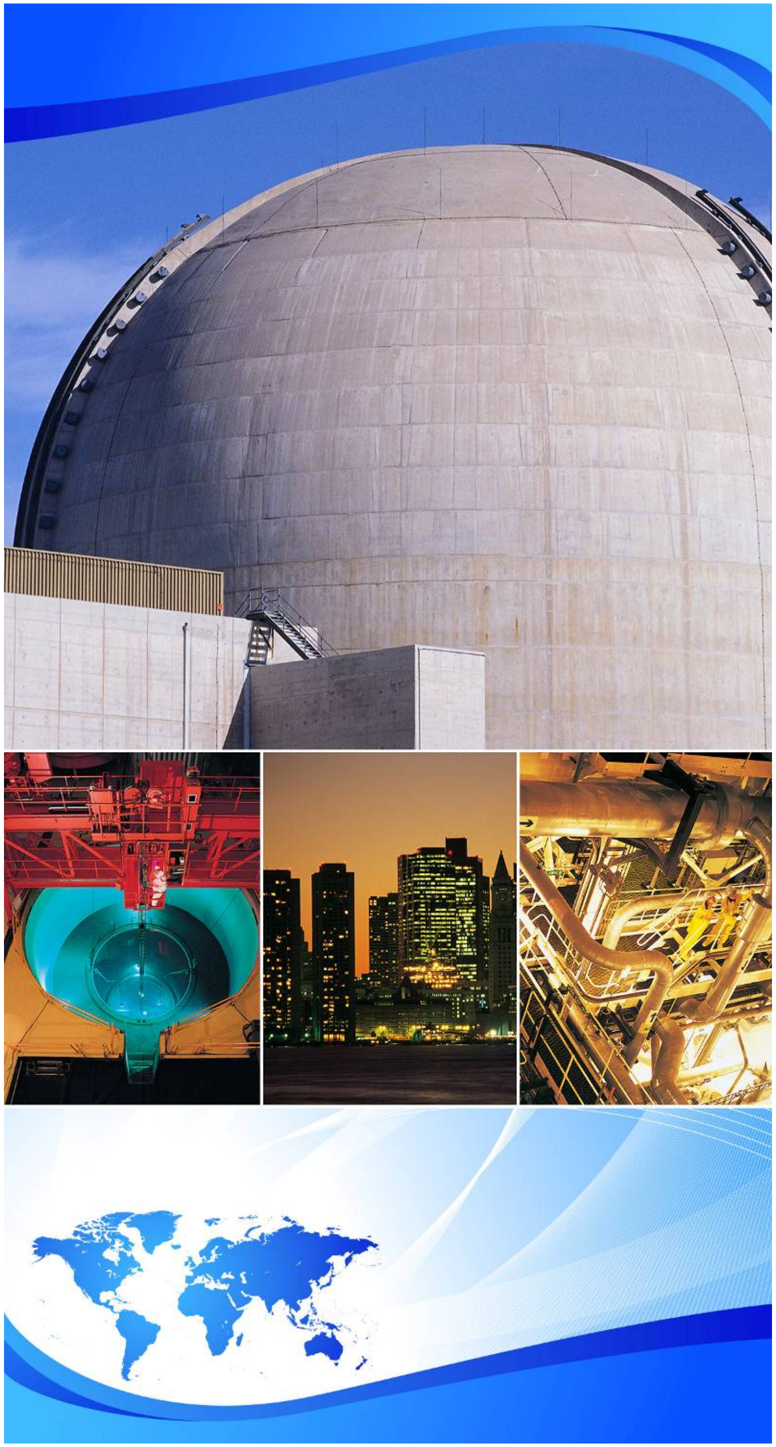

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xLPR Project
Quantification of POD for DM Welds in LBB Lines

NRC Public Meeting

January 7-8, 2009

Outline

- xLPR background and the role of POD
- POD project structure
  - Scope
  - Project activity sequence
  - Project Participants
  - Risks
- POD Communications Plan
- Detailed discussion of POD Modeling Project

xLPR background

xLPR – Extremely Low Probability of Rupture

- GDC #4 – "*Environmental and dynamic effects design bases*" allows use of analyses "reviewed and approved by the Commission" (i.e., Leak Before Break (LBB)) to demonstrate an extremely low probability of rupture (xLPR)
- LBB analysis widely applied to certain RCS lines in PWRs
  - Has limited the need for pipe hangers and restraints
  - Based on service experience and analytical capabilities of the '70's & '80's
  - No safety credit is taken for inspection under LBB

xLPR background

xLPR Project

- The collaborative xLPR Project will
  - Develop a more robust, fully probabilistic, approach to GDC #4 compliance
  - Incorporating current service experience
  - Allow for evaluation of degradation mechanisms
  - Credit inspections
- Full development of the probabilistic fracture mechanics evaluation methodology and tools will take a few years to complete
- This presentation focuses on one aspect: NDE reliability in support of credit for inspections

xLPR background
NDE reliability

- Credit for inspection requires a measure of NDE reliability
- NDE reliability often is expressed using probability of detection (POD) curves
  - Usually expressed as a function of one or more flaw parameters
  - The following are developed:
    - POD mean value curve
    - Confidence bounds
  - Obtaining small bounds at high confidence requires many, many measurements (thousands)
- The safety significance of POD can be quantified only within an integrated structural integrity assessment
  - POD by itself is of limited use, and can be misleading if applied without a quantitative understanding of its safety significance

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xLPR background

POD analysis goals

- Develop reliable PODs
  - For DM weld configurations within typical LBB lines
  - Based on PDI data
- Manage understanding & communications
  - To avoid consideration of POD results independently from integrated structural integrity calculations
  - Through effective communication and project transparency between industry team, utility executives, and NRC

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POD project structure
Scope

- Develop probability of detection (POD) information
  - Relevant specifically to inspection of plant dissimilar metal welds of Alloy 82/182 within LBB lines
  - Inferred from the Performance Demonstration Initiative (PDI) database (while protecting the PDI test blocks' truth information)
  - Tailored for use in xLPR probabilistic analysis

POD project structure

Project activity sequence

- Establish advisory/oversight groups (Core, Project, Executive)
- Develop & approve POD Communications Plan
- Prepare PDI data for analysis
- Develop POD evaluation methodology
  - Software tools
  - Binning approach for data subsets
  - Dry-run calculation process (artificial data)
- Meet with NRC (today)
  - Program overview & context
  - Present POD Communications Plan
  - Detailed review of methodology
  - Build consensus on approach
- POD evaluation
  - Assess results
- Report results

POD project structure
POD EPRI technical leads

- Craig Harrington – MRP
- Greg Selby – Director, NDE
- Carl Latiolais – Senior Program Manager, Appendix VIII Qualification
- Frank Ammirato (EPRI contractor)

POD project structure

POD advisory oversight

Core Team

Danny Cordes – Southern Co - MRP
Tony Oliveri – PSEG - MRP, BWRVIP
Gary Loftus – Southern Co - PDI
Randy Linden – PPL - PDI
Rich Ciemiewicz – Exelon - BWRVIP
Greg Selby – EPRI NDE Center
Jack Spanner – EPRI NDE Center
Phil Ashwin – EPRI NDE Center
Frank Ammirato – Contractor

POD Executive Committee

Joe Hagan – FENOC	PMMP EOC (MRP) BWRVIP
Rick Libra – Exelon	BWRVIP
Joe Donahue – Progress	NDE APWG, PMMP EOC (MRP), MEOG
David Czufin – Exelon	PMMP EOC (MRP), BWRVIP
John Meyer – Luminant	PMMP EOC (MRP)
Jeff Gasser – Southern Nuclear	PMMP EOC (MRP), MEOG

Project Team

Greg Kammerdeiner – FENOC - MRP
Danny Cordes – Southern Co - MRP
Tony Oliveri – PSEG - MRP, BWRVIP
Gary Loftus – Southern Co - PDI
Randy Linden – PPL - PDI
Rich Ciemiewicz – Exelon - BWRVIP
Bob Geier – Exelon - BWRVIP
Chuck Wirtz – FENOC - BWRVIP
Scott Boggs – FPL - MRP
Terry McAlister – SCANA - MRP, NDE
Denny Weakland – FENOC - MRP
Greg Selby – EPRI NDE Center
Jack Spanner – EPRI NDE Center
Phil Ashwin – EPRI NDE Center
Bob Carter – EPRI
Carl Latiolais – EPRI NDE Center
Jeff Landrum – EPRI NDE Center
Frank Ammirato – Contractor

POD project structure

Risks in POD Quantification

- What POD is good enough? There's no fixed standard
  - "Good enough" only defined through an integrated assessment
  - Understand implications of POD results before taking action
- Many LBB locations are expected to exhibit "high" PODs, but POD might not be "high" for <u>all</u> locations
  - Challenge to previous analyses
  - Challenge to previous examinations
  - Challenge to inspection qualification program
  - Challenge to existing operability determinations with a basis predicated on an assumed POD (across BWRs and PWRs)
- Misinterpreting POD
  - Sparse data may lead to low statistical confidence, even if POD is high; could be misinterpreted as inadequate NDE performance

Current Issues w/ Application of POD in xLPR

- Approach and technical basis will be presented for:
  - Treatment of axial flaw data
  - Treatment of sizing error
  - Binning strategy
  - Use of passed + failed results
  - Use of mean POD versus lower bound

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POD Communications Plan - Overview

- **Major sections**
  - Introduction and Scope
  - Definitions and Descriptions
  - Utility Communications
  - Regulator Communications
  - Attachments

POD Communications Plan

- **Introduction and Scope**
  - ***Background of LBB and xLPR***
  - ***Role of POD***
  - ***Importance of Communications***
  - ***Identification of Stakeholders***
    - Industry Issue Programs (MRP, NDE, PDI, BWRVIP, PWROG)
    - Utilities
    - NRC

POD Communications Plan

- **Definitions and Descriptions**
  - ***POD definitions and interpretation***
  - ***POD modeling approach***
  - ***ASME B&PV Code, Section XI, Appendix VIII***
    - Statistical basis
    - Relevance in POD modeling
  - ***PDI data***
    - Description
    - Use in POD modeling
    - Preparation of raw data for analysis

POD Communications Plan

- **Utility Communications**
  - ***Hierarchy of oversight and communication***
    - Core & Project Teams (MRP, NDE/PDI, BWRVIP)
    - POD Executive Committee
  - ***Criteria for communication level and frequency pertaining to project results***
      - **Initiating historical screening of analyses for POD use**
    - **Green –** "satisfactory" results – continue as planned
      - Consistent with past POD analytical inputs & no known adverse impact on plants
    - Yellow **– "**uncertain" results – Core Team notified w/in 24 hrs
      - Potentially inconsistent with past POD analytical inputs & plant impact possible
    - **Red – "**unsatisfactory" results - Core Team notified immediately
      - Probable inconsistentency with past POD analytical inputs & potential adverse plant impact
      - Yellow **& Red** – initiate Impact Evaluation
  - ***Communication process***
    - **Identification of communication lead**
      - Routine correspondence thru Project Team & MRP IIG Chair
      - Commitments thru POD EC
    - **Communication protocol –** Core Team - initial results review, draft docs, etc.

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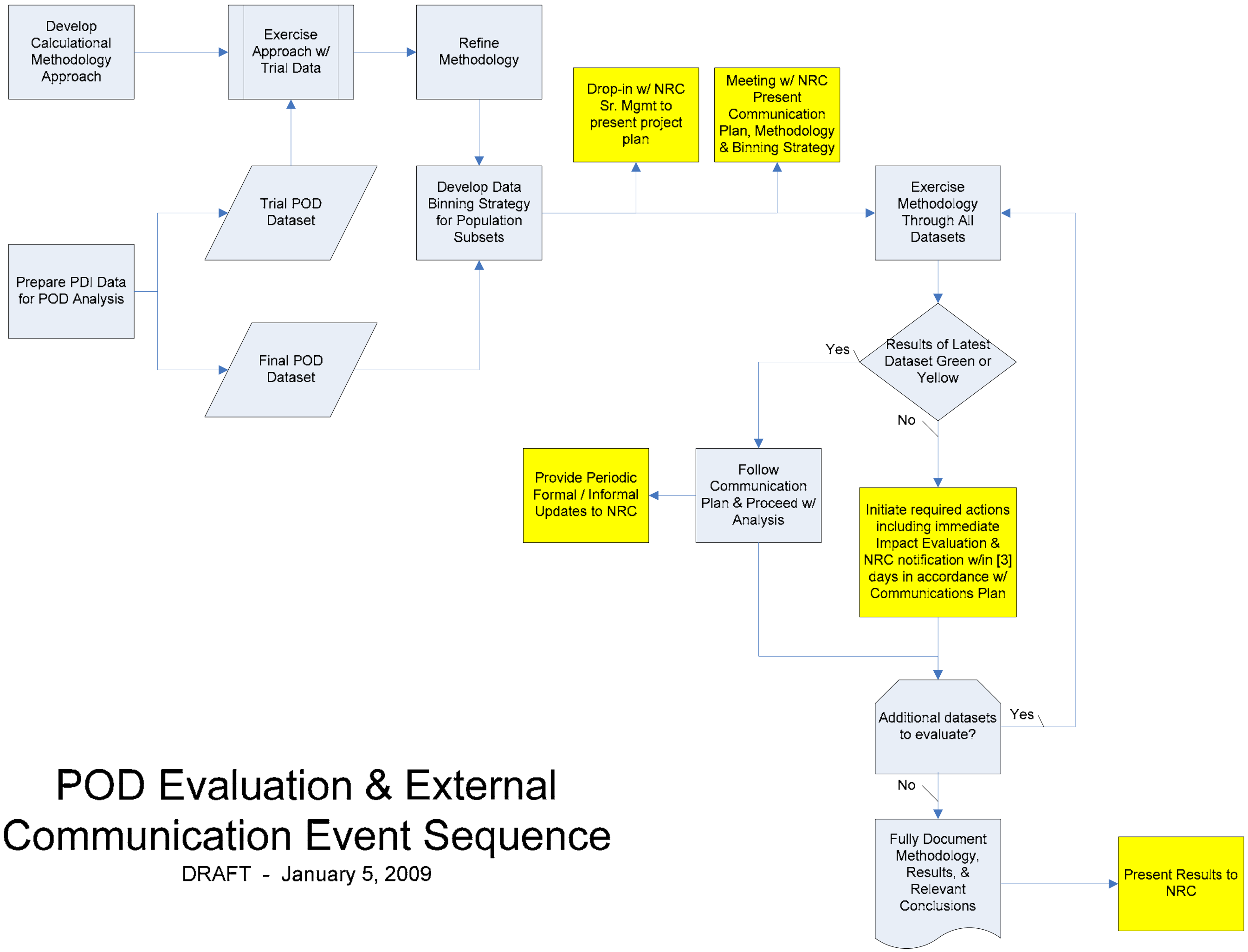
POD Communications Plan

- **NRC Communications**
  - ***Target audience –*** NRC-RES, NRC-NRR, PNNL (NDE expertise)
  - ***Objective of communication –*** transparency to develop confidence
  - ***Level of detail to be communicated*** – ensure full understanding and transparency
  - ***Frequency and schedule***
    - **Periodic updates**
      - *Overall project scope and schedule*
    - **As needed**
      - *POD Issues: Definitions, Applicability, Statistical basis & limitations, etc.*
      - *Evaluation methodology and data treatment*
      - *Results*
    - **Formal meetings**
      - *Minimum: at beginning and end of project*

POD Communications Plan

- **NRC Communications – cont'd**
  - ***Utility review and approval process for NRC communications***
    1. Schedule and general project status – *EPRI PM / Core Team*
    2. Prepared "educational" materials on POD Issues – *Core Team technical review; Project Team review of "soft issues"; EC review if to be presented to senior NRC management*
    3. Working meetings to develop methodology and data treatment methods – *Core Team review of approach*
    4. Routine, informal interaction with NRC and their contractor (e.g., PNL) by phone or in person to discuss methodology, data treatment methods, and related technical issues – *report periodically to EPRI PM / Core Team (apply green, yellow, red criteria above)*
    5. Formal presentation of POD Project positions on evaluation methodology and data treatment – *Core Team technical review; Project Team review of "soft issues"; EC review if to be presented to senior NRC management*
    6. Actual Results - *Core Team technical review; Project Team review of "soft issues" and evaluation against past uses of assumed POD analytical inputs; EC review*
    7. Identification of "Red" condition - *Core Team technical review; Project Team review of "soft issues" and plan for evaluation against past uses of assumed POD analytical inputs; EC review of prepared notification to NRC*

Project Communication Flowchart



POD Evaluation & External Communication Event Sequence

DRAFT - January 5, 2009

POD Oversight Membership

Core Team

Danny Cordes – Southern Co - MRP
Tony Oliveri – PSEG - MRP, BWRVIP
Gary Loftus – Southern Co - PDI
Randy Linden – PPL - PDI
Rich Ciemiewicz – Exelon - BWRVIP
Greg Selby – EPRI NDE Center
Jack Spanner – EPRI NDE Center
Phil Ashwin – EPRI NDE Center
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David Czufin – Exelon	PMMP EOC (MRP), BWRVIP
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Jeff Gasser – Southern Nuclear	PMMP EOC (MRP), MEOG

Project Team

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Danny Cordes – Southern Co - MRP
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Bob Carter – EPRI
Carl Latiolais – EPRI NDE Center
Jeff Landrum – EPRI NDE Center
Frank Ammirato – Contractor

Near-term Actions

– Meet with NRC

– Compile results of historical POD use screening

– Proceed with POD Evaluation

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Scope of POD Study*

- Locations containing Alloy 600/182/82 materials with LBB approvals
  - RPV inlet/outlet
  - SG inlet/outlet
  - PZR surge (hot leg and PZR connections)
- Initial scope is unmitigated locations
  - Overlay repaired welds considered for next phase
- Circumferential defects

* As discussed in NRC Research-EPRI/MRP meeting 9/13/2007

POD Modeling to Support xLPR

- Objective: Develop POD estimates from PDI qualification data for input to xLPR assessment
- POD is one of many inputs to a probabilistic assessment to support xLPR
- POD alone is of limited usefulness
  - No definitive criteria are available for judging POD in the absence of an integrated PFM methodology
  - PFM methodology enables assessment of sensitivity of rupture probability to POD

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POD Definition

- POD in this study is defined as the conditional probability of detecting a flaw during *performance demonstration* given the existence of a flaw within the procedure scope
- POD is being inferred from the PDI qualification program flaw detection results
  - Field application variables not addressed
  - No adjustments for sizing uncertainty
    - Basis: PWSCC of any size not acceptable by Code without further action

Appendix VIII Considerations Relevant to POD Modeling

- Appendix VIII designed to qualify procedures and personnel
  - Acceptance criteria are Pass/Fail, not quantitative measurement of capability
  - POD not specified or assessed
- Appendix VIII statistical basis
  - Ensure low likelihood of poor performers passing by chance
  - Ensure low likelihood of good performers failing by chance
  - Not based on capability to infer POD
- Many years of operation, however, have resulted in an extensive database of measurements that can allow inference of POD in some applications
  - Sufficient quantity of data is not present for all potential applications

Overview of PDI Database

- PDI formed to implement performance demonstration requirements of Appendix VIII to ASME SXI and 10CFR50.55a
- Extensive database of demonstrations accumulated since 2003
- Every candidate (personnel and procedure demos) must examine a set of realistic mockups with flawed and unflawed grading units and meet applicable acceptance criteria to qualify
  - Detection
  - Sizing (length and depth)
  - False call

Overview of PDI Database

- Demonstrations are closely monitored to ensure operator decisions are based on written logic described in the procedure
- Every attempt (successful or not) is recorded
- All data must be secured at all times to ensure confidentiality of the blind mockup information
  - Security plans are in place for this POD study
  - Places some limits on presentation of results
    - Example—can't show data points on plots

Description of PDI Database

- Operated under QA
  - Security
  - Proprietary vendor information
- PDI data is in a form to facilitate generating qualification certificates
  - Data is not in a format for input to POD modeling
  - Separate database developed for statistical analysis

Data Preparation

- Quality checks of transportation to statistical database for consistency and completeness
- Data queries to extract relevant data for POD modeling
  - Mockup configuration
  - Flaw selection
    - Alloy 600/182/82
    - Circumferential
    - Detection results only (excludes sizing)
  - Scanning considerations
- Format for input to POD model

POD Assessment

- Select all PDI data for identified LBB locations within xLPR scope
- Group data into bins corresponding to LBB locations configurations (more discussion later)
- Fit the data with a POD model using binary regression (Hit/Miss analysis)
- Logistic Model for POD
- Selection Basis:
  - Well established
  - Flexible
    - Linear or log size can be used
    - POD(0) not constrained to = 0
  - S shape fits well with experiment for many applications
  - Validated public domain software available for calculations

$$POD(x) = \frac{e^{a+bx}}{1+e^{a+bx}}$$

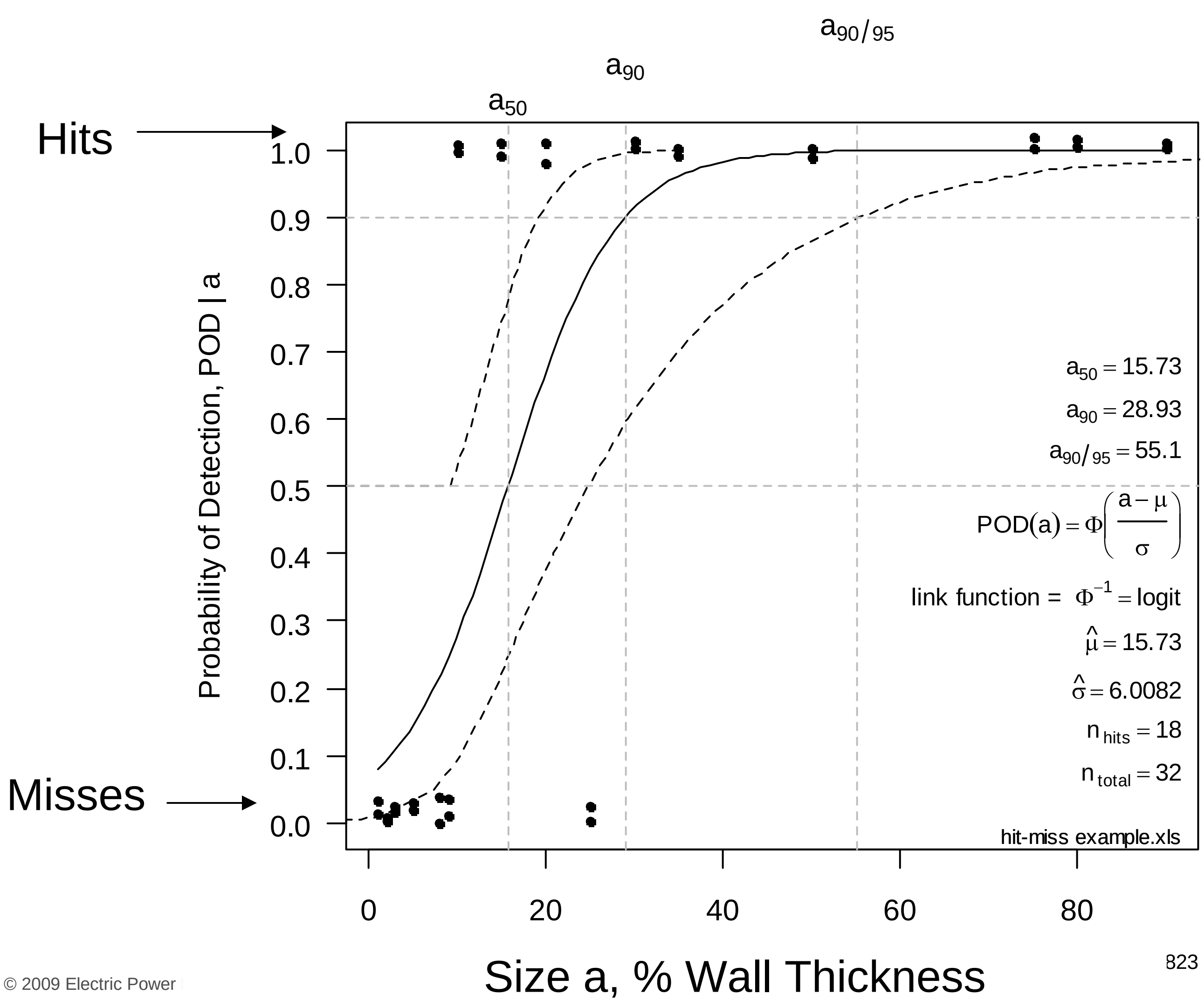
Modeling

- One parameter logistic model adopted using flaw size as the independent variable
  - Flaw size (through wall extent as % of wall thickness)
  - Insufficient data available to support multi-parameter modeling
    - Considerations of independence (flaw depth, length, etc)
- Calculations performed with R code
  - Same methodology and algorithms as used in previous POD studies (ex. BWRVIP-108, ASME Appendix L, PWR RPV Nozzle IR exams)
  - Use MIL-STD-1803 software as pre- and post-processor
- Code calculates 2-sided 95% confidence interval (~2.5% either side) around mean POD curve
  - Confidence intervals indicate uncertainty in estimate-sample size dependent
  - Not determined at this time what POD (mean, 90%, 95%, 1-sided confidence bound, etc) input will be used in PFM assessment in xLPR

POD Modeling Considerations

- Organizing the data into appropriate sets (“binning”)
- PDI Data is available only for flaws larger than ~ 10% T (Code criterion)
    - ∴POD curve perhaps not well defined at lower range of flaw size
    - Full S-shape may not be formed
- False calls not addressed
    - FC rate within qualification limit
- High detection rate (large preponderance of hits over misses) overdetermines the model
    - Possibly a poor fit; S-shape does not match well with flat line
    - Fit may not converge
    - May need to consider simpler model (e.g., simple proportions, x/n)

Binary Regression with Logistic Model-Example



Note: Data points showing hits and misses will not be shown on final plots in order to prevent identification of true flaw sizes in secure mockups

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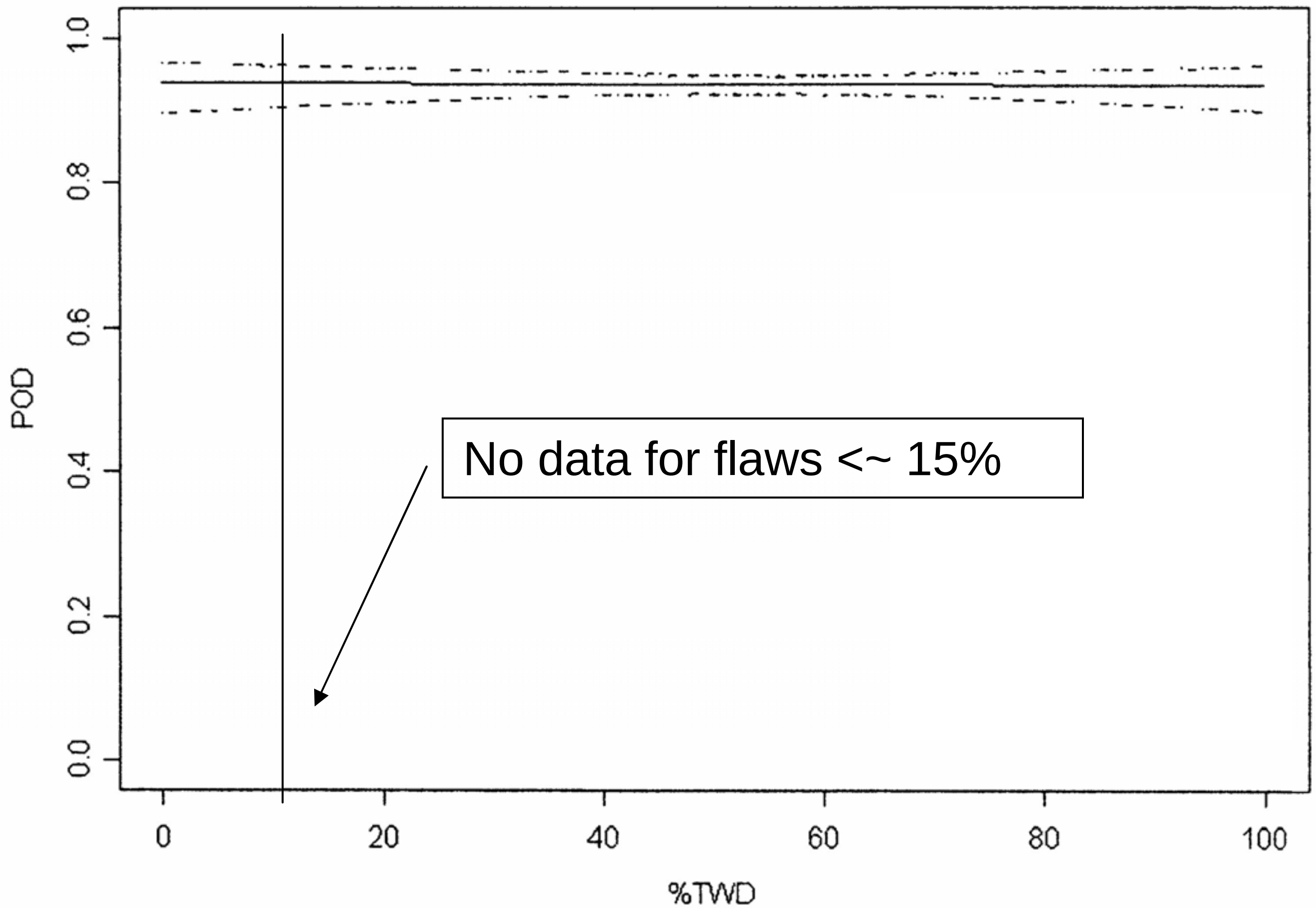
Example of High Detection Rate & Lack of Small flaw Data



Selection of Data for Modeling POD

- Limited to results on mockups with Alloy 600/82/182 material
- Analyzing only results from successful DM weld (Appendix VIII Supplement 10) demonstrations
  - Only qualified personnel and procedures can be used in ISI
- Circumferential flaw results only
  - Axial flaws have negligible contribution to rupture probability

Binning

- Definition: Partitioning PDI qualification data into groups (bins) with similar characteristics
  - Joint Configuration (Buttering, safe-ends, materials)
  - Wall thickness
  - Diameter
- Enables evaluation of NDE capability when configurations are significantly different or performance may vary among bins
  - Must ensure that a statistically sufficient amount of data is available for realistic modeling

Two Binning Approaches

- Bottom up
  - Evaluate all possible contributors to performance, e.g.,
    - Material
    - Crack geometry/type
    - NDE access
    - NDE procedure
    - Examiner qualification
    - Pipe diameter
    - Pipe wall thickness

    $$i * j * k * l * m * n * \ldots$$
  - Factorial design (many bins)
  - Consolidate where justified to a few bins

Two Binning Approaches

- Top down
  - Utilize previous experience (ASME Appendix L for example)
    - 56 bins collapsed to 4
  - Group according to physical characteristics of the locations in a limited LBB scope-reduces factorials
    - Only 2 Configuration classes: Large vessel nozzles, Smaller surge nozzles
    - Only 1 material: Alloy 600/182/82
    - Only 1 flaw orientation: Circumferential
    - Limited Procedure variation: determined by application (RPV-auto ID, Surge-manual & auto OD, SG-OD manual)
- Same result as bottom up approach: few bins

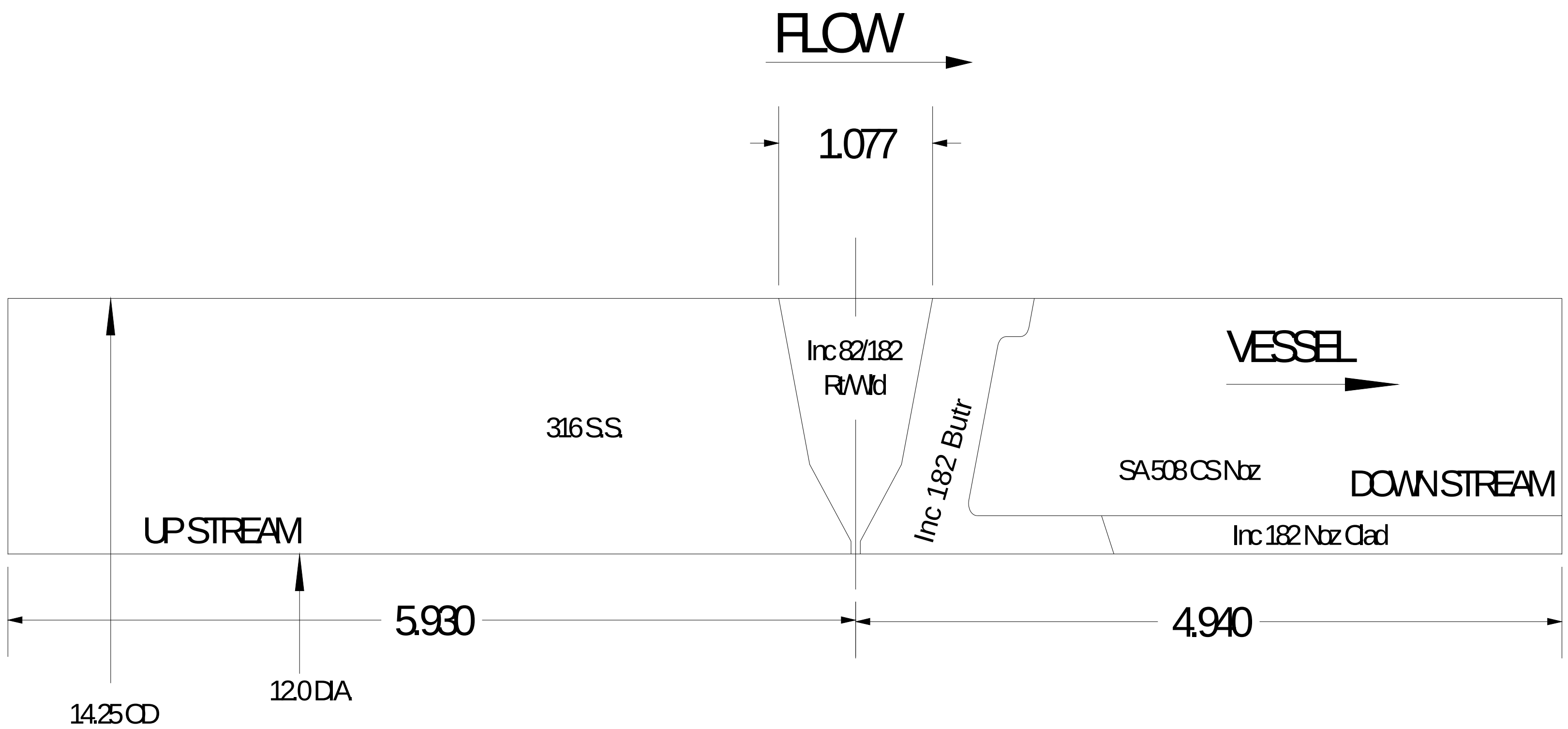
Selection of Bins in xLPR

- Chose Top Down approach
- Correspond to classes of LBB locations
- Bin A—Surge line connections (diameter 12” - 14”, thickness 1.2” - 2.2”)
  - PZR end
  - Hot leg end
  - ~1100 measurements (as of 11/30/08)
- Bin B—Vessel Nozzles (diameter 27” - 31”, thickness 2.5” - 5.25”)
  - RPV inlet & outlet-(Possible sub bin B1)
  - SG inlet & outlet (Possible sub bin B2)
  - RCS-pump welds are bounded
  - ~400 measurements (as of 11/30/08)

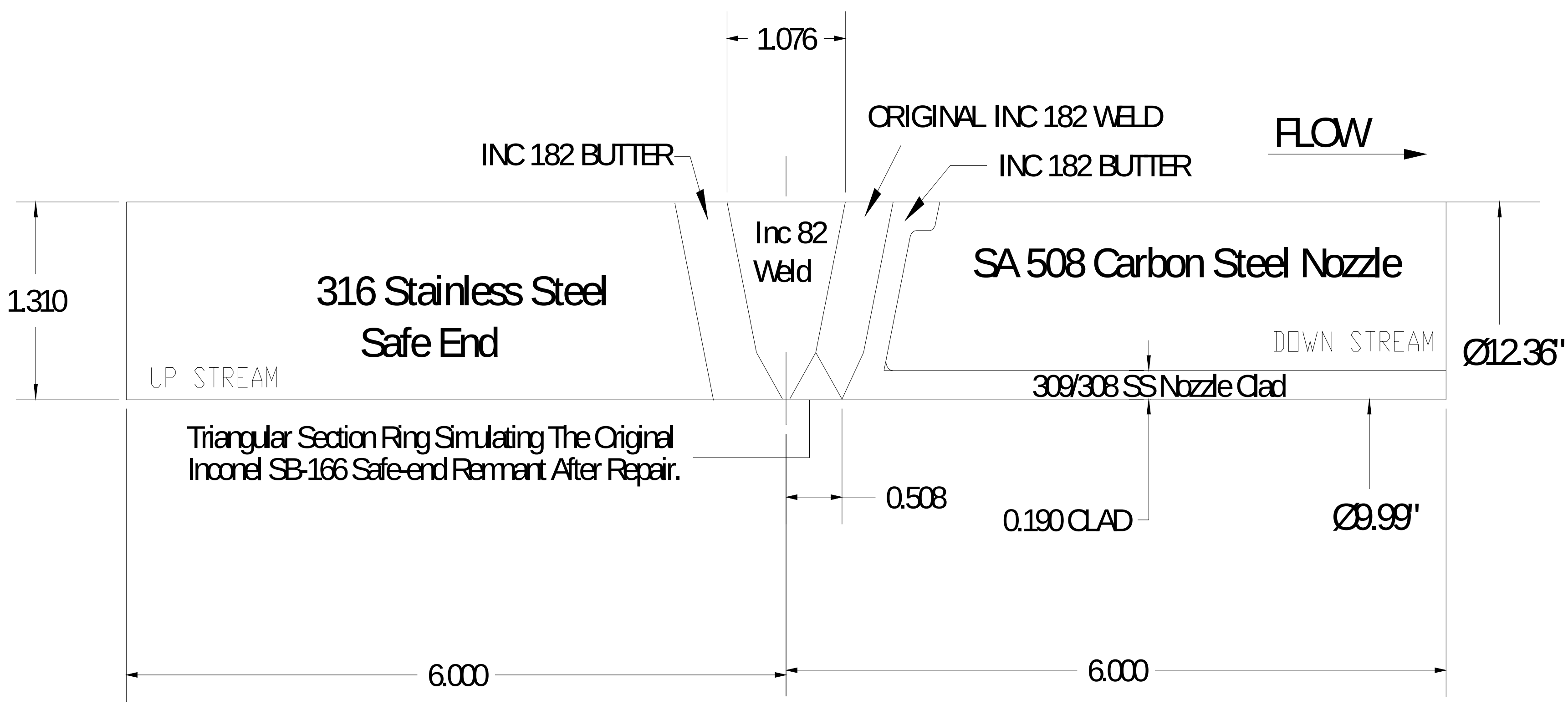
PDI Mockups

- Mockups designed after extensive survey of installed configurations
  - Materials
  - Geometry
  - Access
  - Surface conditions
- Mockups selected for POD study that match the LBB configurations

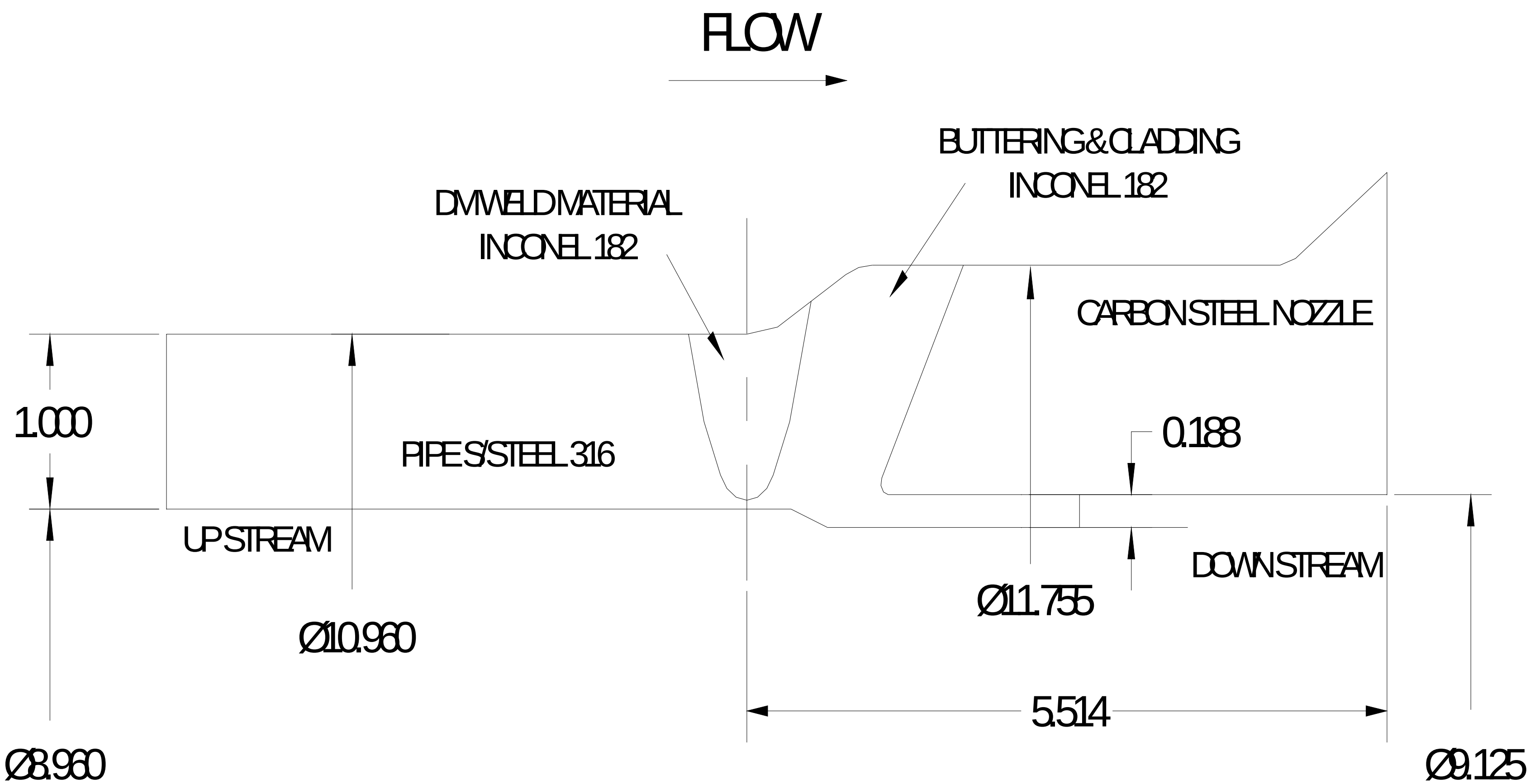
Bin A
Sample 705 Surge



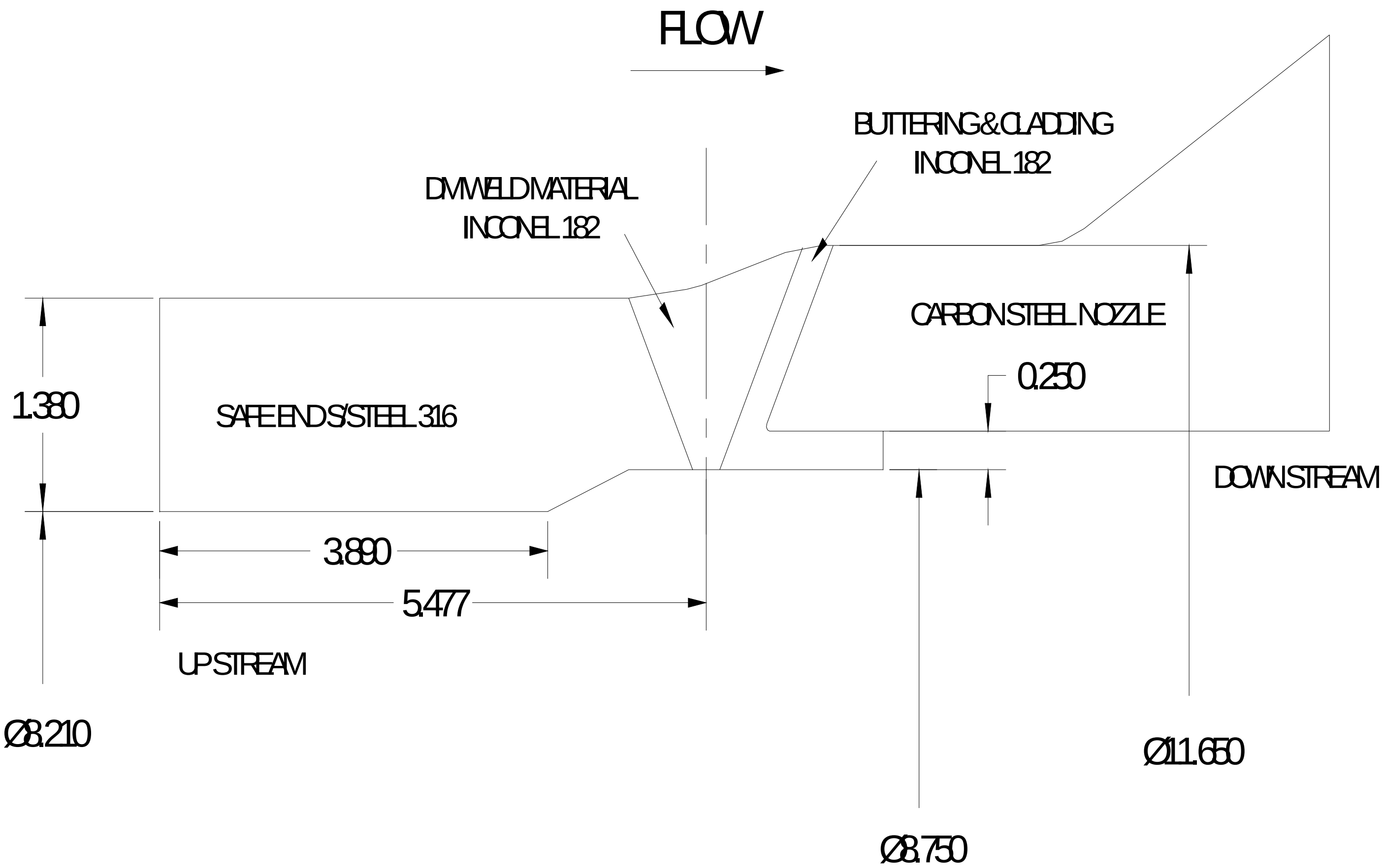
Bin A
Sample 706 Surge



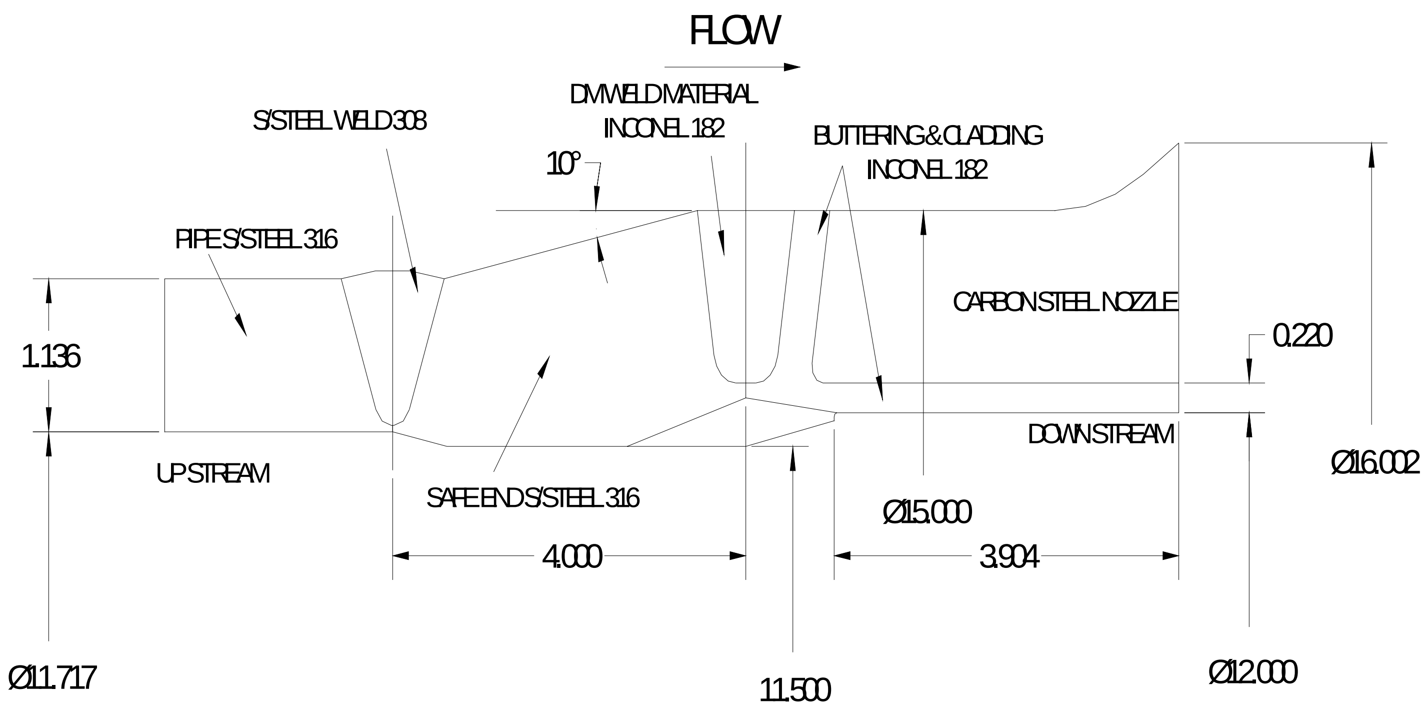
Bin A
Sample 708 Hot Leg Surge



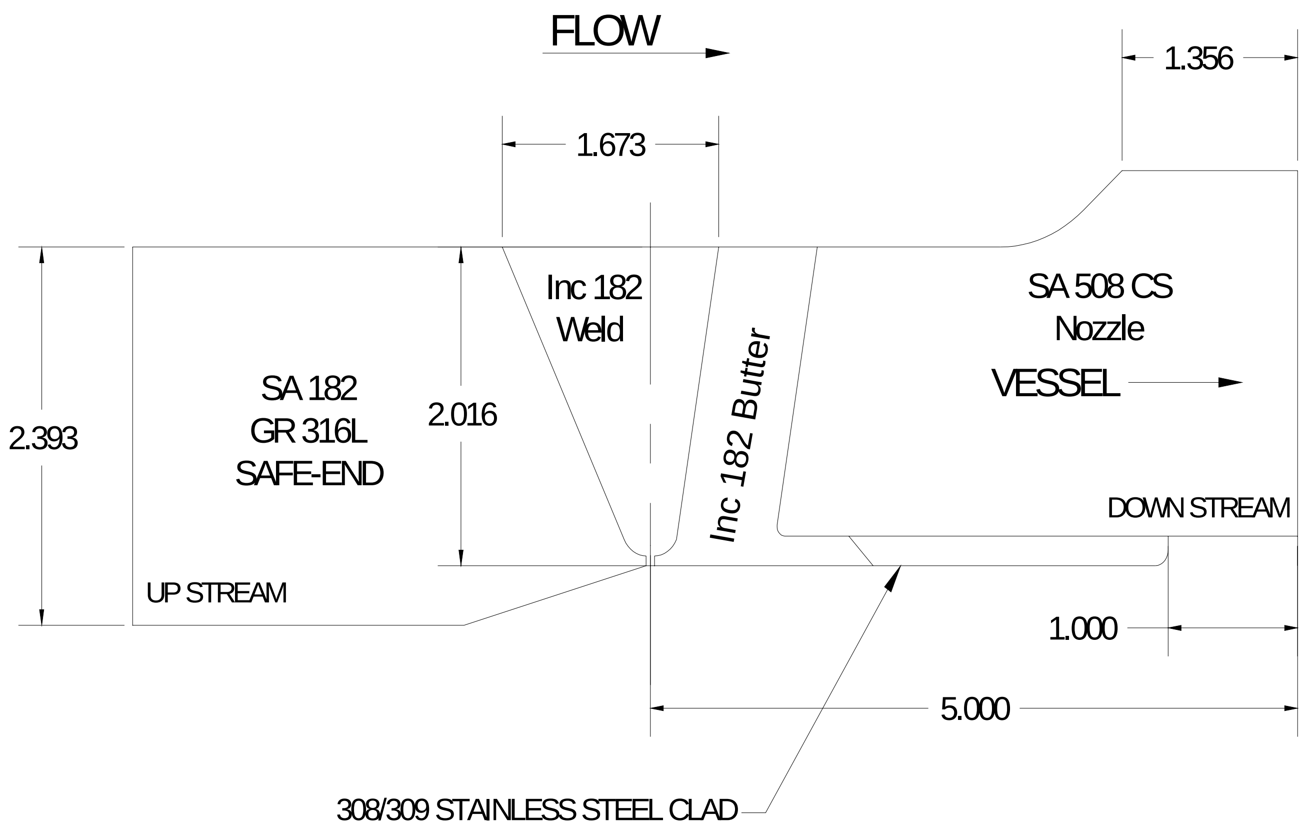
Bin A
Sample 708/x PZR Surge



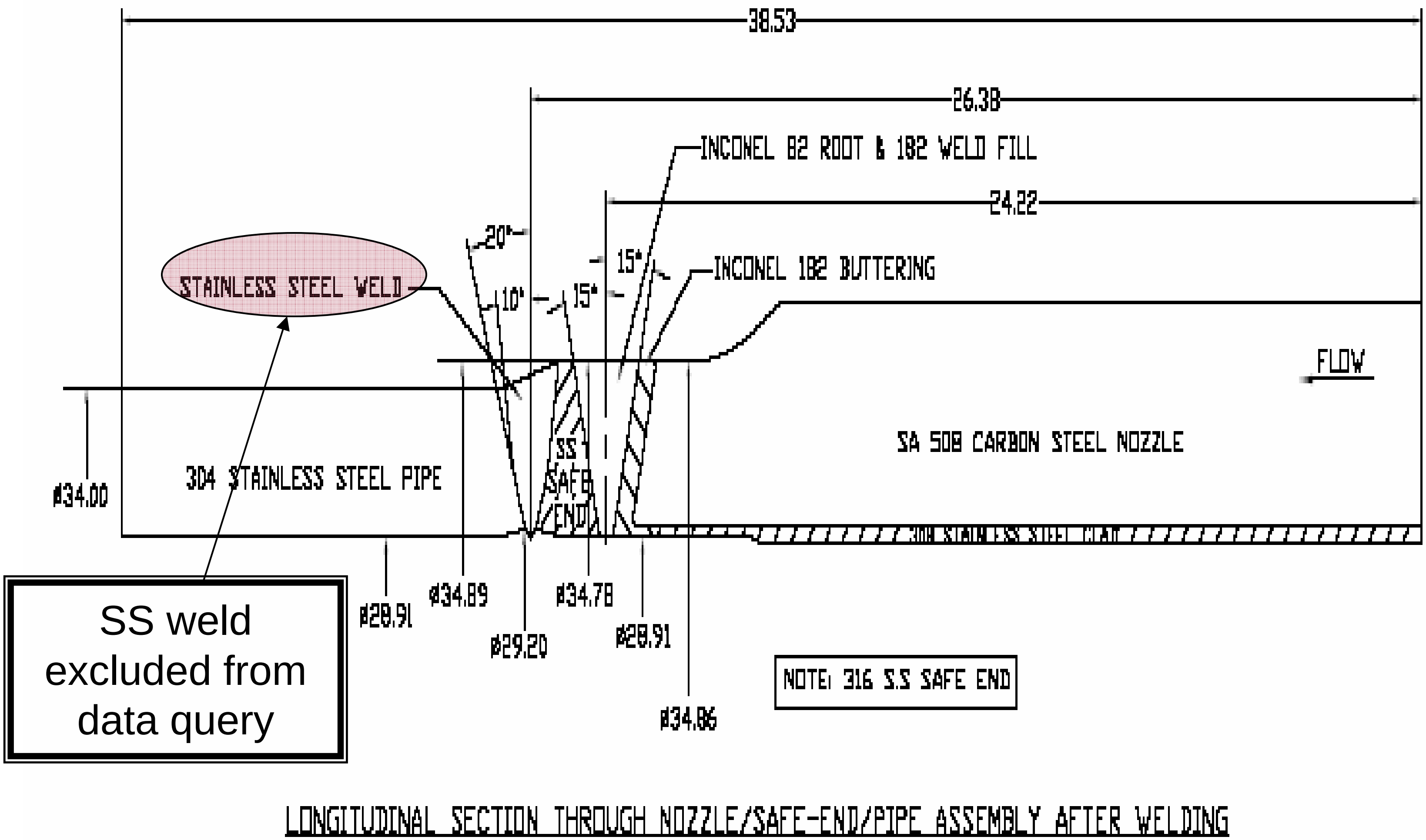
Bin A
Sample 708/x PZR Surge



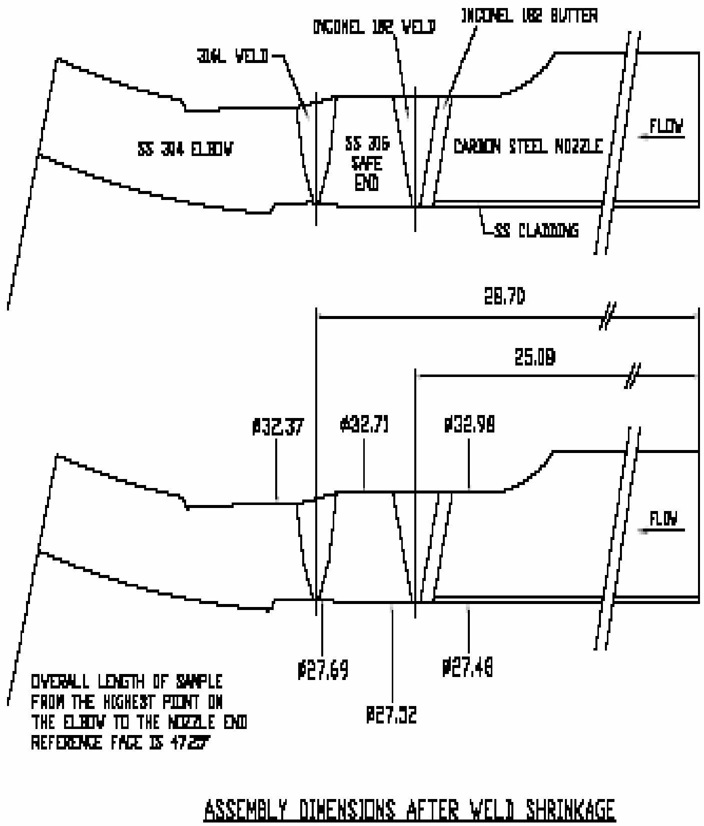
Bin A
Sample 708/x Surge Nozzle

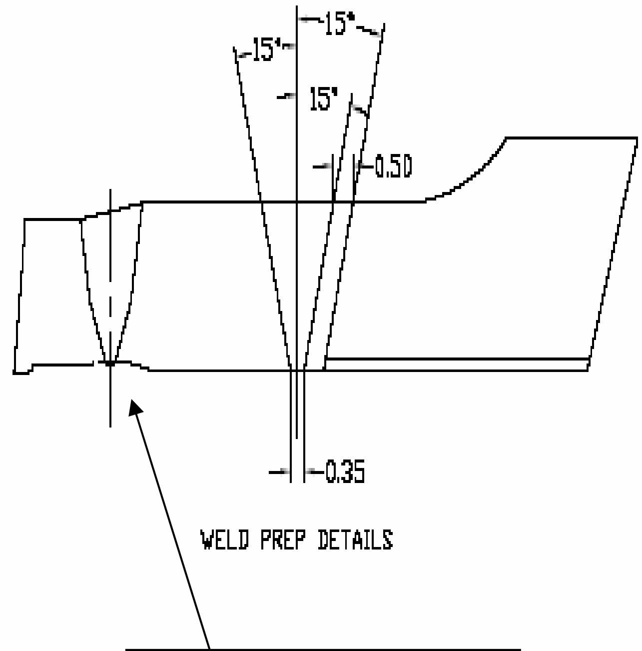


Bin B
Sample 601-Hot Leg



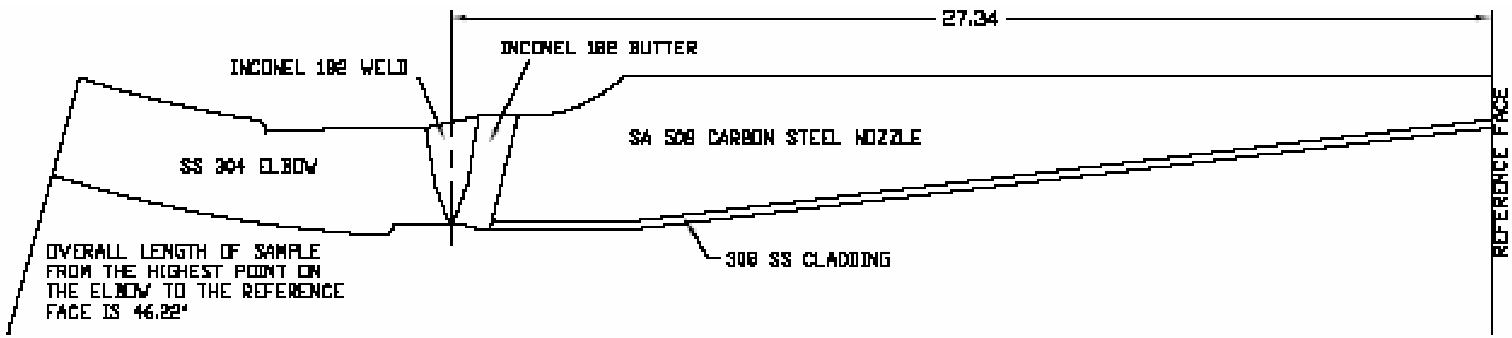
Bin B
Sample 603-Cold Leg



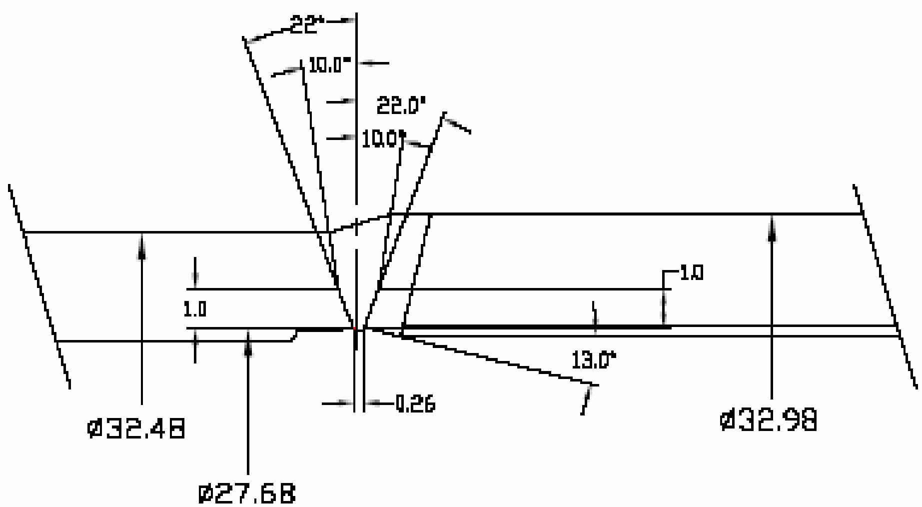


SS weld excluded from data query

Bin B
Sample 604-Cold Leg



NOZZLE TO ELBOW ASSEMLY DIMENSIONS AFTER WELD SHRINKAGE



DETAIL OF WELD PREP.

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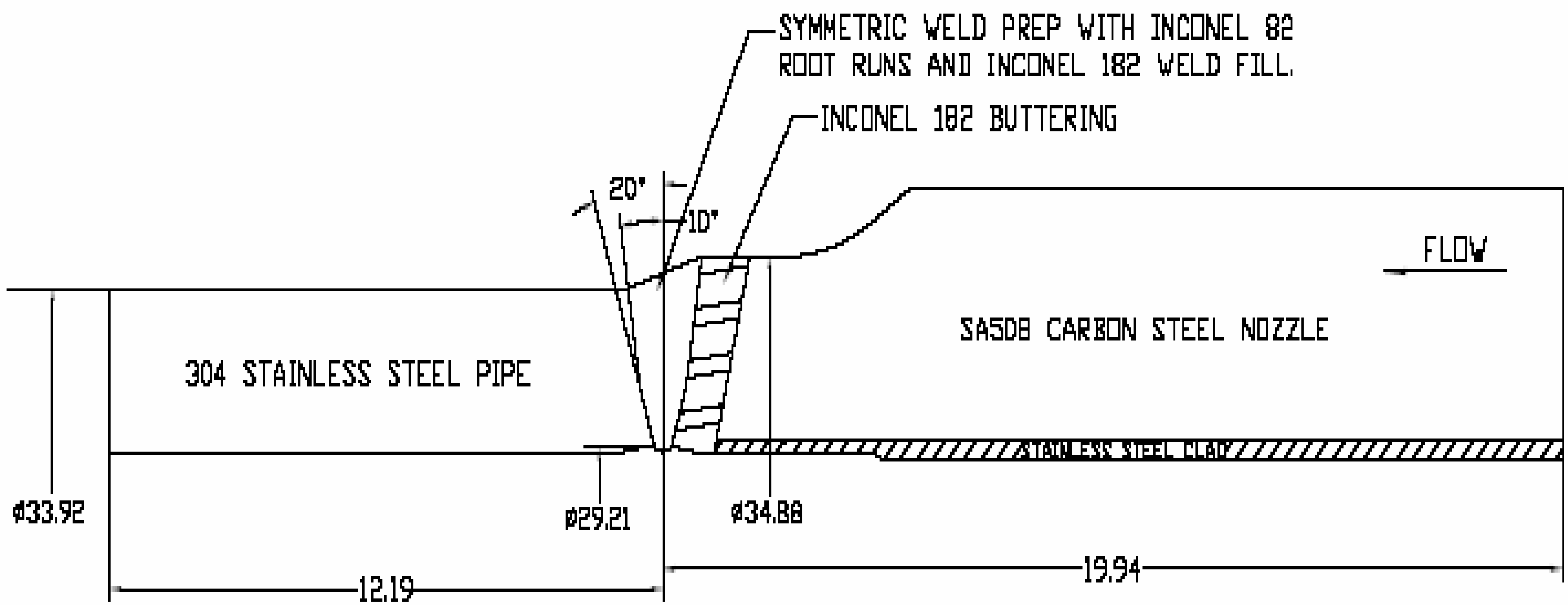
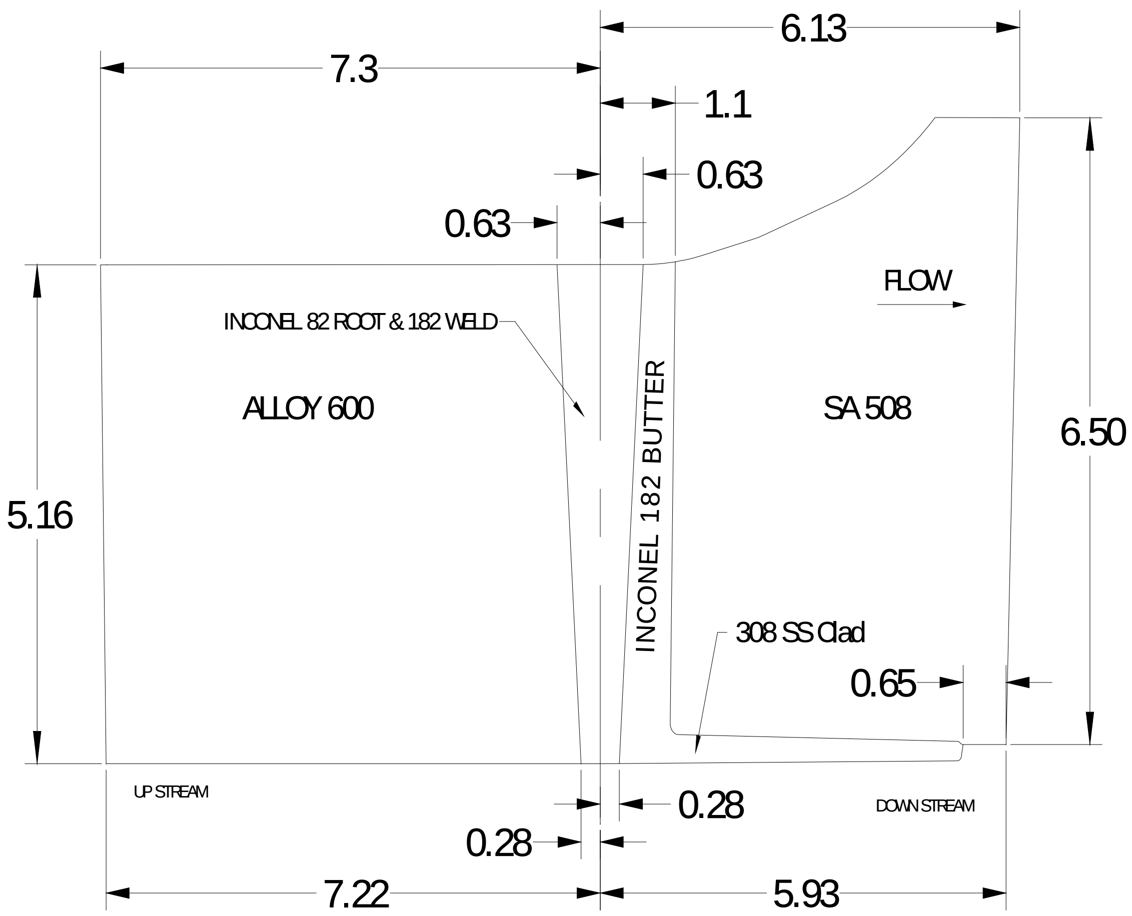
Bin B
Sample 602-Hot Leg



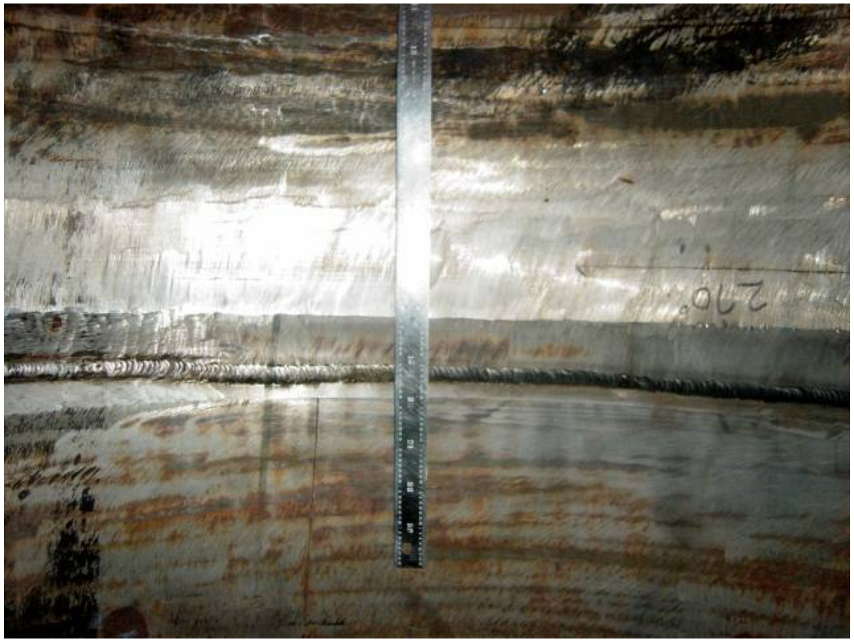
LONGITUDINAL SECTION THROUGH THE SPECIMEN SHOWING THE WELD CENTERLINE LOCATION

Bin B
Sample 712 Steam Generator Nozzle



Large vessel nozzles

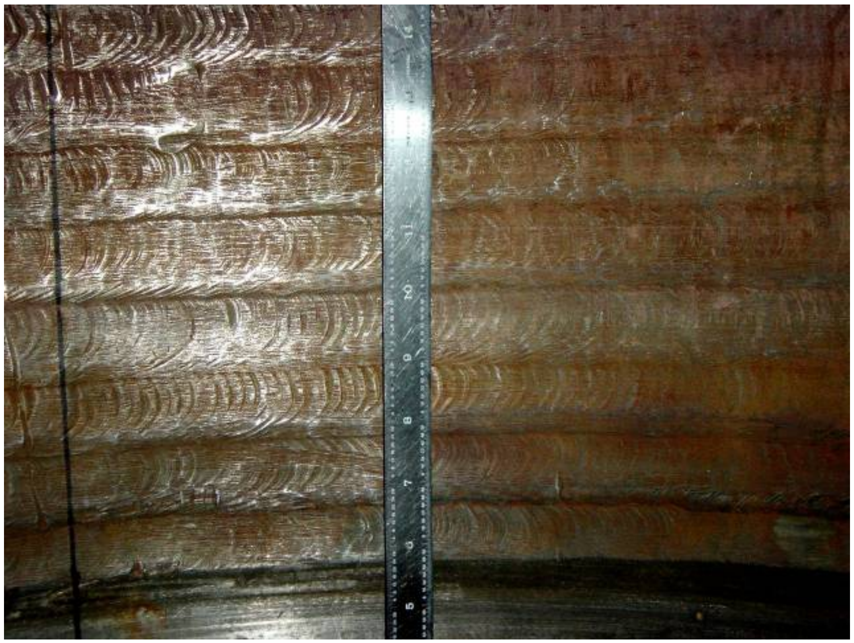
Large vessel nozzles



Large vessel nozzles

Challenging inside surface conditions

Large vessel nozzles – inside surface conditions



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Summary

- Extensive PDI database is being queried to provide data for POD inference to support xLPR
- POD models are consistent with previous POD studies
- PDI Mockups selected that map to LBB locations
- Relatively large amount of data has been identified and checked for POD modeling
- Determination of role of POD within xLPR is under development

Discussion

- Schedule
- Future meetings
- ??

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