evaluated and shall meet the requirements of IWB-3640. Both axial and circumferential planar flaws shall be assumed.</p>

Figure 1 Appendix Q and Proposed CC-740-1



Examination Volume A-B-C-D

New Figure 1 Proposed CC-740-1

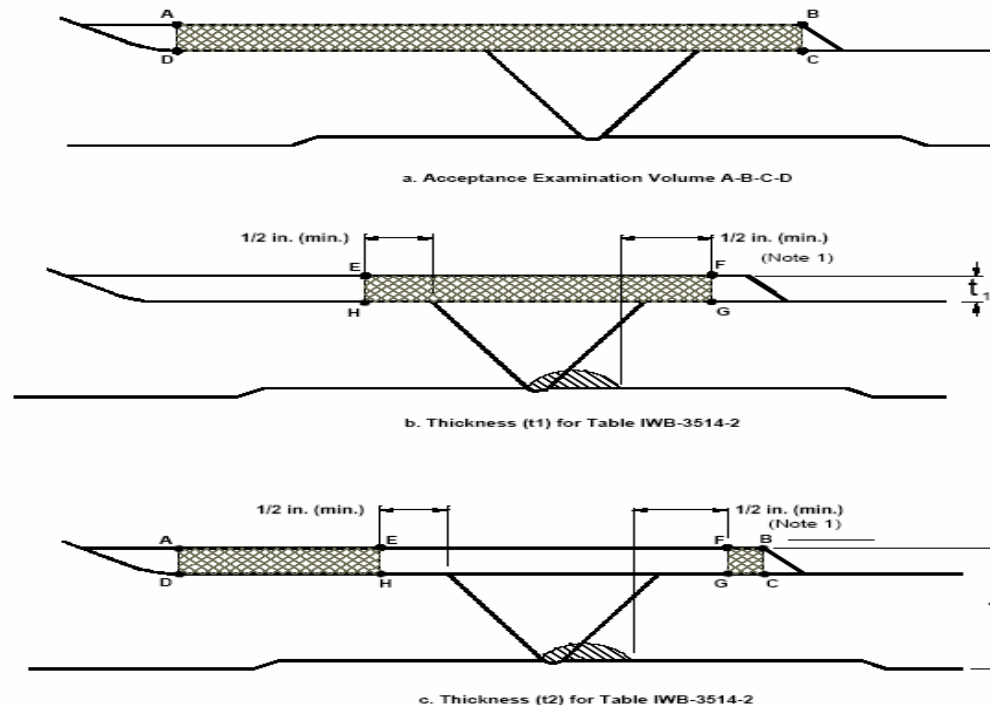
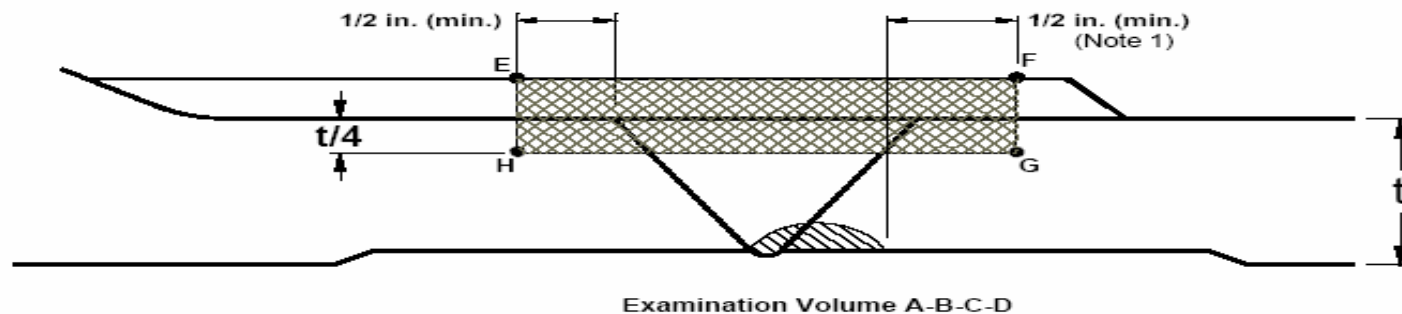


Fig. 1 Acceptance Examination Volume and Thickness Definitions

Notes:

- (1) For axial or circumferential flaws, the axial extent of the examination volume shall extend at least $\frac{1}{2}$ in. (13mm) beyond the toes of the original weld.
- (2) The weld includes the weld end butter, where applied.

Figure 2 Appendix Q, CC-740 and CC-740-1



NOTES:

- (1) For axial or circumferential flaws, the axial extent of the examination volume shall extend at least 1/2 in. (13mm) beyond the as-found flaw and at least 1/2 in. (13mm) beyond the toes of the original weld.
- (2) The weld includes weld end butter, where applied.

Fig. 2
Preservice and Inservice Examination Volume

Flaw Evaluations (Proposed Code Case N-740-1)

- The acceptance criteria in the proposed CC-740-1 have been revised to address several items
 - Any laminar flaw >3.0” shall be rejected (Too aggressive)
 - Did not take into account size of overlay
 - Did not take into account that it may not be affecting the examination
 - Words still need to be changed
 - Remove reference to nominal pipe diameter
 - Reduction of coverage calculations should be calculated for the ISI volume (Figure 2) not the PSI volume (Figure 1a)
 - The ISI volume is the most critical volume and should be the one used for this calculation since this is the volume that will be inspected in the future
 - Consideration should be placed on location of the flaw when performing acceptance calculations
 - Flaws on the edge of overlay outside of the ISI examination volume should be evaluated to the inservice rules
 - Repair of overlay for benign non-structurally significant flaws that do not interfere with examination of the ISI volume do more harm than good

Ultrasonic Technique Limitations

- Sizing accuracy for laminar flaws
 - Currently, the techniques used for determining the width of laminar flaws are not part of the Appendix VIII qualification process
 - No documented acceptance criteria for sizing is available to judge the accuracy of these techniques
 - Currently, width determination is same process as measuring length of flaw
 - 0.75" RMS
 - Tends to oversize width of very small flaws

Ultrasonic Technique Limitations

- Sizing planar embedded flaws
 - Currently, the techniques used for depth sizing embedded planar flaws are not part of the Appendix VIII qualification process
 - No documented acceptance criteria for sizing is available to judge the accuracy of these techniques
 - Currently the same techniques used for measuring upper extremity (qualified to 0.125" RMS) of embedded planar flaws used for measuring lower extremities
 - Tip diffraction
 - Believed to be accurate

Ultrasonic Technique Limitations

- Examination below upper 25% of original weld and base material (Covered in more detail in separate presentation)
 - Currently, the techniques used for examination are optimized to examine only the upper 25% of the original weld and base material
 - Appendix VIII requires that all qualification flaws extend into outer 25% of weld or base material
 - There is at present no way to qualify a procedure for examination below the upper 25%
 - No appropriate flaws in test samples
 - No Code criteria or regulatory basis for testing or acceptance

Ultrasonic Technique Limitations

- Examination of overlays applied to cast components
(Covered in more detail in separate presentation)
 - Appendix VIII does not address examination of overlays over cast material
 - No flaws in current test samples to qualify procedures and personnel
 - No Code criteria or regulatory basis for testing or acceptance
 - Do not know if present techniques will work in cast material

Ultrasonic Technique Limitations

- Projects approved to address these limitations
 - *“Inspection & Mitigation of Allow 82/182 Butt Welds”*
 - Jointly funded by MRP, MEOG, and EPRI NDE
 - Addresses examination of cast material and examination beyond the upper 25% of base material
 - *“Indication Evaluation & Disposition for Weld Overlays”*
 - Funded by EPRI NDE
 - Addresses sizing of embedded planar flaws and laminar flaws
 - All projects include development of code cases and relief requests in order to get criteria accepted by NRC and Code

Alloy 52 Weld Overlay Guidance Document

- NDEC is working with RRAC in the development of an Alloy 52 Guidance Document
 - Funded by several interested utilities using either RRAC or NDEC SRA funds
 - Contact Shane Findlan or Carl Latiolais for more information
 - Contains lessons learned and recommendations from both a welding and NDE perspective
 - Currently in a draft form
 - NDE Draft 3
 - Welding Draft 9
 - Revision 0 to be issued in Summer 2007
 - Will be revised after each series of applications in order to capture lessons learned

Guideline Document

- Welding evaluation plans
 - Introduction
 - Development plans and qualification for Inconel 52M weld material
 - Lessons learned from a welding perspective
 - Wire classification and screening
 - Cleaning (interpass)
 - Welding progression
 - Wire diameter
 - Grinding
 - First layer considerations (Cr % and TB)

Guideline Document

- Welding evaluation plans (cont.)
 - Field experience - problem areas
 - BM issues
 - Aggressive schedules
 - Equipment reliability
 - Defects found (includes metallographic data) – root cause
 - Contour measurements (templates, thickness measurements)
 - Expertise (weld craft, supervisors)
 - Communication (shift change out)
 - Interpass temperature
 - Required Code Cases (welding and NDE) – (e.g. 48-hour hold)

Guideline Document

- Required preparation for applying weld overlays from a welding perspective
 - Weld mockups (fidelity)
 - Walk down (interference, accessibility)
 - Weld travelers (heat input, TS)
 - Bead logs
 - Minimum overlay – welding procedures to maintain contour
 - Non-360° welds (striping), layer sequencing
 - Training
 - Contingency planning
 - Defect removal and acceptance (BM, 360° or localized)
 - Additional shrinkage
 - Weld repairs
 - Material review (hot cracking issues)

Alloy 52 Weld Overlay Guidance Document

- NDE evaluation plans
 - Introduction
 - Examination plans
 - Overlay design considerations
 - Surface condition
 - Shape and length
 - Minimum and maximum overlay thickness
 - Scan plan development
 - Preservice examinations
 - Inservice examinations

Alloy 52 Weld Overlay Guidance Document

- NDE evaluation plans (cont.)
 - Search unit selection
 - Pre-overlay considerations
 - Contouring
 - Thickness readings
 - Weld travelers

Alloy 52 Weld Overlay Guidance Document

- NDE evaluation plans (cont.)
 - Acceptance criteria
 - Flaw evaluation processes
 - Lessons learned from an NDE perspective
- Appendix 1 Meeting Minutes from RRAC meeting Jacksonville, FL (6/19/2006)
- Appendix 2 Appendix 1 from Generic Procedure PDI-UT-8
- Appendix 3 Draft relief request template for use of Code Cases N-638-2, N-504-2 and Appendix Q
- Appendix 4 Draft relief request template for use of Code Case N-740
 - Note both reliefs include sections that allow the use of the PDI program in lieu of Supplement 11

Summary

- The application of acceptable overlays is possible
- PDI ultrasonic techniques being used today are not significantly different from those used in the past
- Significant amount of work underway to expand the application of weld overlays
- Work is needed on the acceptance criteria for weld overlays
- Guideline documents are being developed to capture lessons learned and assure consistent processes