Industry Response
Alloy 82/182 Weld Cracking

NRC Review – March 23, 2001

Materials Reliability Program
Alloy 600 Issue Task Group (ITG)

Larry Mathews, SNC, Chairman

Agenda

- Introduction & Background
- Interim Assessment Results Alloy 82/182 Butt Welds
  - Westinghouse Plant Designs
  - Combustion Engineering Plant Designs
  - B&W Plant Designs
- Interim Assessment for CRDM Head Penetrations
- Interim Inspection Guidance
- Overview of MRP Activities and Schedule
- Discussion

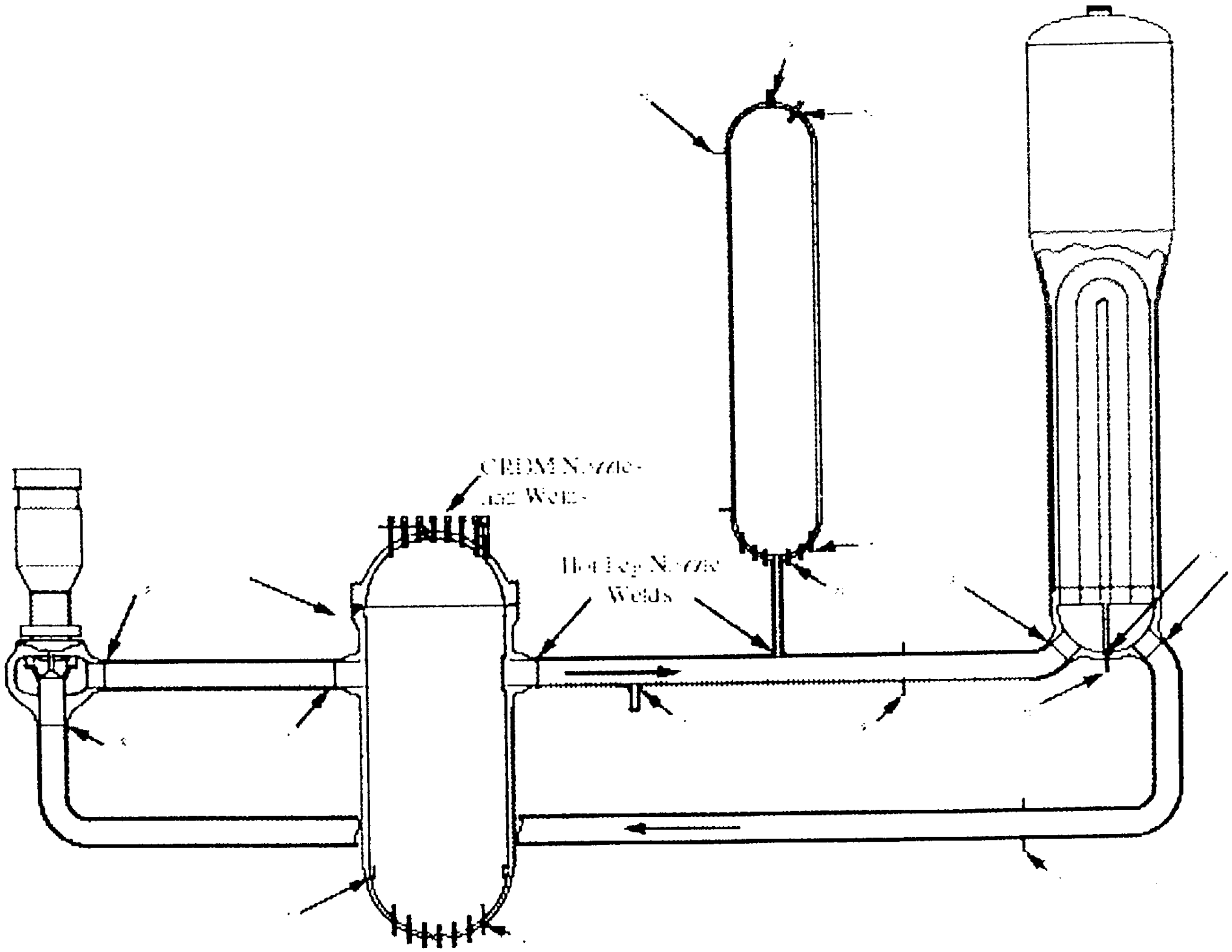
Purpose of Review

- Describe technical work in progress on pipe weld and CRDM nozzle cracking issues
  - Organizations performing work
  - Preliminary findings and assumptions
  - Planned deliverables
  - Schedule
- Solicit NRC comment on
  - Work performed to date
  - Planned deliverables
  - Schedule

Industry Response Organization

- **Integrated effort is being coordinated through**
  - **EPRI Materials Reliability Project - Alloy 600 ITG**
    - » NEI - Regulatory Interface
    - » Committees Under Alloy 600 ITG
      - Assessment
      - Inspection
      - Repair/Mitigation
    - » Owners Groups
- **Work is being performed by**
  - **Utilities**
  - **NSSS Vendors**
  - **Contractors**

Alloy 82/182 Weld Locations



Alloy 82/182 Weld Locations

LOCATION	NSSS
• **HL RV Nozzles**	W, 1 CE
• CL RV Nozzles	W, 1 CE
• Core Flood Nozzles	B&W
• RV Seal Taps	B&W,W,CE?
• HL SG Nozzles	W, 1 CE
• CL SG Nozzles	W, 1 CE
• Pump Inlet	CE, B&W
• Pump Outlet	CE, B&W
• HL Branch Connections	CE, B&W
– **HL to Surge Line Nozzle**	CE, B&W
• CL Branch Connections	CE, B&W

Alloy 82/182 Weld Locations

LOCATION	NSSS
• PZR Heater Sleeves	CE
• PZR Instrument Nozzles	CE, B&W
• **PZR Surge Line Nozzle**	W, CE, B&W
• PZR S/R Valve Nozzles	W, CE, B&W
• PZR Spray Nozzles	W,CE, B&W
• **CRDM J Groove Welds**	W, CE, B&W
• CRDM Dissimilar Metal Welds	W, CE, B&W
• Head Vent & Instrument Nozzles	W, CE, B&W
• BMI Nozzles	W, CE, B&W

Alloy 82/182 Safety Evaluation for Westinghouse Plant Designs

Phase 1 Program

W. H. Bamford, C. Holmes, B. Bishop and D. Bhowmick

Westinghouse Electric Company

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Attachment 3

- Introduction
- Alloy 82/182 Locations
- Fracture Evaluation
- Leak Before Break
- Risk Evaluation

Introduction

- This assessment was prompted by recent service experience at V. C. Summer, Ringhals, and Oconee.
- In all these cases, cracking attributed to PWSCC of Alloy 82 and 182 welds.
- Goal of this assessment: put the safety implications of these events into proper perspective relative to the other operating plants.

Alloy 82 / 182
Weld Locations in Westinghouse Plants

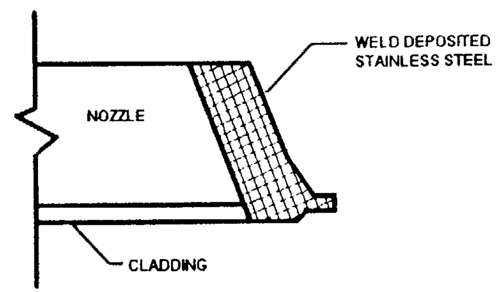
- Reactor Vessel:
  - Five Safe-end configurations in domestic plants
  - Four of five contain Alloy 82 / 182 weld material

Alloy 82 / 182
Weld Locations in Westinghouse Plants

Reactor Vessel Type 1: Stainless Steel Buttering

Applicability:

16 Plants

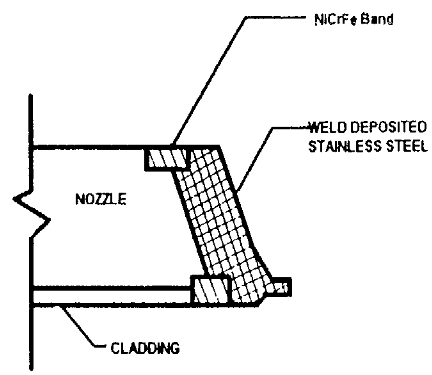


Alloy 82 / 182
Weld Locations in Westinghouse Plants

Reactor Vessel Type 1A: Stainless Steel Buttering with Alloy 82 bands

Applicability:

2 Plants

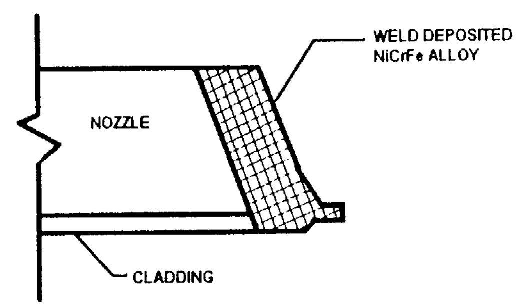


Alloy 82 / 182
Weld Locations in Westinghouse Plants

Reactor Vessel Type 2: NiCrFe Alloy Buttering

Applicability:

2 Plants

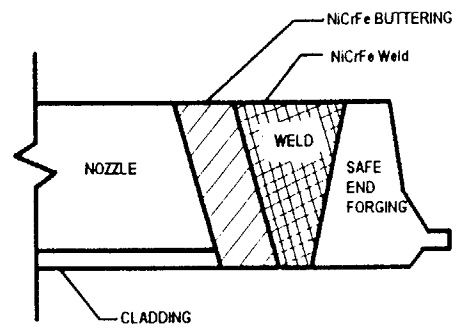


Alloy 82 / 182
Weld Locations in Westinghouse Plants

Reactor Vessel Type 3A: SS Safe End Forging, NICrFe Butter & Weld

Applicability:

19 Plants



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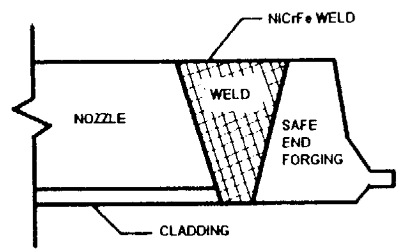
Alloy 82 / 182
Weld Locations in Westinghouse Plants

Reactor Vessel Type 3B: SS Safe End Forging, NiCrFe Narrow Groove Weld

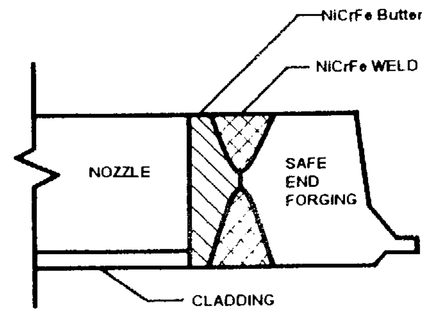
Applicability:



9 Plants

Alloy 82 / 182
Weld Locations in Westinghouse Plants

Reactor Vessel Type 4: SS Safe End Forging with NiCı



Applicability:

No Domestic Plants

Alloy 82 / 182
Weld Locations in Westinghouse Plants

- Pressurizer:
  - Three Locations of Interest
    - Surge Nozzle
    - Spray Nozzle
    - Safety & Relief Nozzles

Alloy 82 / 182
Weld Locations in Westinghouse Plants

- Pressurizer:
  - Two Safe-end Configurations in domestic plants
    - Type 1: Stainless steel safe-end with 82/182 butter & attachment weld
    - Type 2: Stainless steel safe-end with stainless steel attachment weld

Alloy 82 / 182
Weld Locations in Westinghouse Plants

- Pressurizer:
  - Surge Line
    - 27 Plants confirmed Type 1
    - 2 Plants confirmed Type 2
  - Spray Nozzles
    - 30 Plants confirmed Type 1
    - 9 Plants confirmed Type 2

Alloy 82 / 182
Weld Locations in Westinghouse Plants

- Pressurizer:
  - Safety & Relief Nozzles
    - 30 Plants confirmed Type 1
    - 9 Plant confirmed Type 2

Alloy 82 / 182
Weld Locations in Westinghouse Plants

- Steam Generators:
  - 3 Classes of Steam Generators
    - Original Equipment Supplied by Westinghouse
    - Replacements Supplied by Westinghouse
    - Replacements Supplied by Others

Alloy 82 / 182
Weld Locations in Westinghouse Plants

- Steam Generators:
  - Original Westinghouse Steam Generators
    - 2 Plants confirmed to have SS welds
  - Replacement Steam Generators
    - 8 Plants confirmed to have Alloy 52/152*

* Includes Plants with B&W Canada RSGs

Preferred Flaw Orientations

- All significant flaws found thus far are axial.
  - 6 at V. C. Summer
  - 4 at Ringhals 4
  - 2 at Ringhals 3

- At V. C Summer, two circumferential indications.
  - 1 artifact
  - 1 confined to the Alloy 182 cladding

- In all cases examined, operational hoop stresses significantly exceed axial stresses.

Fracture Evaluation

- Fracture Toughness for Alloy 82 Welds
- Critical Flaw Size Methodology
- Plants and Geometries Evaluated
- Loadings Considered
- Results and Discussion

Fracture Toughness for Alloy 82/182 Welds

- Toughness is similar to that of stainless steel base metal.

- Flux welds do not have low toughness as with stainless steel.

Critical Flaw Size Methodology

- Toughness is very high, so ductile limit load will be the governing failure mode.
- Ductile limit load solutions available for through-wall and part through-wall flaws.
- Methods available for both axial and circumferential flaws.
- For circumferential flaws, both axial bending moment and torsion are specifically treated.

Plants and Geometries Evaluated

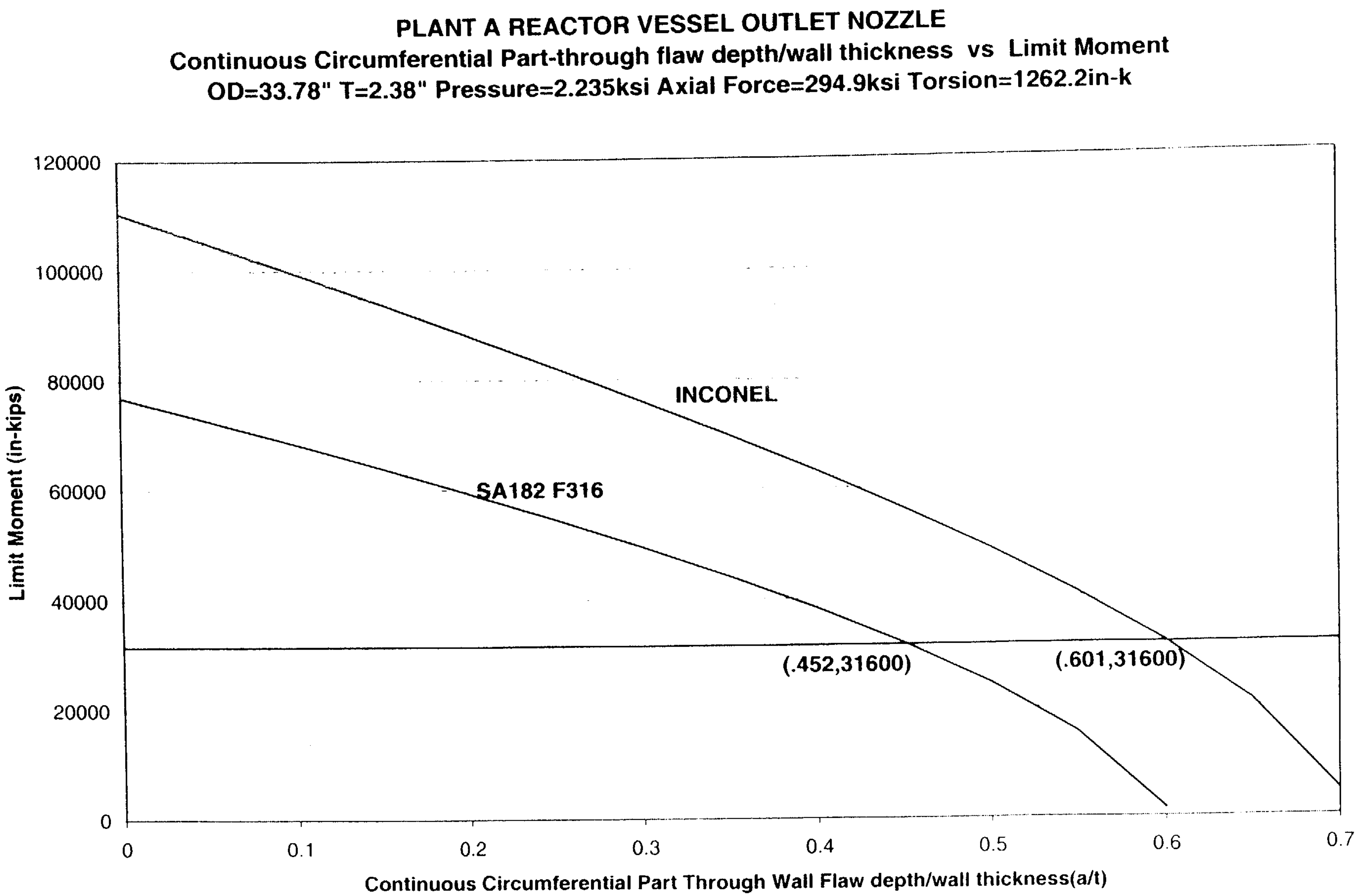
- Loads were compiled for all Westinghouse designs with Alloy 182 welds, along with one CE design.
- Three plants with the highest piping loads were selected for evaluation along with the CE design.
- Outlet nozzle to pipe weld region geometries:
  - Pipe OD: 33 - 38 inches
  - Thickness: 2.4 - 3.1 inches
- Geometries include both three and four loop Westinghouse designs.
- No two loop W domestic plants have 82/182 welds at this location.

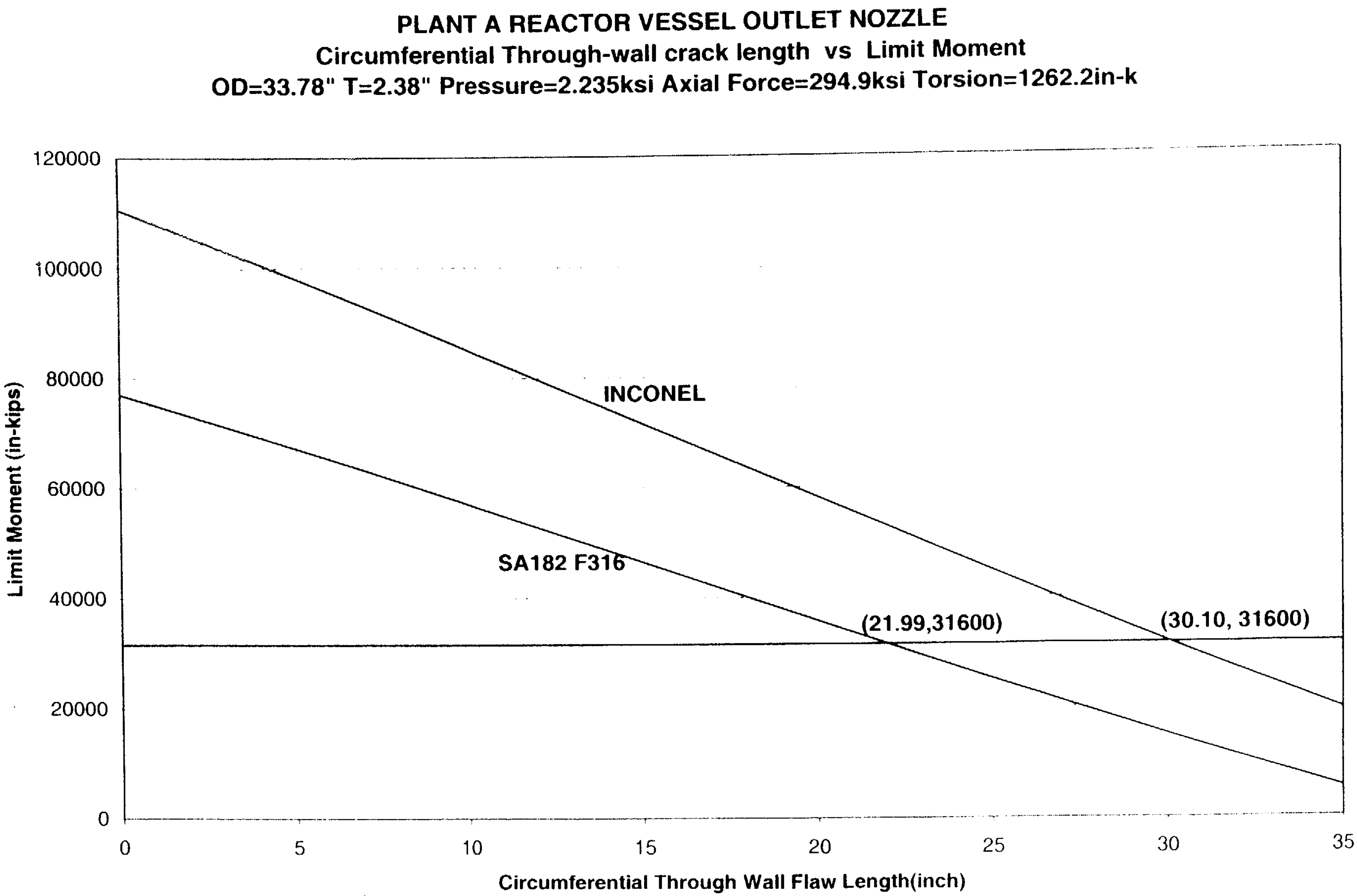
Loadings Considered

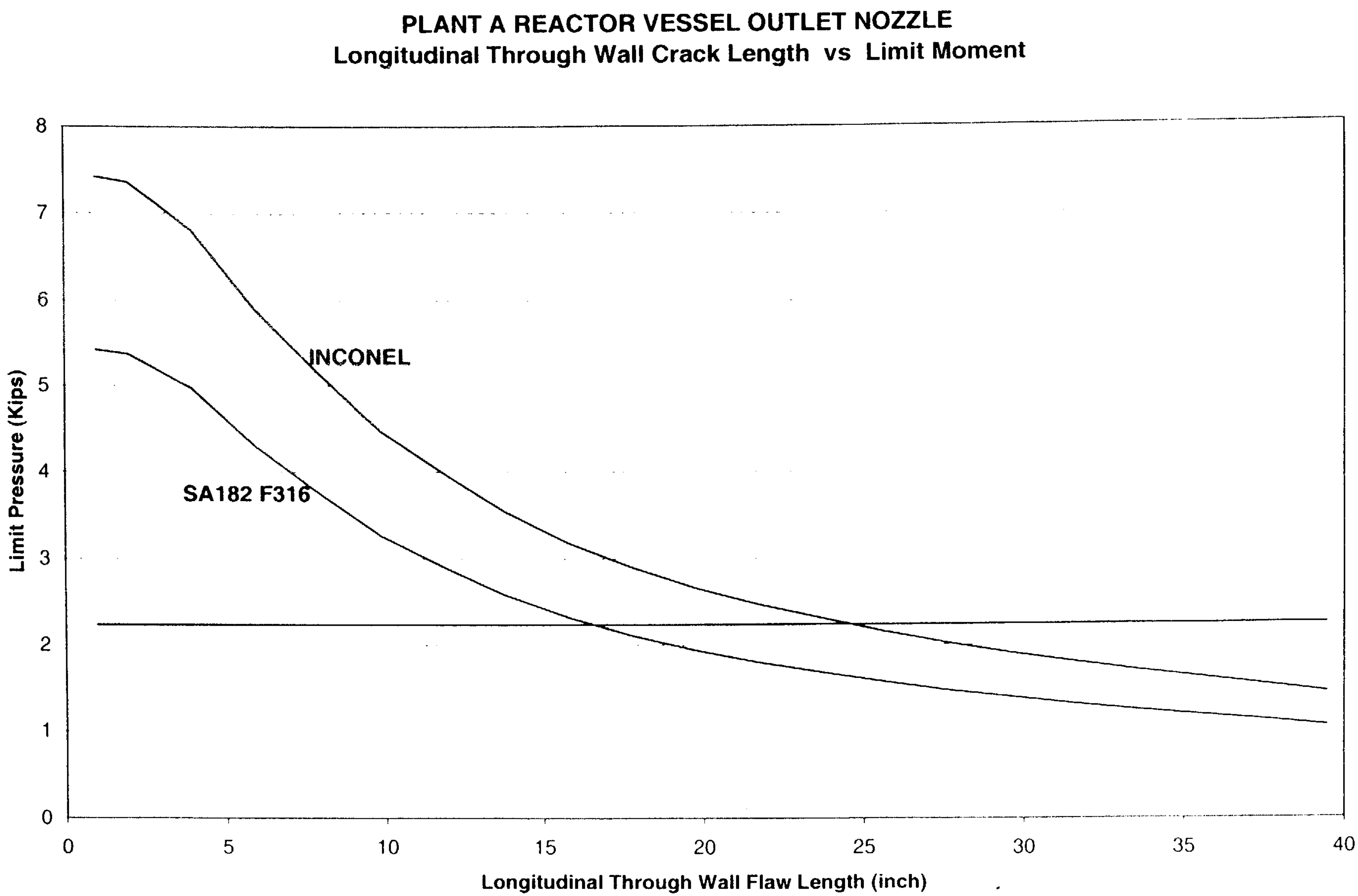
- Loadings from the plant piping analysis of record were used.
- Where necessary, loadings were updated to account for:
  - Power upratings
  - Snubber reductions
  - S/G replacements
- Loadings considered: Circumferential Flaws
  - Thermal normal - 100% power
  - Dead weight
  - Steady state pressure
  - SSE
- Loadings considered: Axial Flaws
  - Steady state pressure
  - Others have no impact

Results and Discussion

- Results presented for all four governing plants.
- Specific results:
  - Critical flaw depth: continuous part-through circumferential flaw
  - Critical flaw length: through-wall circumferential flaw
  - Critical flaw length: through-wall axial flaw
- All part through axial flaws are stable, regardless of depth.
- Very large critical flaw sizes were found for all plants.


PLANT A REACTOR VESSEL OUTLET NOZZLE
Continuous Circumferential Part-through flaw depth/wall thickness vs Limit Moment
OD=33.78" T=2.38" Pressure=2.235ksi Axial Force=294.9ksi Torsion=1262.2in-k
Limit Moment (in-kips)
120000
100000
80000
60000
40000
20000
0
INCONEL
SA182 F316
(.452,31600)
(.601,31600)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Continuous Circumferential Part Through Wall Flaw depth/wall thickness(a/t)


PLANT A REACTOR VESSEL OUTLET NOZZLE
Circumferential Through-wall crack length vs Limit Moment
OD=33.78" T=2.38" Pressure=2.235ksi Axial Force=294.9ksi Torsion=1262.2in-k
120000
100000
80000
60000
40000
20000
0
Limit Moment (in-kips)
INCONEL
SA182 F316
(21.99,31600)
(30.10, 31600)
0
5
10
15
20
25
30
35
Circumferential Through Wall Flaw Length(inch)



PLANT A REACTOR VESSEL OUTLET NOZZLE
Longitudinal Through Wall Crack Length vs Limit Moment
Limit Pressure (Kips)
0
1
2
3
4
5
6
7
8
INCONEL
SA182 F316
0
5
10
15
20
25
30
35
40
Longitudinal Through Wall Flaw Length (inch)

Critical Flaw Size Results

Plant	Axial Thru-Wall Length (in)	Circ. Thru-Wall Length (in.)	Cont. Circ. Flaw Depth (a/t)
A	25.0	30.1	0.60
B	26.3	24.3	0.52
C	27.0	24.9	0.53
D	38.0	43.0	0.71

Leak Before Break

- Methodology
- Plants and Geometries Evaluated
- Loadings Considered
- Results and Discussion

Methodology

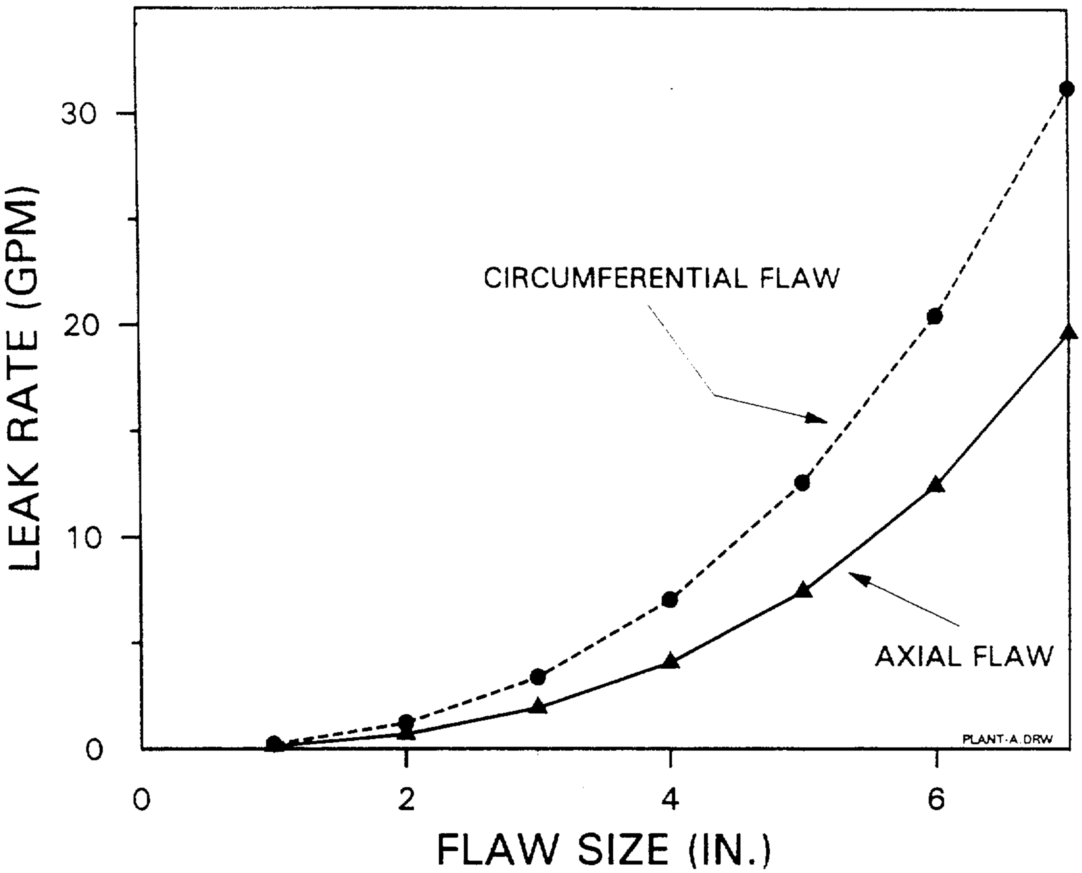
- Calculate crack opening area.
- Determine leak rate using two-phase flow formulation.
- Account for surface roughness.
- Plot leak rate vs flaw length.
- Methods follow guidelines of NUREG 1061, and the NRC standard review plan.
- Similar calculations reviewed and approved by NRC over the past 15 years or more.

Plants and Geometries Evaluated

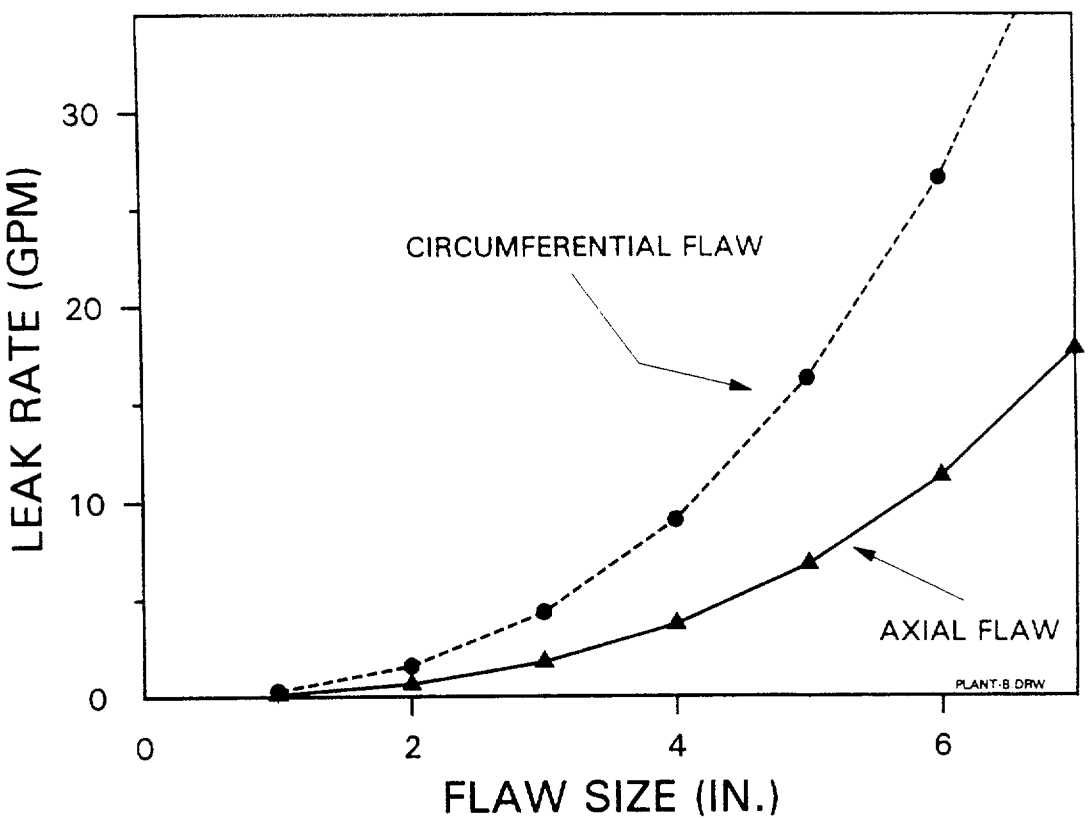
- Same four plants evaluated for Critical Flaw Size.
- Included V. C. Summer for comparison.
- Outlet nozzle geometries similar for all Westinghouse fleet.

Loadings Considered

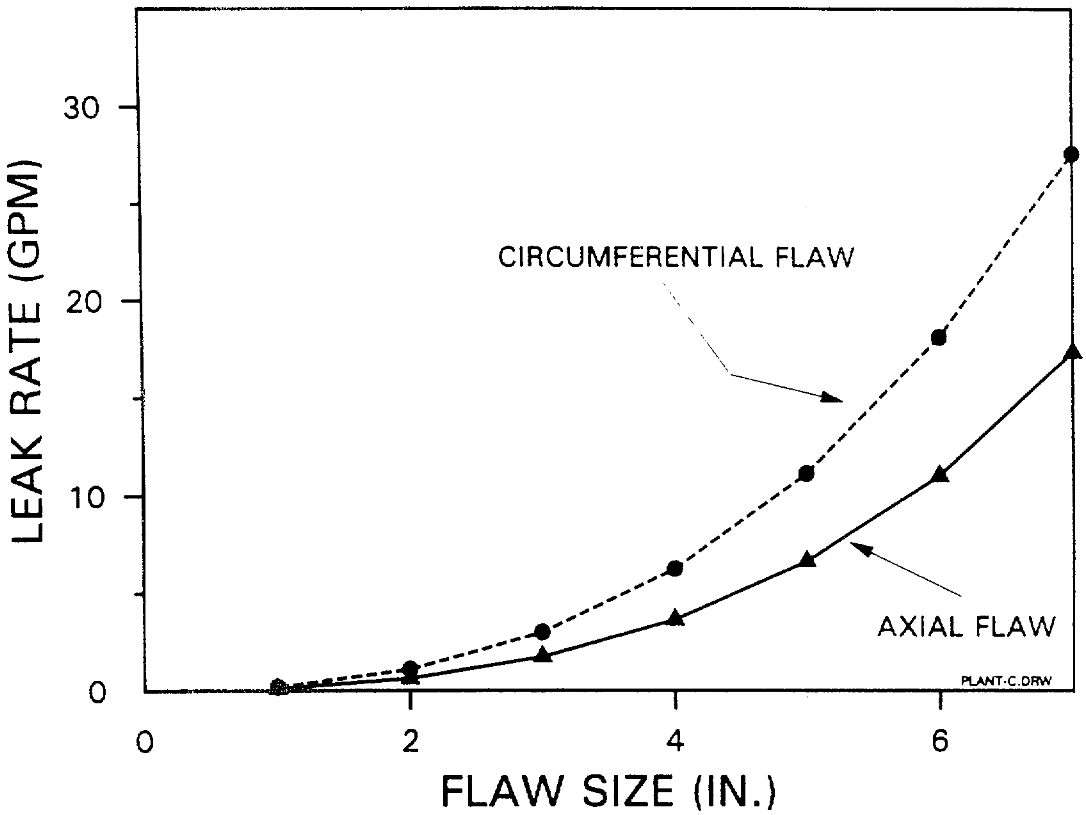
- Loadings from the plant piping analysis of record were used.
- Where necessary, loadings were updated to account for:
  - Upratings
  - Snubber reductions
  - S/G replacements
- Loadings considered: Circumferential Flaws
  - Thermal normal - 100% power
  - Dead weight
  - Steady state pressure
- Loadings considered: Axial flaws
  - Steady state presssure
  - Others have no impact



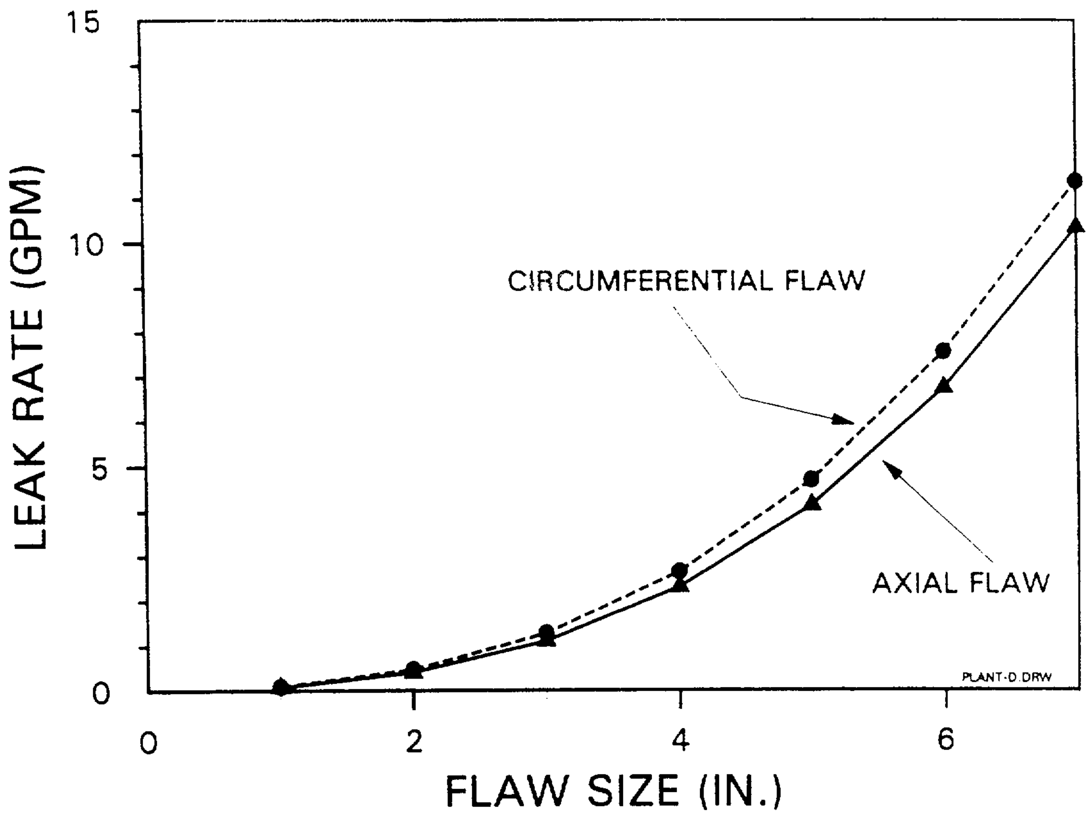
Leak Rate vs Flaw Size for Plant A



Leak Rate vs Flaw Size for Plant B



Leak Rate vs Flaw Size for Plant C



Leak Rate vs Flaw Size for Plant D

Results and Discussion

- Results show leak rate vs. flaw length.
- One GPM leakage is generally reached for a 2-3 inch long flaw.
- Regardless of flaw orientation, there is about a factor of 10 between leak detection and critical flaw size.

Alloy 182 PWSCC Risk
Study of RPV Outlet Nozzles

- Industry Experience
- Expected Probability of Large Leak
- Expected Risk Results

Industry Experience

- For different weld repair states, flaws have been axial and limited to weld width.
- Probability of this type flaw is relatively high but consequence of the very small leak ($\leq$ 0.1 GPM) on core damage is negligible.
- CD Risk of larger leaks can be successfully managed.

Expected Probability of Large Leak (5000 GPM)

- Experience to date is axial flaws with limited length.
  - Probability of large leak due to any event is very very low ($\sim 10^{-8}$).
- Probability of fabrication-induced circumferential surface flaws is low.
  - Assuming a circumferential flaw, with SCC, probability of 5000 GPM leak is $<10^{-4}$.
  - Probability of undetected growth from 1 to 5000 GPM is 2-3 orders of magnitude lower.
  - Probability of a large part through circumferential flaw leading to break is also 2-3 orders of magnitude lower.

Expected Risk Results

- Conditional core damage probability of 0.01 - 0.02 (from RI-ISI evaluations).
- Increase in CDF is insignificant ($\leq 10^{-6}$/yr.) per Regulatory Guide 1.174 requirements.
  - Defense in Depth: Pipe break analyzed event in FSAR
- Conclusions reached thus far unlikely to change, but uncertainties need further evaluation:
  - Incomplete understanding of PWSCC
  - Variations in material, environment, loading

ALLOY 82/182 SAFETY EVALUATION FOR CE PLANTS

Phase 1 Program

WESTINGHOUSE ELECTRIC COMPANY

Presenters David J. Ayres and Karl H. Haslinger

Attachment 4

Number of Affected Weld Locations in CE Plants

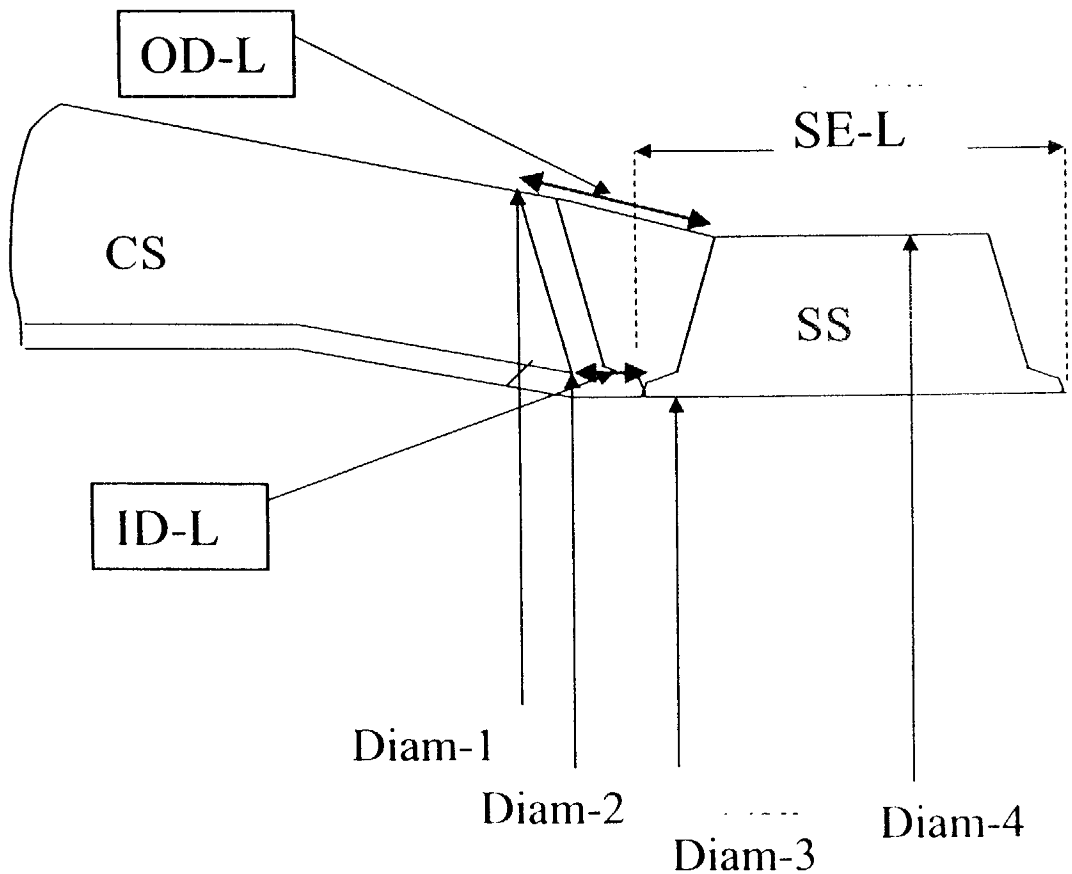
	Plant A	Plant B	Plant C	Plant D	Plant E	Plant F	Plant G	Plant H	Plant I
Main Coolant Loop Piping									
RCP Suction to RC Pipe	4	4	4	N/A	4	4		N/A	4
RCP Discharge to RC Pipe	4	4	4	N/A	4	4		N/A	4
RV Inlet and Outlet Nozzles							6		
SG Inlet and Outlet Nozzles							6		
Branch Line Connections									
RC Pipe to Surge Line Connection	1	1	1	1	1	1		1	1
Charging Inlet Nozzles	2	2	2	2	2	2		2	2
Safety Injection and SDC Inlet Nozzle	4	4	4	4	4	4		4	4
Shut Down Cooling Outlet Nozzle	1	1	1	1	1	1		1	1
Spray Nozzles	2	2	2	2	2	2		2	2
Let-Down and Drain Nozzles	5	5	5	5	5	5		5	8
Pressurizer Nozzles									
PZR Surge Line Nozzle	1	1	1	1	1	1	1	1	1
Spray Nozzle	1	1	1	1	1	1	1	1	1
Safety Valve Nozzles	3	3	3	3	3	3	3	4	2
Reactor Vessel and CEDMs									
CEDM Motor Housing	2/CEDM	Yes	Yes	Yes	Yes	Yes	No	No	Yes
CEDM Nozzle to RV Head Welds	All CEDMs		~91+10 ICI	Yes	Yes	Yes	Yes	Yes	Yes
ICI Nozzles to Guide Tube Welds	-	-	-	61	-	-	-	-	-

Prioritization of Alloy 82/182 Welds in CE Plants

	Location Temperature	Likelihood of PWSCC	Typical Size (Sch 160)	Order of Significance
Main Coolant Loop Piping				
RCP Suction to RC Pipe	Cold Leg	Low	30"	3
RCP Discharge to RC Pipe	Cold Leg	Low	30"	3
Branch Line Connections				
RC Pipe to Surge Line Connection	Hot Leg	High	12"	1
Charging Inlet Nozzles	Cold Leg	Low	2"	
Safety Injection and SDC Inlet Nozzle	Cold Leg	Low	14"	
Shut Down Cooling Outlet Nozzle	Hot Leg	Medium	14/16"	4
Spray Nozzles	Cold Leg	Low	3"	
Let-Down and Drain Nozzles	Cold Leg	Low	2"	
Pressurizer Nozzles				
PZR Surge Line Nozzle	PZR, High	High	10" & 12"	2
Spray Nozzle	PZR, High	High	4"	2
Safety Valve Nozzles	PZR, High	Medium	6"	2
Reactor Vessel and CEDMs				
CEDM Motor Housing	CEDM, Low	Low		
CEDM/ICI Nozzles to RV Head Welds	RV Top, High	High	3.5"- 4.74"	3
ICI Nozzles to ICI Guide Tubes	RV Bottom, Low	Low		

Notes: All Bimetallic Welds are "Shop-Welds" (except certain ICI to Guide Tube Welds)
Small Bore Nozzles Covered by Separate Tasks.

Typical CE Surge Line Nozzle Geometry



Basis for Selection of Surge Line Nozzle Phase 1 Safety Evaluation in CE Plants

- RCP Suction and Discharge Nozzle Safe-Ends are the only Alloy 82/182 Welds in CE Plant MCL Piping (with Exception of Fort Calhoun). Due to their Location within Cold Legs, Stress Corrosion Concerns are lower.
- One CE p'ant has Stainless Steel MCL Piping and will be included with the W-Fleet. Hot-leg Temperature is relatively low.
- Surge Line Nozzle at MCL Piping in CE Plants is Exposed to Highest Temperature of all Branch Lines .
- Surge Line Nozzles experience highest Amount of Steady-State Thermal Loading and Duty-Cycling of all Branch Lines, including Thermal Stratification.
- Thus Selection of MCL Side Surge Line Nozzle for Phase 1 appears justified.

Basis for Limit Load Analysis:

- For limiting crack size bending moments are combined for each plant: Dead weight + thermal + stratification or SSE algebraically by direction component, then vectorally for resultant. The greatest resultant is used as the enveloping value for all CE plants.
- For leakage crack size, the bending moments are combined for each plant: Dead weight + thermal algebraically by direction component, then vectorally for resultant. The smallest resultant is used as the enveloping value for all CE plants.

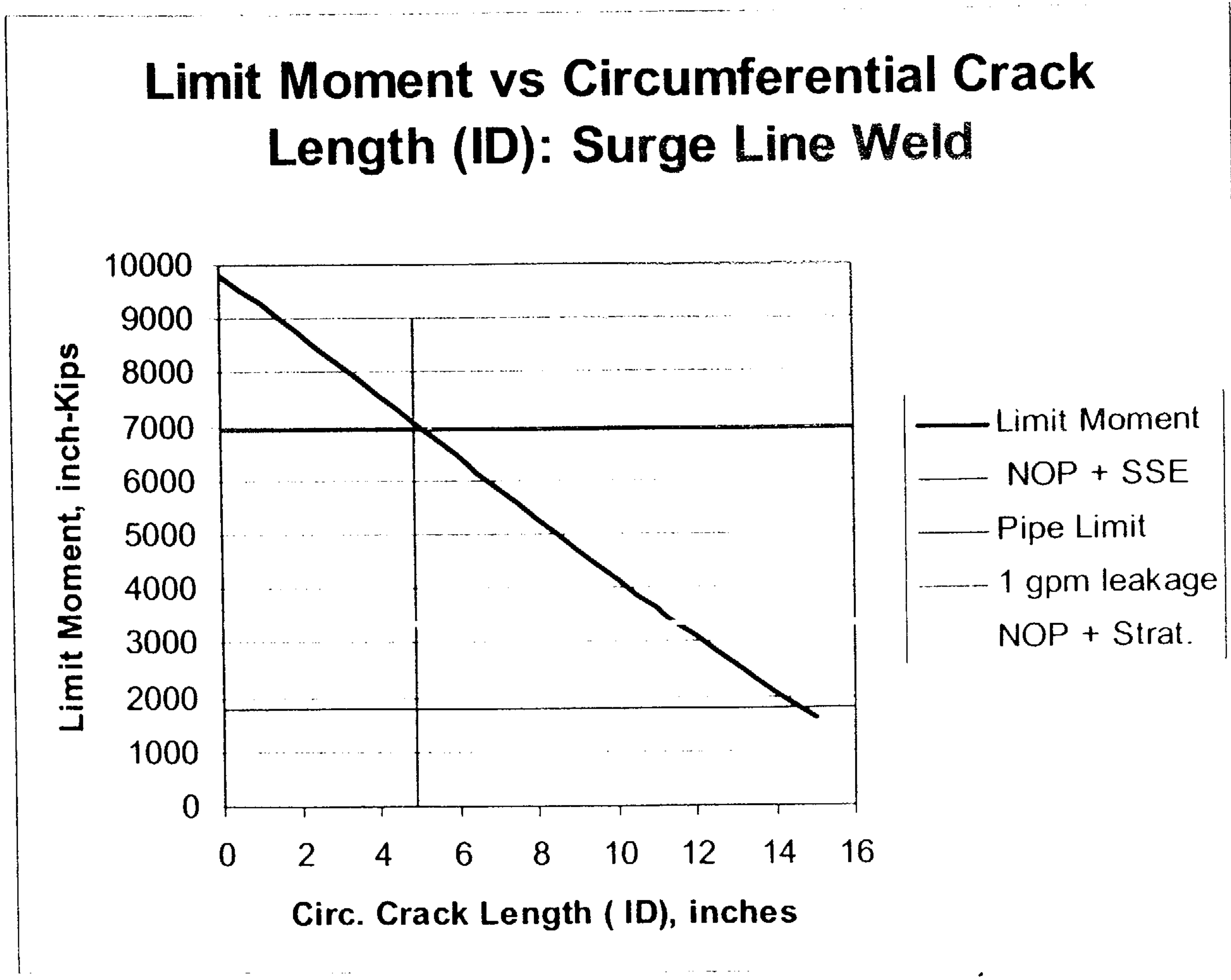
Basis for Limit Load Analysis, Materials:

- For circumferential cracks, the crack is presumed to be in the weld material.
- For axial cracks, cracks longer than the weld width are presumed to be in the safe end / pipe material.
- Note that the uncracked safe end / pipe material has a lower limit load than the uncracked weld because the weld material has higher strength.

Limit Load Calculation Process

- The resultant bending moment is the dominant loading on a circumferential crack.
- The axial force due to mechanical and thermal loads and the torsion moment do not significantly change the limit moment or the leakage.

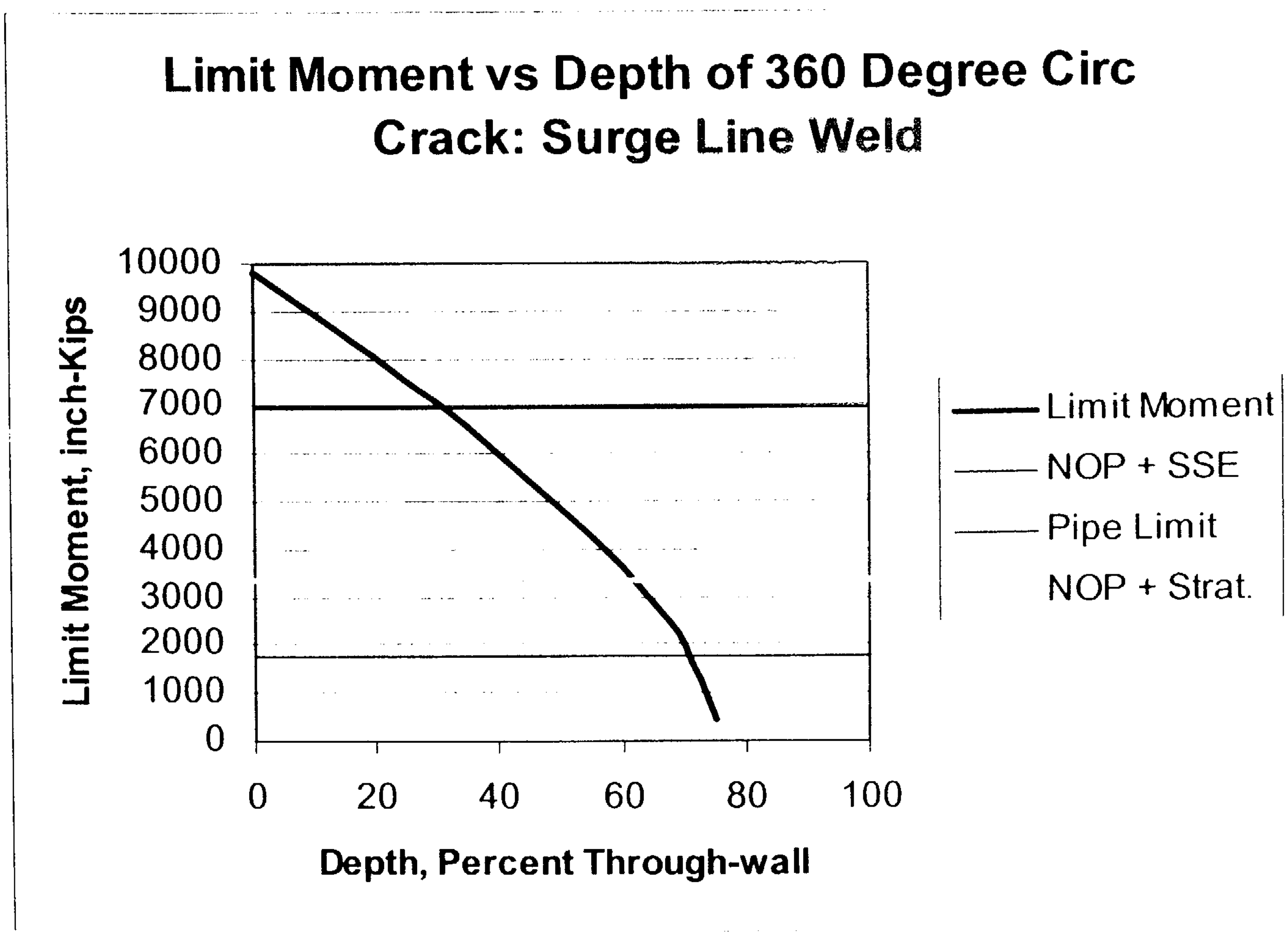
Results for Circumferential Crack



Observations on Through-wall Circ Crack Results

- One gpm leakage crack size is about 4.5 inches.
- Governing load condition is most severe stratified flow transient: critical crack size about 11.5 to 12 inches.
- Significant margin exists between detectable leak and critical crack size.
- Note: this is a bounding comparison between plant with smallest leakage and plant with greatest stratification moment.

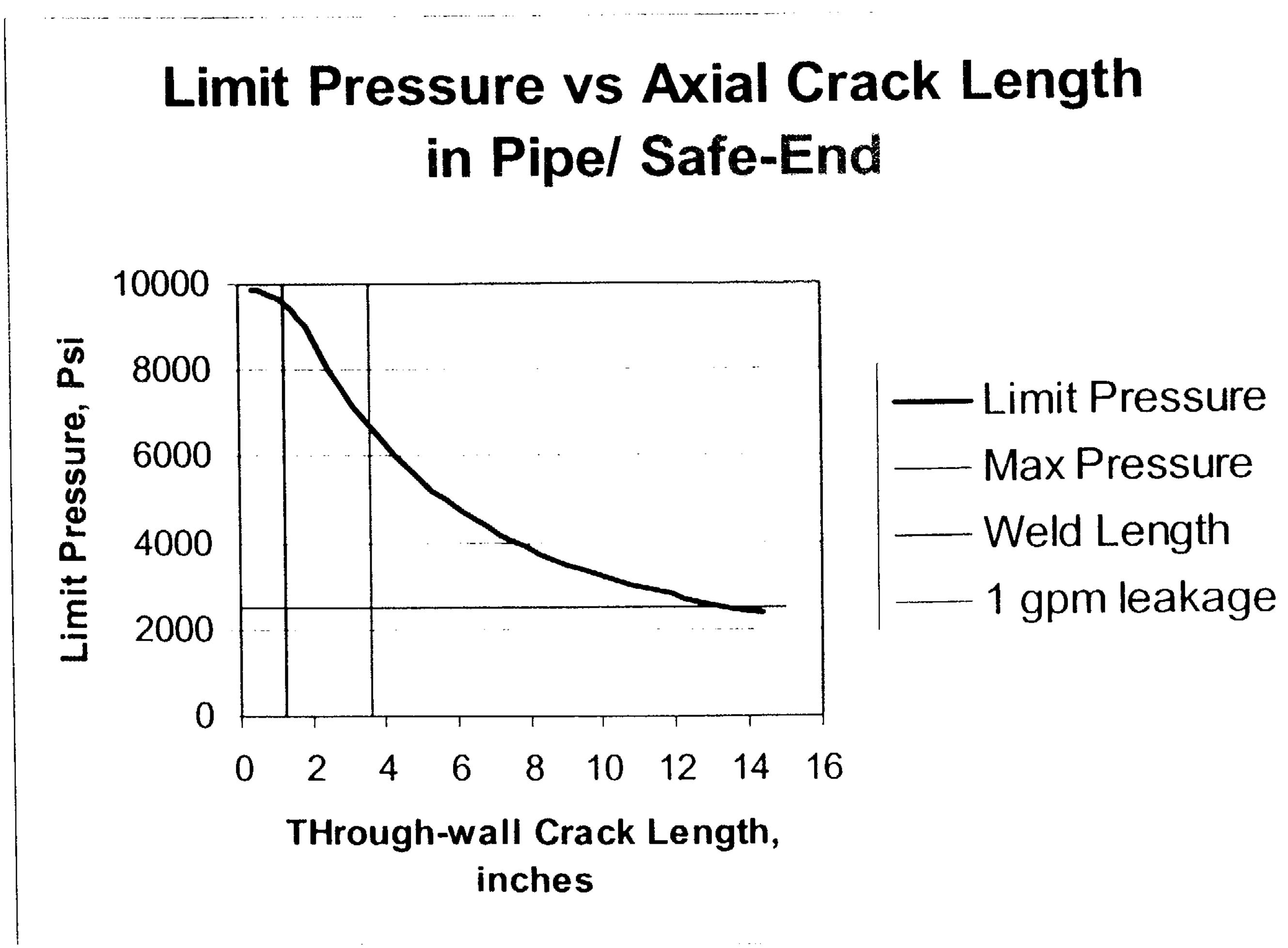
Results for 360 Degree Circ. Crack



Observations on Part Through-wall Circumferential Crack

- Critical crack depth for 360 degree crack is about 60 % through-wall.

Results for Axial Crack



Observations on Axial Crack Results

- Axial length of weld is small relative to one gpm leakage crack and critical crack, so axial crack is a concern only if it extends into the safe end and pipe.
- Safe end and pipe material is not susceptible to PWSCC.
- Significant margin exists between one gpm leakage crack and critical crack.
- Axial crack in weld is very small relative to critical crack.

Proposed Outline of Project Continuation

- Issue Phase 1 Safety Evaluation Report by 03/30/01
- Perform Fatigue and Stress Corrosion Induced Crack Growth Calculations for Surge Line Nozzle.
- Summarize and Document Plant Specific and Envelope Type Loads for All Locations of Concern.
- Perform Limit Load, Leak Rate, Fatigue and Stress Corrosion Cracking Analyses for
  - Surge Line Nozzles at MCL Piping (see above)
  - PZR Surge Line, Spray and Safety Valve Nozzles
  - CEDM to RV-Head J-Welds
  - Shut Down Cooling Line Nozzles and RCP Nozzles

Alloy 82/182 Safety Evaluation for B&W-Design Plants

S. Fyfitch

Framatome ANP

Attachment 5

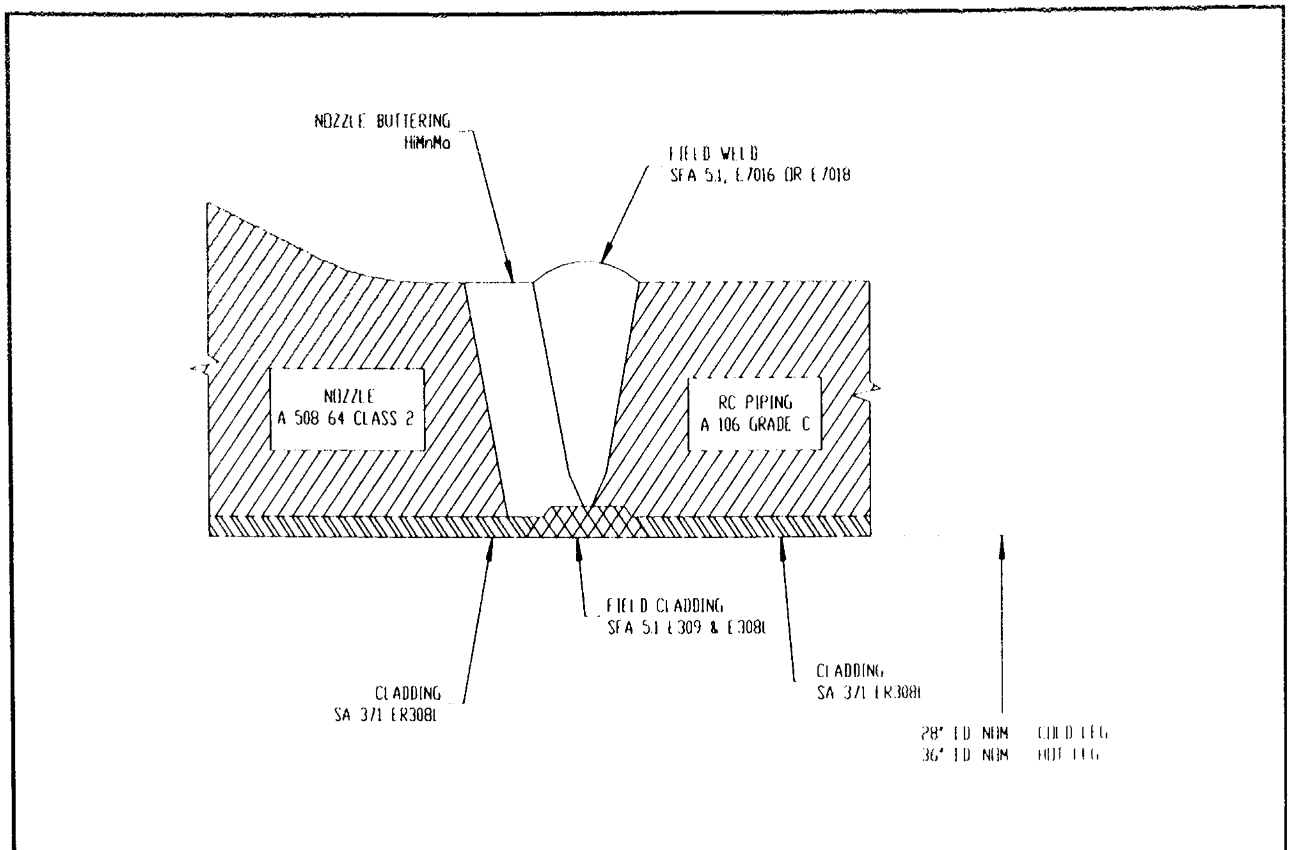
Outline of Presentation

- Introduction
- B&W RV Nozzle Design
- B&W-Design Plant Alloy 82/182 Weld Locations
- Current Status
- Summary and Conclusions

Introduction

- This assessment was prompted by recent service experience with RV inlet and outlet nozzle-to-pipe welds at V.C. Summer and Ringhals
- Observed cracking attributed to Alloy 82/182 full penetration welds
- Objective of assessment is to demonstrate that RV inlet and outlet nozzle-to-pipe welds at B&W-Design plants are not susceptible to PWSCC

Typical RV Nozzle-to-Pipe Weld Configuration in B&W-Design Plants



B&W RV Nozzle Design

- Nozzle buttering was performed prior to final post-weld heat treatment
- Field welds also subjected to a final post-weld heat treatment

B&W RV Nozzle Design

Part	V.C. Summer Materials	B&WOG Materials
RV Nozzle	SA-508 Class 2	A 508 Class 2
RV Nozzle Buttering	Alloy 182	Hi MnMo
RCS Piping	SA-376 Type 304N	A 106 Grade C
Cladding	Stainless Steel	SA-371 ER308L
Field Weld	Alloy 182/82	SFA 5.1, E70 Series
Field Cladding	Alloy 182	SFA 5.4, E309 & E308L

B&W-Design Plant Alloy 82/182 Weld Locations

- B&WOG performed a record search in 1996 to determine Alloy 82/182 weld locations
- Alloy 82/182 weld locations include full penetration, partial penetration, and fillet-type welds
- Preliminary assessment for full penetration welds that a utilize similar combination of materials to V.C Summer
- Additional evaluations underway to assess the safety significance of all Alloy 82/182 weld locations

B&W-Design Plant
Full Penetration Weld Locations
(With Carbon or Low Alloy Steel-To-Stainless Steel Connections Using Alloy 82/182 Weld Materials)

- Pressurizer
  - Surge nozzle weld
  - Pressure relief nozzle welds
- Reactor Vessel
  - Core flood nozzle weld
  - CRDM motor tube welds

B&W-Design Plant
Full Penetration Weld Locations
(With Carbon or Low Alloy Steel-To-Stainless Steel Connections Using Alloy 82/182 Weld Materials)

- Reactor Coolant System Piping
  - Surge nozzle weld
  - Drain nozzle weld
  - Reactor coolant pump welds
  - High-pressure injection weld
  - Decay heat nozzle weld
- Core Flood Tank
  - Outlet nozzle weld

Current Status

- Weld locations believed to be most susceptible to PWSCC are currently being ranked
- Initial thoughts concerning the bounding locations include:
  - **Pressurizer surge nozzle welds**
  - **Decay heat nozzle weld**
- Detailed safety assessments will be completed for those locations considered most limiting

Summary and Conclusions

- Through-wall leakage of primary coolant at the RV nozzle-to-pipe weld locations, resulting from PWSCC, will not occur at B&W-Design plants
- Augmented inspections of RV nozzle-to-pipe welds for PWSCC degradation at B&W-Design plants are not necessary from a safety perspective
- Inspections of these weld locations are performed in accordance with ASME Code Section XI ISI requirements

Summary and Conclusions

- Most likely bounding weld locations include the pressurizer surge nozzle welds and the decay heat nozzle weld
- Additional evaluations are underway to assess the safety significance of all Alloy 82/182 weld locations at the B&W-Design plants

Industry Response
Alloy 82/182 Weld Cracking

NRC Review – March 23, 2001

Materials Reliability Program
Alloy 600 Issue Task Group (ITG)

Assessment Committee Chairman
Vaughn Wagoner, CP&L

Pipe Welds - Assessment Findings
Summary

- Susceptible locations have been identified
- Most cracks will be axial
- There is a large tolerance for through-wall axial and partial-arc circumferential cracks
- The probability of deep 360° circumferential cracks is very low
- Leakage will be detected long before axial and partial-arc circumferential cracks reach limit load size
- Several factors provide significant defense in depth

Integrity Assessment for Head Penetrations

- Introduction
- Previous Cracking Incidents
- Evaluations of Cracking
- Assessment of Operating Plants

Introduction

- Cracking was first observed in Alloy 600 head penetrations (1991).
- Recent cracking in attachment welds has been found at Oconee.
- This assessment was prepared to update existing work to cover this new form of cracking.

Previous Cracking Incidents

- First crack identified at Bugey 3 in Fall 1991 (Leak).
- Lack of fusion was detected in attachment welds at Ringhals in 1992.
- Safety assessments were developed in early 90's for these types of cracking.
- In November 2000, a through-wall leak was found at Oconee Unit 1, resulting from an axial flaw in the attachment weld.
- February 2001, several more similar flaws were found at Oconee Unit 3.

Evaluations of Cracking

- Stress analyses showed that hoop stresses are controlling at the inner surface of the penetrations, so flaws would be expected to be axially oriented.
- Service experience confirms this.
- Cracks at the ID of the head penetration would require at least 8 years to propagate through the wall, and extension above the weld would take another 2 years.
- Cracks resulting in significant leakage could cause erosion of the head, and this would require 6-8 additional years to cause significant degradation.
- A through-wall flaw 11 to 20 inches long would be required to produce a failure.
- Studies of postulated circumferential cracks showed 40 to 100 years would be required for cracks to grow to an unacceptable size.

Assessment of Operating Plants

- Cracking in 182 attachment welds cannot be ruled out.
- Crack growth rate is five times that for Alloy 600.
- Flaws are all axially oriented, as would be expected from the stresses.
- Axially oriented flaws have no impact on the structural integrity of the attachment weld, but could lead to cracking of the head penetration.
- Head penetration cracking has already been evaluated.
- Leakage to date has been very small, so head wastage is not expected.

Head Penetration Conclusions to Date

- Re-assessment of Safety Evaluations performed previously concludes they remain valid
- Utilities comply with 10CFR50.55a and meet the intent of GDC-14
- Recent events are being evaluated for generic implications as details become known

Industry Response
Hot Leg Cracking Experience

Materials Reliability Program
Alloy 600 Issue Task Group (ITG)
Inspection Committee

Tom Alley, Duke Energy
Chairman

March 23, 2001

Attachment 7

Inspection Topics

- MRP 82/182 Weld Integrity Inspection Committee, Short Term Inspection Guidance
- ISI Vendor Capability Demonstrations to Support Spring 2001 10 yr RPV ISI
- Procedure Enhancements Made as a Result of Demonstrations

MRP 82/182 WELD INTEGRITY INSPECTION COMMITTEE, SHORT TERM INSPECTION GUIDANCE

- Letter from Jack Bailey to MRP Senior Representatives 3/1/01 provides guidance for units with Spring 2001 outages
- Longer range plans to address findings from Spring inspections, applicability and need for considering other NDE techniques, development of additional mock-ups, and recommendations for qualification and coordination with PDI

MRP 82/182 WELD INTEGRITY INSPECTION COMMITTEE, SHORT TERM INSPECTION GUIDANCE

- Units with Spring 2001 Outages
  - Proceed with currently planned ISI using qualified inspectors and procedures
  - No need for augmented volumetric examinations to include Alloy 82/182 welds not already scheduled for ISI
  - Review GL 88-05 boron inspections and ASME pressure testing programs, enhance awareness of inspectors, and emphasize areas known to contain 82/182
  - Review leak detection programs and sensitize inspectors & operators to small changes in leak rates and potential leak sources
  - Review VC Summer and Oconee events with ISI vendors and sensitize inspectors to capabilities, limitations. For 82/182 locations, review previous history for obstructions, limitations, and findings.

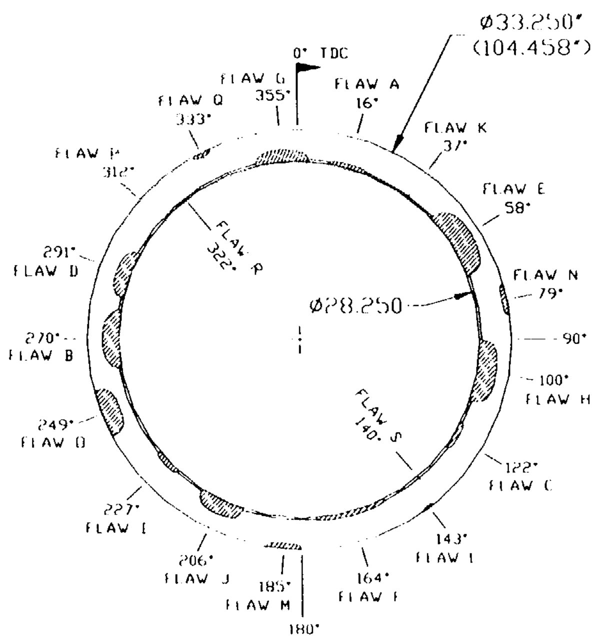
MRP 82/182 WELD INTEGRITY INSPECTION COMMITTEE, SHORT TERM INSPECTION GUIDANCE

- **For units with 10-yr RPV ISI in Spring 2001, additional guidance was provided**
  - **Continue with current plans for applying UT from the inside surface**
    - » Inspection committee determined that this is the best available technique
    - » Considered adequate for the Spring ISI
  - **Conduct a demonstration of UT capability**
  - **Communicate ISI planning, demonstrations, and results with EPRI NDE Center to ensure consistency of application**

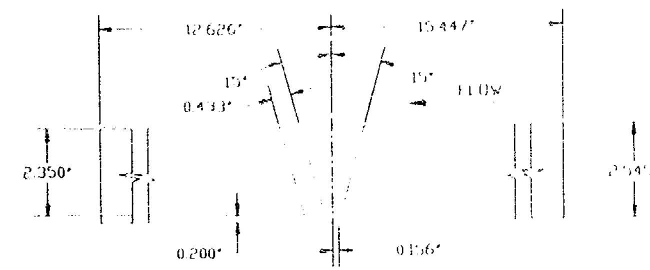
ISI VENDOR CAPABILITY DEMONSTRATIONS TO SUPPORT SPRING 2001 10YR ISI

- MPR Guidance recommends demonstrations of ISI vendor capability
- Participants
  - *Framatome ANP*
  - *WesDyne*
  - *IHI Southwest Technologies*
- Scope
  - *Demonstrate capability of relatively smooth bore inside surface automated ultrasonic examination*
  - *Demonstration focused on detection capability for inside surface-connected flaws*
  - *Open demonstrations*

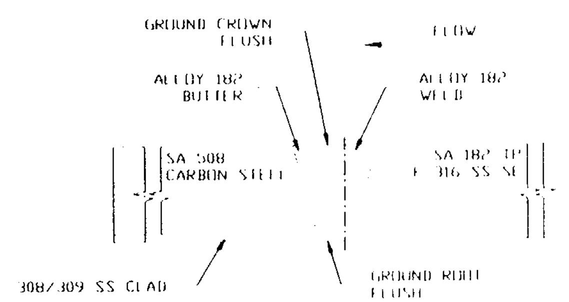
EPRI DEMONSTRATION MOCKUP



SECTION VIEW



WELD PREP
(NOMINAL DIMENSIONS)



WELD PROFILE

FLAW TYPE

- **Mockup contains thermal fatigue flaws**
  - The VCS through-wall flaw UT response was compared to the response from one of the deep flaws in the EPRI mockup. The results of this comparison showed that the ultrasonic responses had similar signal-to-noise and overall signal characteristics, but PWSCC flaw had somewhat lower amplitudes
- **This same kind of flaw is used in Sweden for qualifying ISI**
  - Similar comments made about similarity of response (mockups compared to Ringhals flaw)
  - EPRI NDE Center will visit Ringhals/SQC to further explore this issue

DEMONSTRATION RESULTS

ISI Vendor	No. Flaws Exam.	Flaws Detected	Comments
IHI Southwest	6	100%	Procedure Enhancements
WesDyne	5	100%	EPRI, VCS, ANII, and NRC representatives selected most challenging flaws due to time constraints at VCS.
Framatome	12	100%	Procedure Enhancements

- **EPRI NDE Center participated in all demonstrations – results will be formally documented through MRP**

PROCEDURE ENHANCEMENTS

- IHI SOUTHWEST
  - **Scan sensitivity**
    - » Noise level
  - **Scan index**
    - » Finer increment for circumferential scans
  - **Search units**
    - » Added 70-deg RL for enhanced detection and confirmation of inside surface-connected flaws
  - **Data analysis**
    - » Added more structured decision flow to detection process

PROCEDURE ENHANCEMENTS

- FRAMATOME ANP
  - Scan sensitivity
    - » Noise level
  - Scan index
    - » Finer increment for circumferential scans
  - Length sizing
    - » Improved approach
  - Search units
    - » Added a supplemental search unit to improve length sizing of short flaws
  - Data analysis
    - » Clarified sizing approach
    - » Added more structured decision flow

PROCEDURE ENHANCEMENTS

- **WesDyne**
  - **Sled design**
    - » VCS first deployment of new articulating ball housing sled design

Assessment Committee Activities

- Preliminary Assessment Report - April 2001
  - Assessment report for worst case Alloy 82/182 locations
- Overall Assessment Report - End of June 2001
  - Prioritize locations based on safety significance, NDE capabilities, and field experience
  - Assess Spring 2001 inspection results
- Longer Term Assessment Activities
  - Determine inspection requirements
  - Develop consistent flaw evaluation guidelines
  - Assess research needs and oversee tasks
  - Assess predictive models

Inspection Committee Activities

- Guidance for Spring 2001 inspections- complete
- Continue to support Spring 2001 inspections
- Longer Term Actions
  - Evaluate Spring Inspection results/feedback to Fall plants
  - Evaluate need for alternate/new techniques
    - » Evolving Vendor capabilities
    - » International capabilities
    - » Geometry concerns
  - Define additional mockup needs
  - Work with vendors on delivery systems
  - Coordinate demonstrations with current App. VIII actions
  - Provide training/expert help to utilities
  - Evaluate impact on Risk Informed ISI

Repair/Mitigation Committee Activities

- Need for repair/mitigation improvements depends on Assessment and Inspection Committee findings
- Prioritize from repair/mitigation/inspection perspective
  - Likelihood/consequence of failure
  - Implementation difficulty
  - Cost and dose
  - Material availability
- Create a repair/mitigation matrix
  - Assess existing technology
  - Qualification and demonstration
  - Code and regulatory compliance/involvement
    - » Generic Approval Process?

CONCLUSIONS

- The MRP has taken the lead in developing an industry plan
- Cracking of pipe and CRDM welds not a near term safety issue
  - There is no widespread generic safety problem
    - » Visual inspections for boric acid are effective in finding leaks
    - » Previous ISI would have found major problems with pipe welds
  - Analyses show there is significant margin against failure
  - Pipe weld failures are covered by Defense-in-Depth (FSAR)
- Interim guidance has been provided for Spring 2001 outages
  - UT methods have been improved and demonstrated on mockups
  - Awareness of operators and inspectors has been increased
- There is ongoing action regarding assessment, inspection and repair/mitigation
- NRC comments on work are appreciated
  - Will continue to keep NRC informed