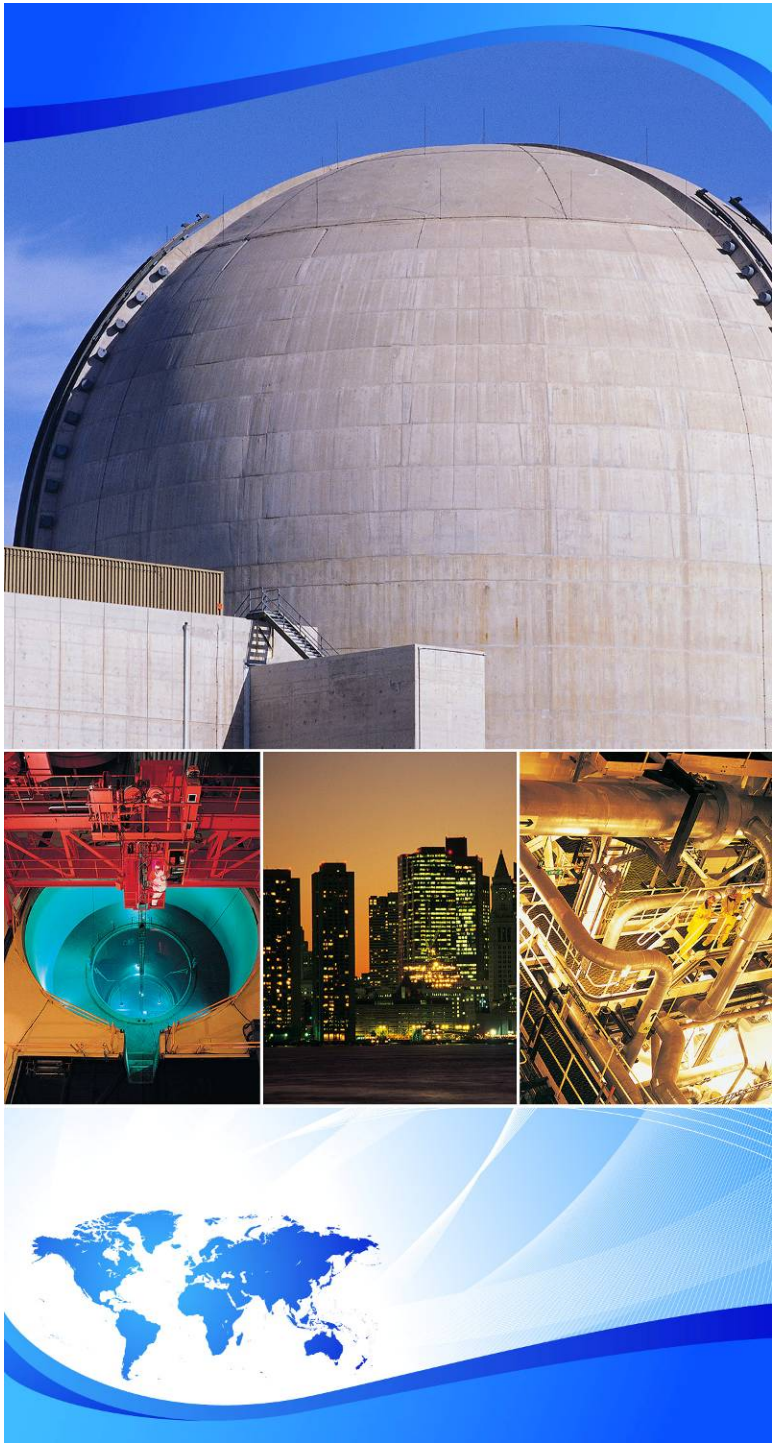

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Results of POD Assessment for Dissimilar Metal Welds in LBB Scope

EPRI / MRP / NRC
Public meeting

September 29, 2009

Outline

- Background
- Data selection, preparation and categorization
- POD modeling approach
- Results
- Next steps, summary, discussion

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Background

POD Study

- Objectives:
  - Develop standardized process for statistical analysis to determine POD
  - Produce POD curves for the subject weld population
  - Support incorporation of these POD results into xLPR
- Scope: Nickel-alloy locations with LBB approvals
  - RPV inlet/outlet
  - SG inlet/outlet
  - Pressurizer surge (hot leg and pressurizer connections)
  - Circumferential defects only

  - Initial focus is unmitigated locations
    - Overlay repaired welds considered for next phase

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Background
POD Study

- Definition of POD in this study
  - Conditional probability of detecting a flaw during *performance demonstration* given the existence of a flaw within the procedure scope
    - *Field application* variables are not addressed
- POD was developed from the PDI qualification program flaw detection results
  - POD was calculated as function of flaw depth (% of wall thickness)
  - Sizing uncertainty was not addressed
  - Three categories of locations were selected based on configuration and examination procedure
  - All original PDI data retained if needed for future use; truth state integrity preserved

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Background

Overview of PDI Program

- PDI was formed to implement performance demonstration requirements of ASME Code, Section XI, Appendix VIII and 10CFR50.55a
- Database of demonstrations since mid ’90s, world’s largest
- 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 calls
- 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 plan in place for this POD study
  - Places some limits on presentation of results
    - Example—can’t show data points on plots

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Background

Description of PDI Database

- PDI qualification program is operated under QA
  - Blind specimens, data, and records
  - Proprietary vendor information
- PDI data is in a form to facilitate generating qualification certificates
  - Personnel information
  - Procedure and revision number
  - Mockups and flaws examined (according to scope)
  - Results
    - Detection
    - Sizing (length, depth)
    - False calls
- Data is not in a format for input to POD modeling
  - Separate database was developed for statistical analysis

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Data selection, preparation and categorization

Selection of Data for Modeling POD

- Selected the qualification results from mockups representative of xLPR scope
- Assembled two data sets (as discussed in 1/09 meeting)
  - Successful (P) qualifications
  - Combined successful and failed (P+F) qualifications
- Circumferential flaw results only
  - Axial flaws have negligible contribution to rupture probability

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Definitions Used in the POD Study

- *Passed (P):* data and POD from qualification attempts that met both the detection and false call criteria
- *Failed (F):* data and POD from qualification attempts that failed either the detection or false call criteria or both
- *Passed + Failed (P+F):* data and POD obtained by combining the P and F results
- *False call:* declaring a flaw detection in an unflawed grading unit

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Data selection, preparation and categorization

Data Preparation

- Data queries made to extract relevant data within the scope for POD modeling
  - Mockup configuration (PWR LBB locations)
    - Some BWR mockups were included when the configuration was similar to a PWR LBB location
  - Flaw data selection (detection data only; circumferential flaws only)
  - Procedure (those that are used for PWR ISI)
- Transportation and reformatting from PDI data to statistical database
  - Process organized for consistency and completeness
  - Quality checks at every step
  - Format for input to POD model
- Process fully documented

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Data selection, preparation and categorization

Data Categories

- Three data categories were established, corresponding to classes of LBB locations
  - A (surge): medium-size welds examined from the outside
  - B1 (RPV): large pipes examined from the inside
  - B2 (SG): large pipes examined from the outside

Category	Application	Diameter Range (in)	Thickness Range (in)	Inspection Surface
A	Pressurizer Surge	12-14	1.2-2.3	Outside
B1	Reactor Vessel Nozzle	27-31	2.5-3.0	Inside
B2	Steam Generator Nozzle	27-31	5.0-5.2	Outside

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POD modeling approach

Type of model

- Fit the data with a POD model using binary regression (Hit/Miss analysis)
  - One-parameter logistic model for POD(x)
    - Independent variable: flaw depth, as % of thickness
  - Regression analysis produces maximum likelihood estimates for model coefficients β_1, β_2
- Result: six curves
  - Three categories (A, B1, B2)
  - Two cases (P and P+F)
- 95% upper and lower confidence bounds calculated for each curve

$$POD(x) = \frac{e^{\beta_1 + \beta_2 x}}{1 + e^{\beta_1 + \beta_2 x}}$$

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POD modeling approach

Modeling tools

- Calculations performed with ‘R’ code (publicly available statistical analysis package)
  - Similar to MIL-STD-1823 implementation of “R” but with improvements by P. Heasler (PNNL)
    - Automated processing
      - Script (programming) provided by Heasler
    - Was able to solve for confidence bounds when MIL-STD software failed
    - Detailed output for documentation

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POD modeling approach

Modeling considerations

- PDI Data available only for flaws ≥ ~10% T and ≤ ~90%T
  - ASME App VIII flaw distribution criteria (10 – 30%, 30 – 60%, 60 – 90%)
  - Curves were extrapolated to 10%T and 100%T to avoid disclosure of actual minimum and maximum flaw sizes in test sets
  - Extrapolation is over a relatively small span
- False calls were not considered relevant to POD calculation
  - False call performance is documented separately in the report
- Three alternative POD models were evaluated (all available within 'R' code)
    - Log likelihood
    - Bayesian (confidence bounds equivalent to log likelihood)
    - Wald (confidence bounds not accurate in small data sets or when POD near 1 or 0)
  - All three produced identical POD curves
    - Confidence bound calculations are different
  - **Log likelihood selected - confidence bounds calculation preferred**

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Results

Sample Population and Average Detection Rate

Circumferential Flaw Detection Performance Summary (Flawed Grading Units Only)

A: Surge line

B1:RPV Nozzles

B2:SG Nozzles

Category	Detection Attempts	Detections	Average Detection Rate
A(P)	1675	1582	94%
A(P+F)	2358	2131	90%
B1(P)	553	539	97%
B1(P+F)	590	576	98%
B2(P)	184	184	100%
B2(P+F)	258	249	97%

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Results

Average False Call Rates

Performance on Unflawed Grading Units

A: Surge

B1: RPV

B2: SG

Category	Attempts	False Calls	Average False Call Rate
A(P)	5020	259	5%
A(P+F)	7167	573	8%
B1(P)	1467	34	2%
B1(P+F)	1539	43	3%
B2(P)	111	18	16%
B2(P+F)	166	32	19%

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Results

Regression results

$$POD(x) = \frac{e^{\beta_1 + \beta_2 x}}{1 + e^{\beta_1 + \beta_2 x}}$$

Case	β_1	β_2	Standard Error β_1	Standard Error β_2
A(P)	2.7076	0.0031	0.2085	0.0045
A(P+F)	1.8789	0.0091	0.1348	0.0031
B1(P)	3.2440	0.0106	0.5490	0.0132
B1(P+F)	3.2996	0.0108	0.5493	0.0132
B2(P)	5.4089	0.0086	3.6423	0.0602
B2(P+F)	3.3148	0.0001	0.9516	0.0148

Flaw size is in units of %T

Note; The final report contains tabulated POD, upper and lower confidence bounds results

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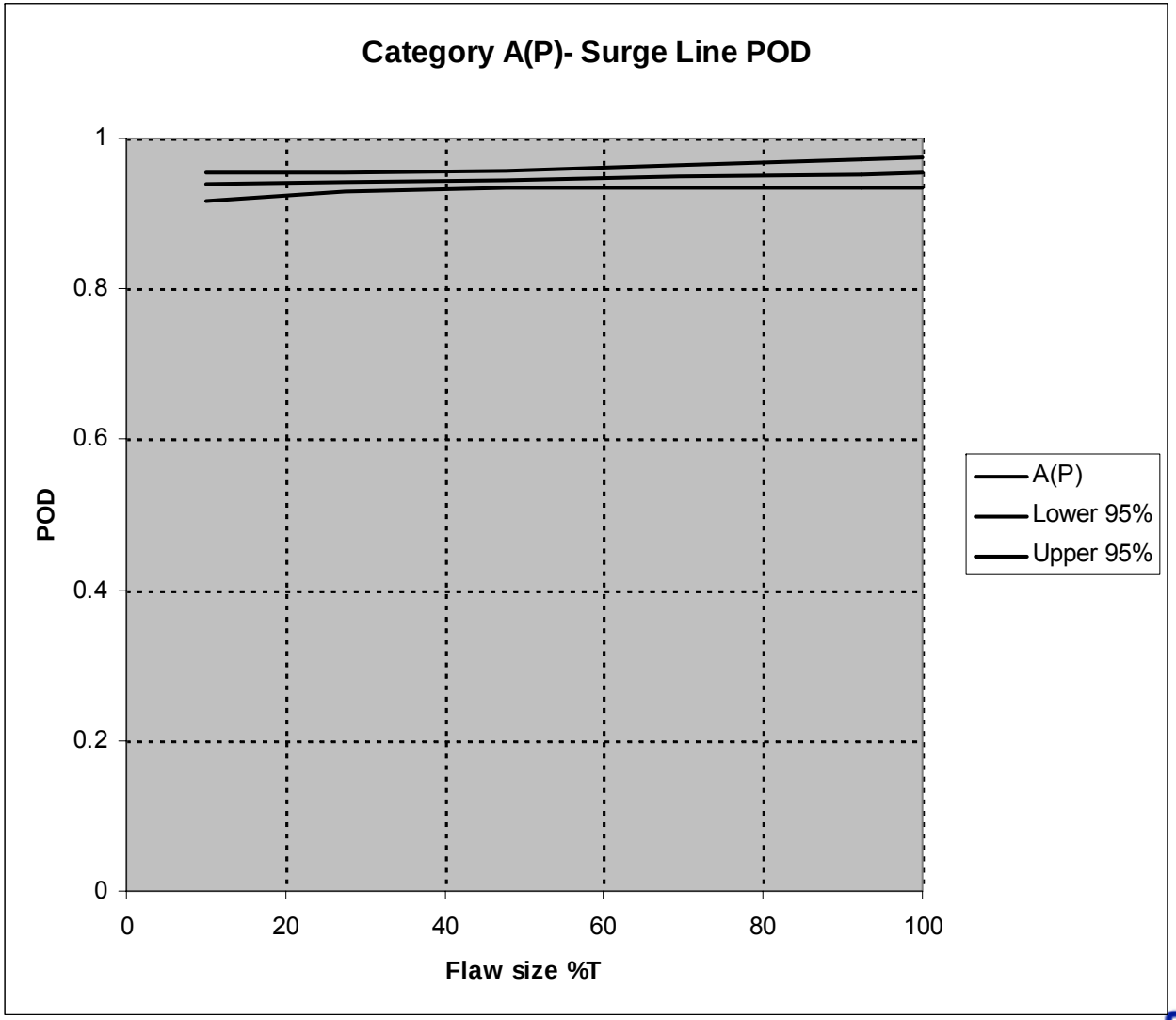
Results

POD: Surge line, passed



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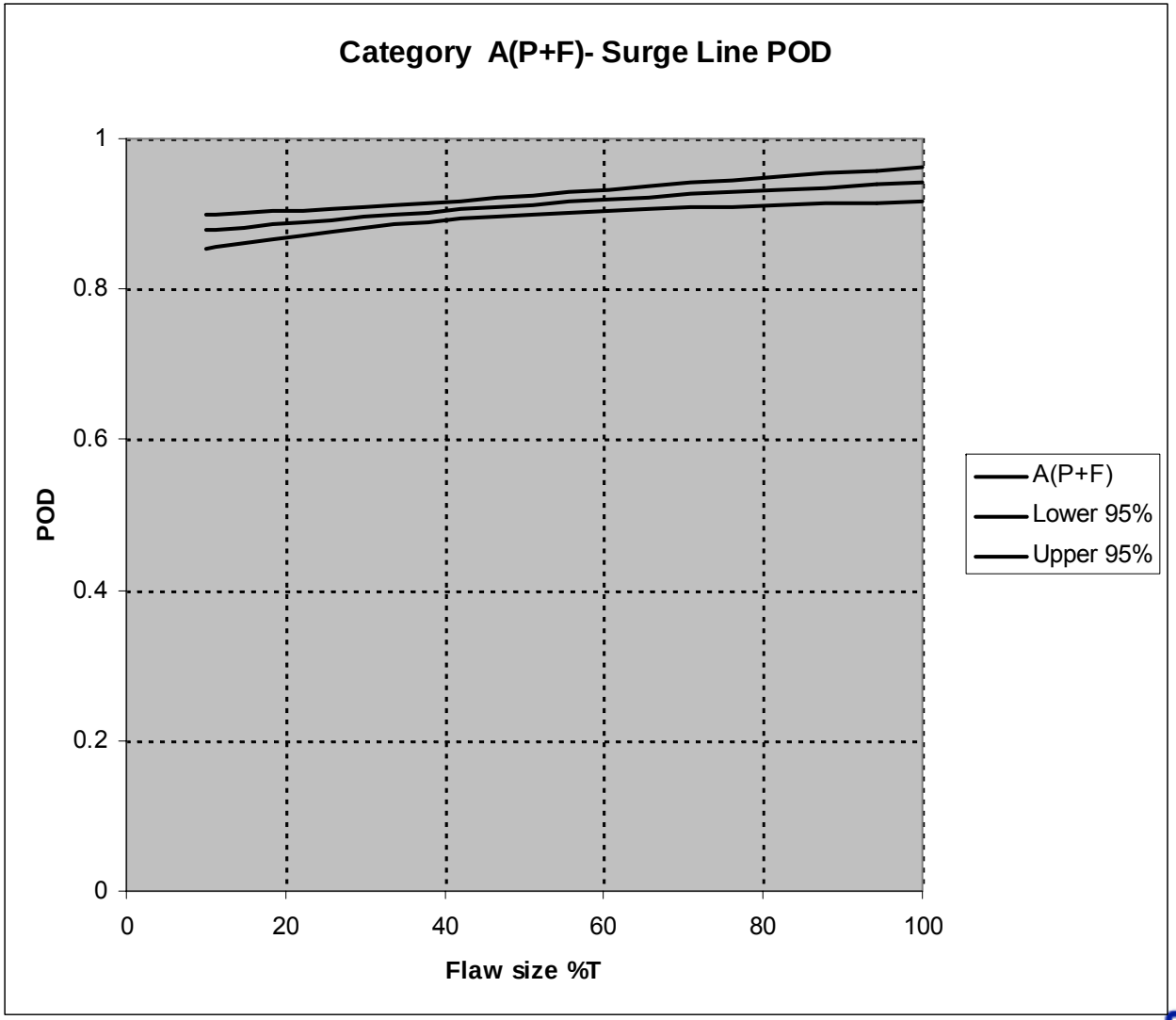
Results

POD: Surge line, passed + failed



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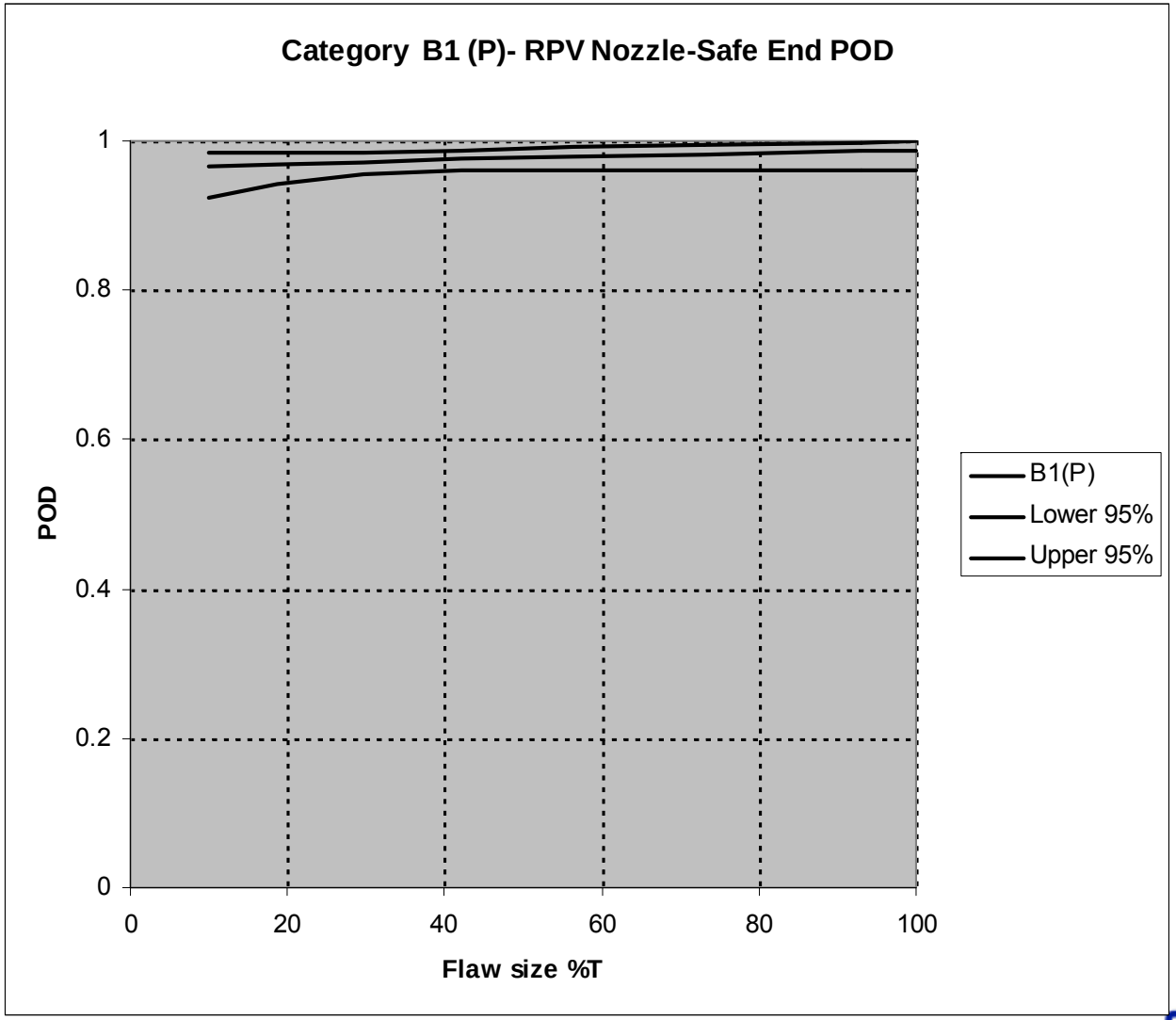
Results

POD: RPV nozzle, passed



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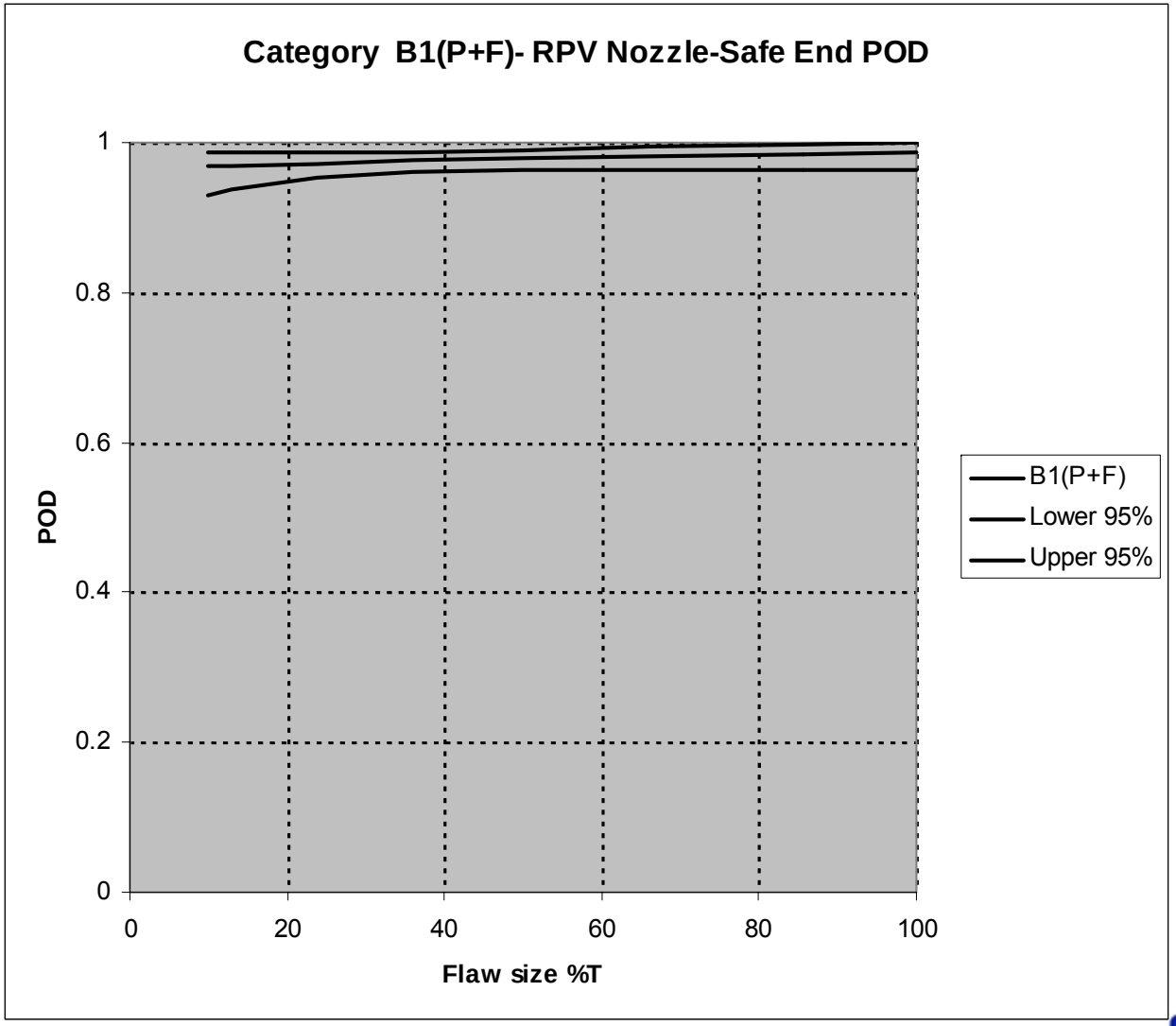
Results

POD: RPV nozzle, passed + failed



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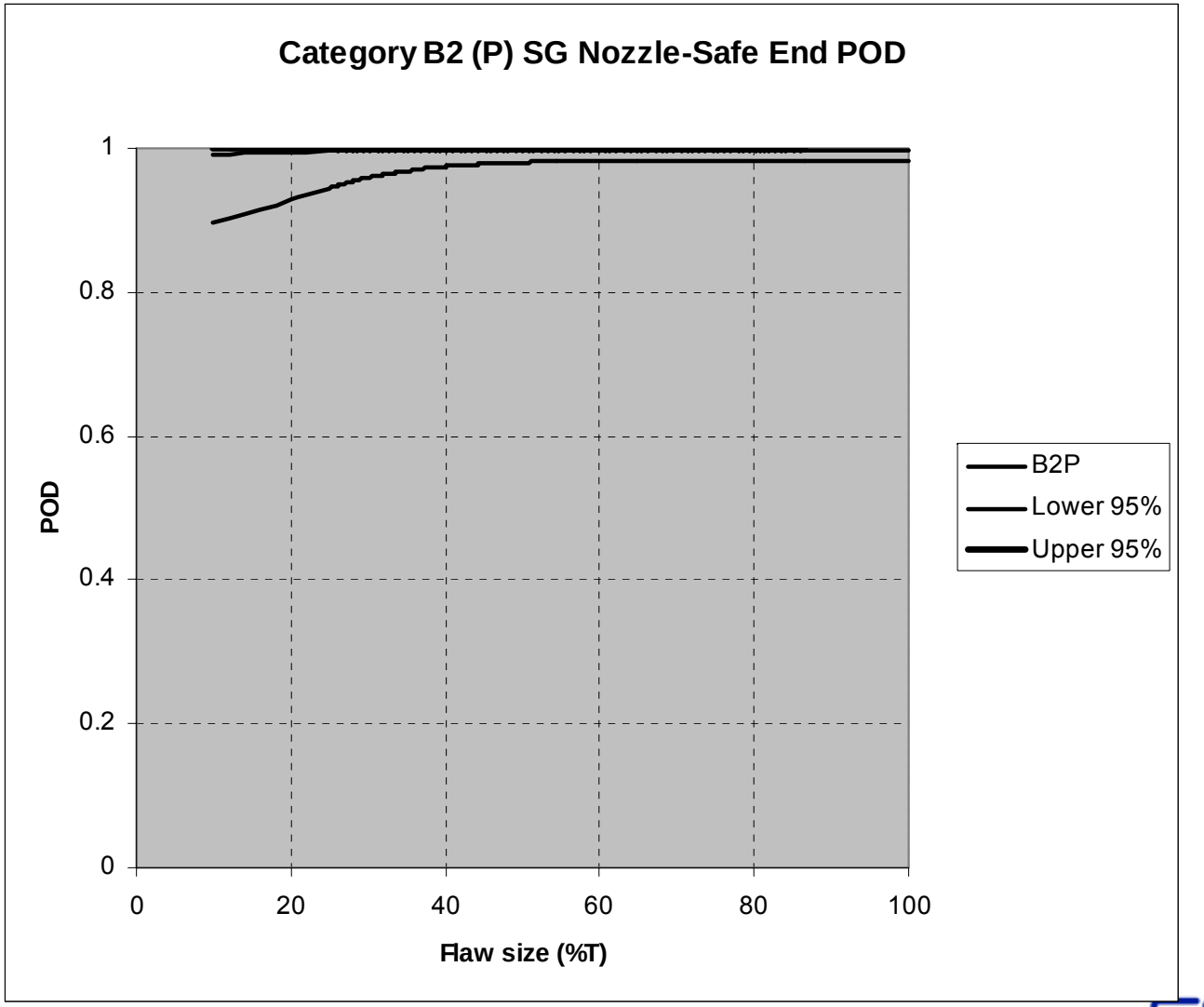
Results

POD: SG nozzle, passed



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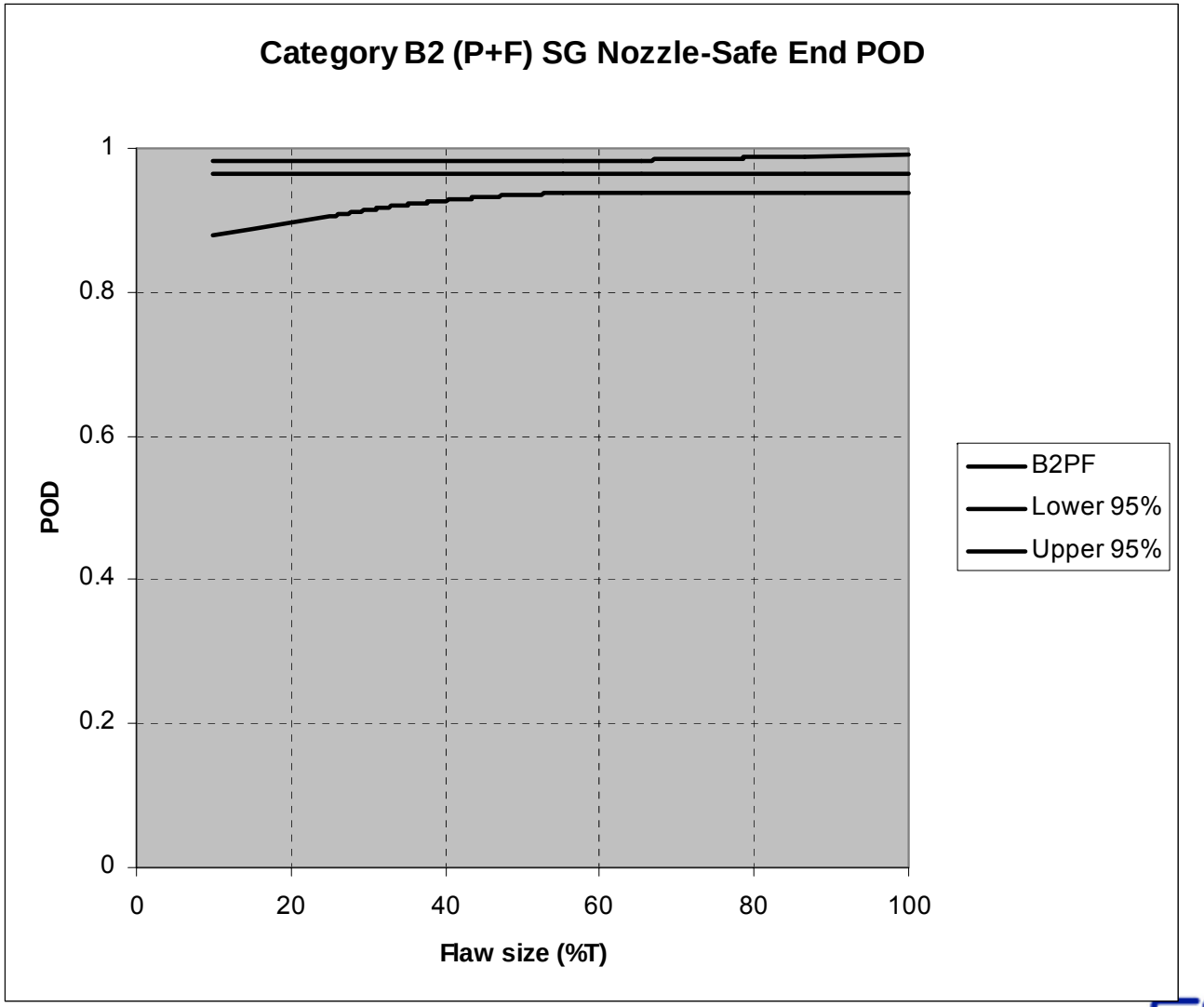
Results

POD: SG nozzle, passed + failed



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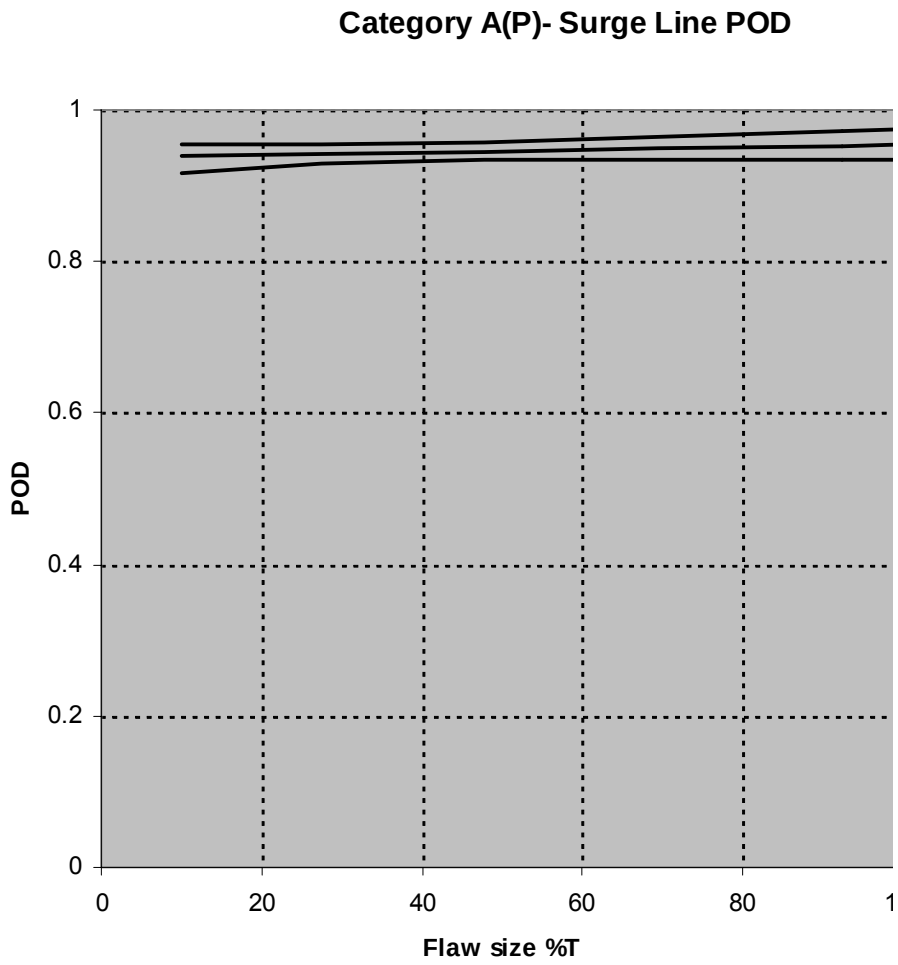
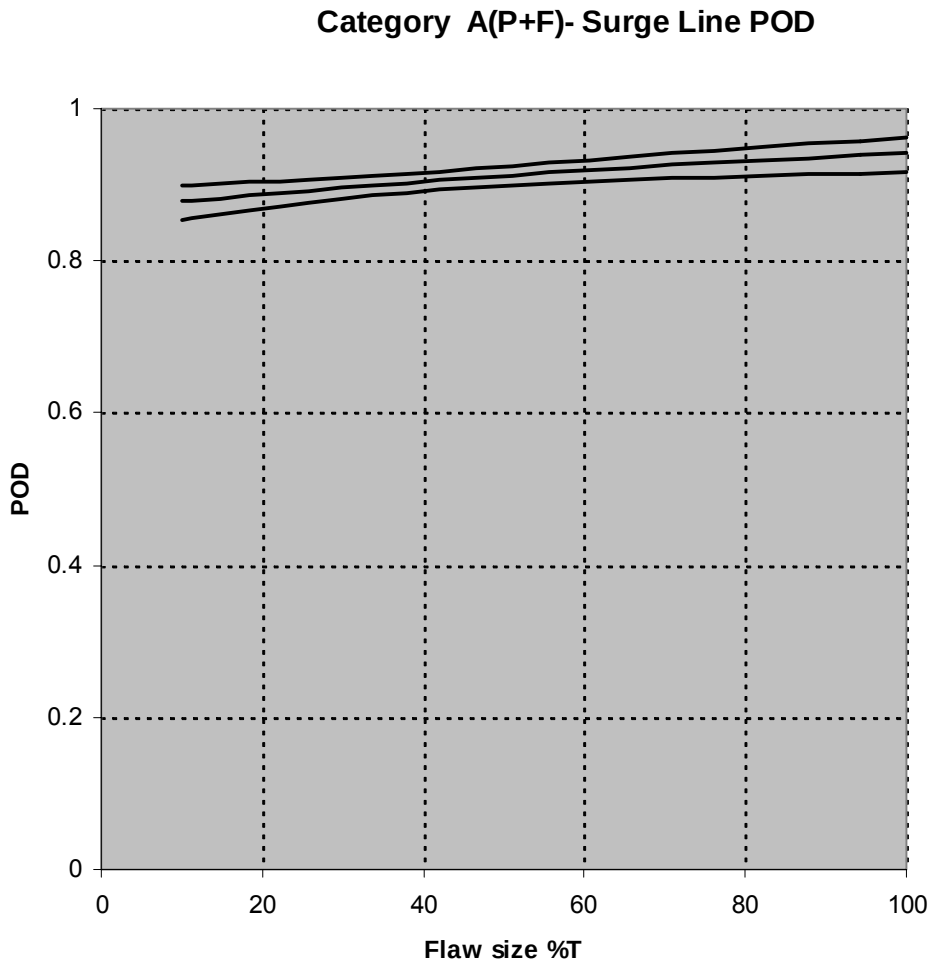
Results

POD: Surge line, P and P+F





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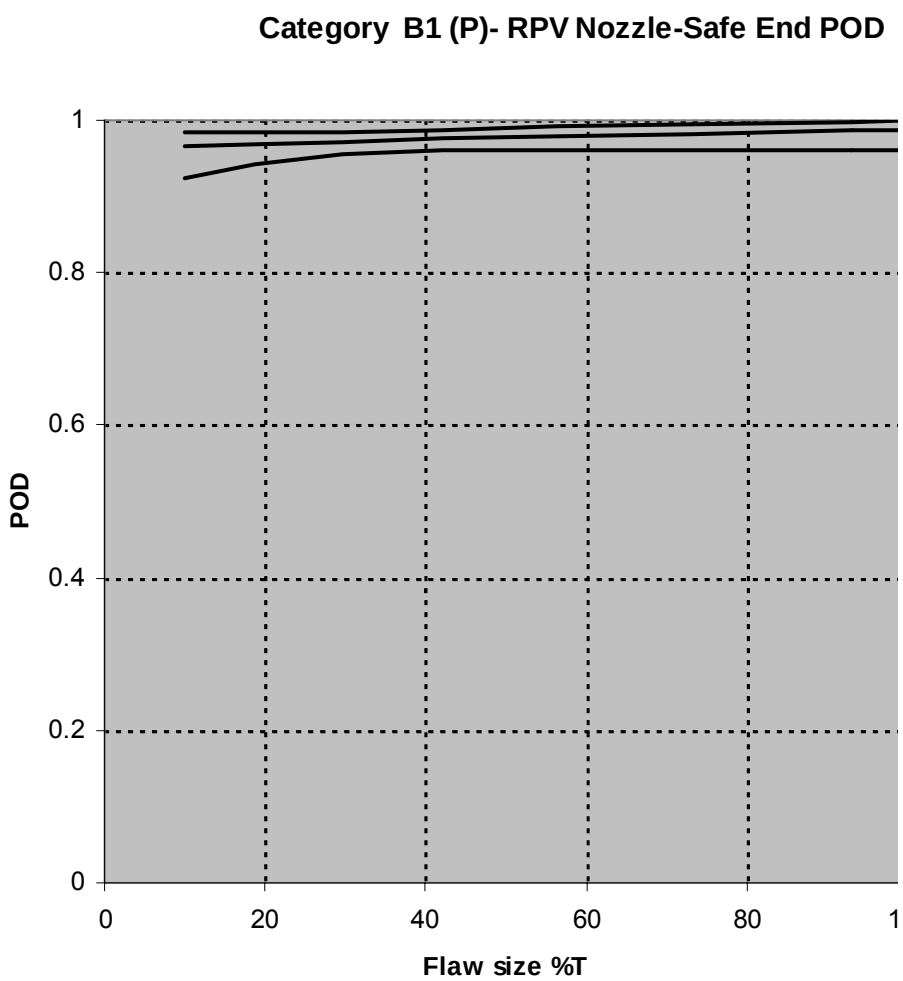
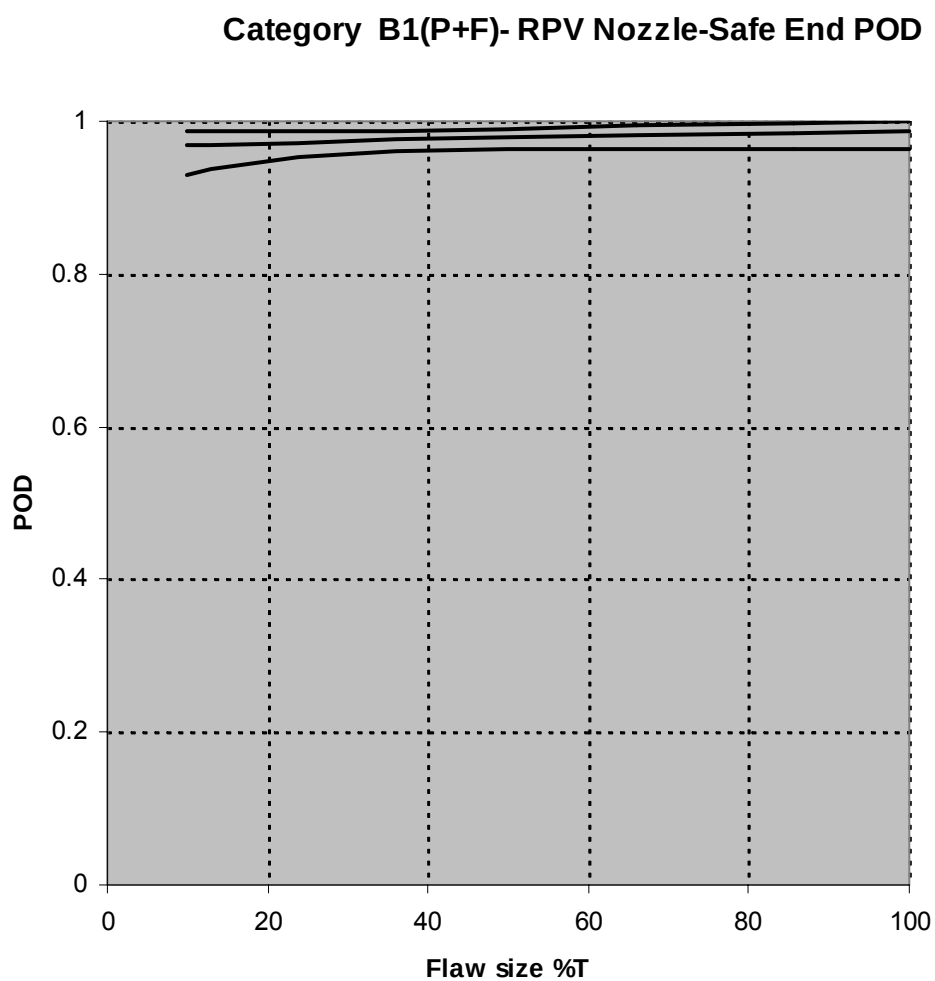
Results

POD: RPV nozzle, P and P+F





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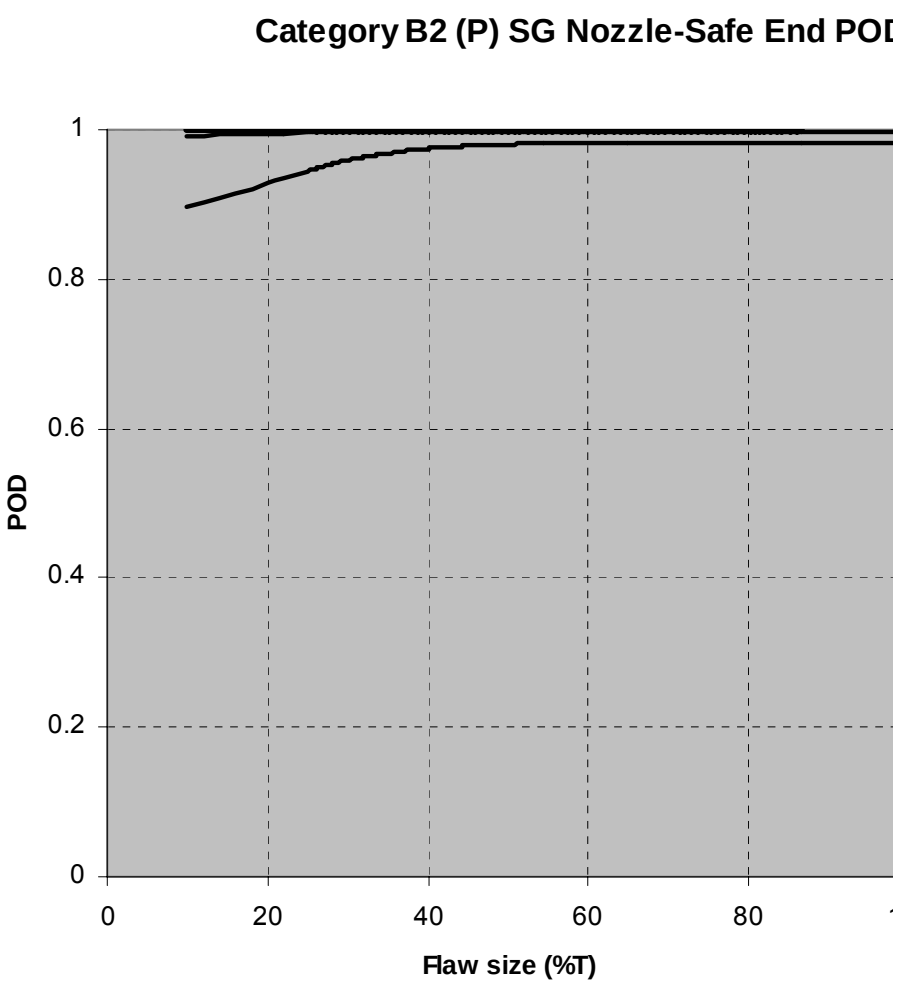
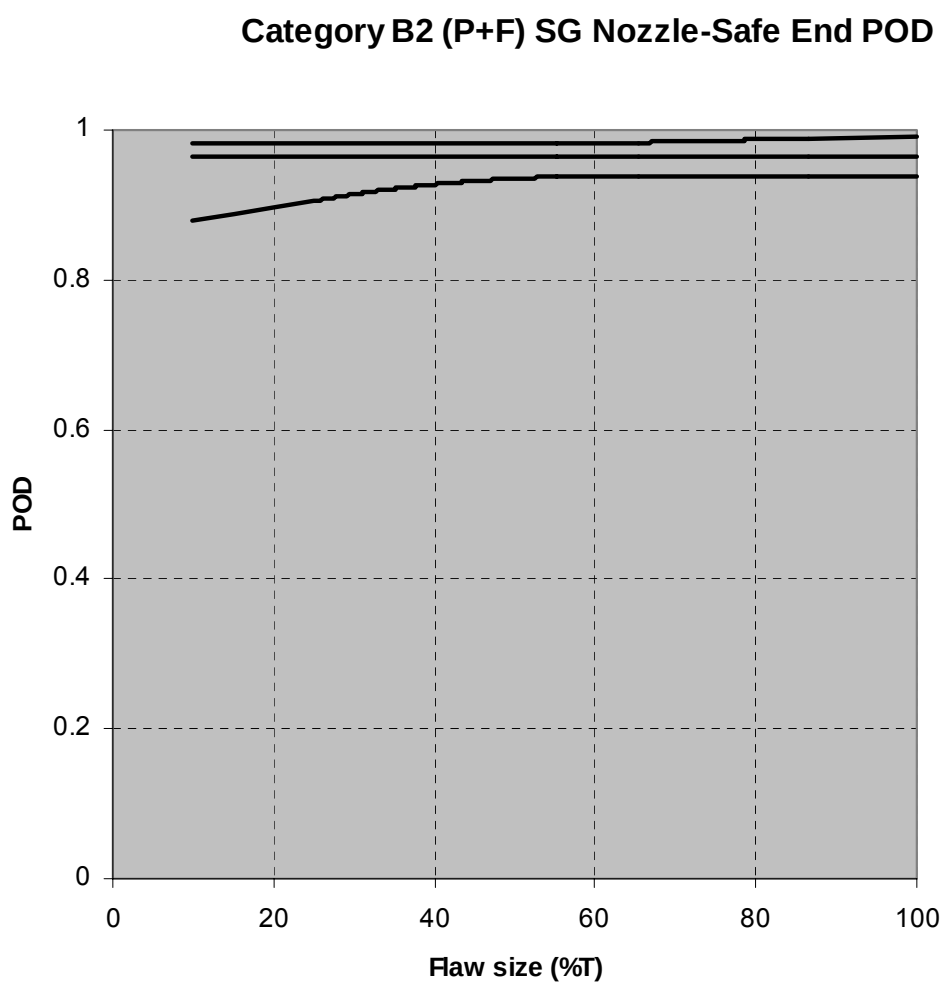
Results

POD: SG nozzle, P and P+F





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Next Steps

- Publish final report:
  - ***"Development of Probability of Detection Curves for Ultrasonic Examination of Dissimilar Metal Welds (MRP-262) Typical PWR Leak Before Break Line Locations"*** **[1019088]**
  - Documents methodology, process, & results
  - Public, non-proprietary report
  - Available in ~two weeks from www.EPRI.com
    - Login not required, search on MRP-262 or 1019088
    - Click report download button and follow instructions
- Develop POD for overlay repaired welds
- Coordinate with xLPR task groups requiring POD models and inputs

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Summary

- PDI database was used to calculate POD for dissimilar metal welds in three categories of PWR locations
  - Surge line
  - RPV nozzles
  - Steam generator nozzles
- Selected data from mockups representative of LBB locations, examined with PWR ISI procedures
- Logistic model fit to detection data to produce POD curves for the three categories for both P and P+F cases
- Data security measures implemented
- Results documented in non-proprietary EPRI report

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Discussion

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