Ginna Station

CRDM Cracking Technical Evaluation

NRC Status Update

Rockville, Maryland
December 12, 2001

Enclosure 3

Rochester Gas & Electric Corporation

Ginna Station CRDM Cracking Technical Evaluation Agenda

Overview/Background	B. Flynn	15 minutes
1999 Inspections	A. Butcavage M. Shields	45 minutes
Reactor Vessel Head Temperature	B. Flynn	30 minutes
Break		10 minutes
Crack Growth Rate Analysis	H. Gustin, SI	30 minutes
Probabilistic Safety Assessment	M. Flaherty	15 minutes
Replacement Reactor Vessel Head	B. Flynn R. Klarner, BWC	30 minutes
Summary / Conclusion	T. Marlow	5 minutes

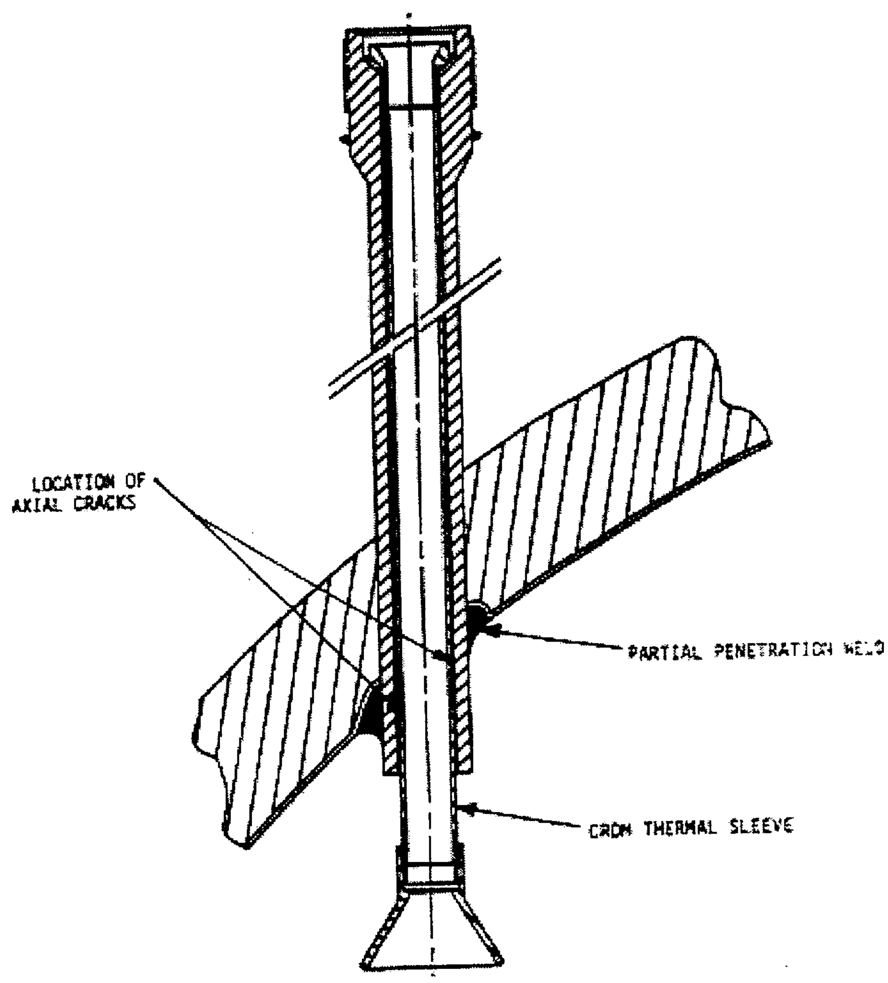
Overview/Background

- 2-Loop Westinghouse PWR
- 490 MWe, Online December, 1969
- Reactor Vessel Manufactured by B&W
- CRDM Tube Material from Huntington

Overview

(continued)

- Reactor Vessel Closure Head
  - 38 Penetrations in Head
    - 29 CRDM's
    - 4 Part Length CRDMs (abandoned)
    - 4 Instrumentation Ports (1 spare)
    - 1


LOCATION OF
AXIAL CRACKS
PARTIAL PENETRATION WELD
CRDM THERMAL SLEEVE

Background

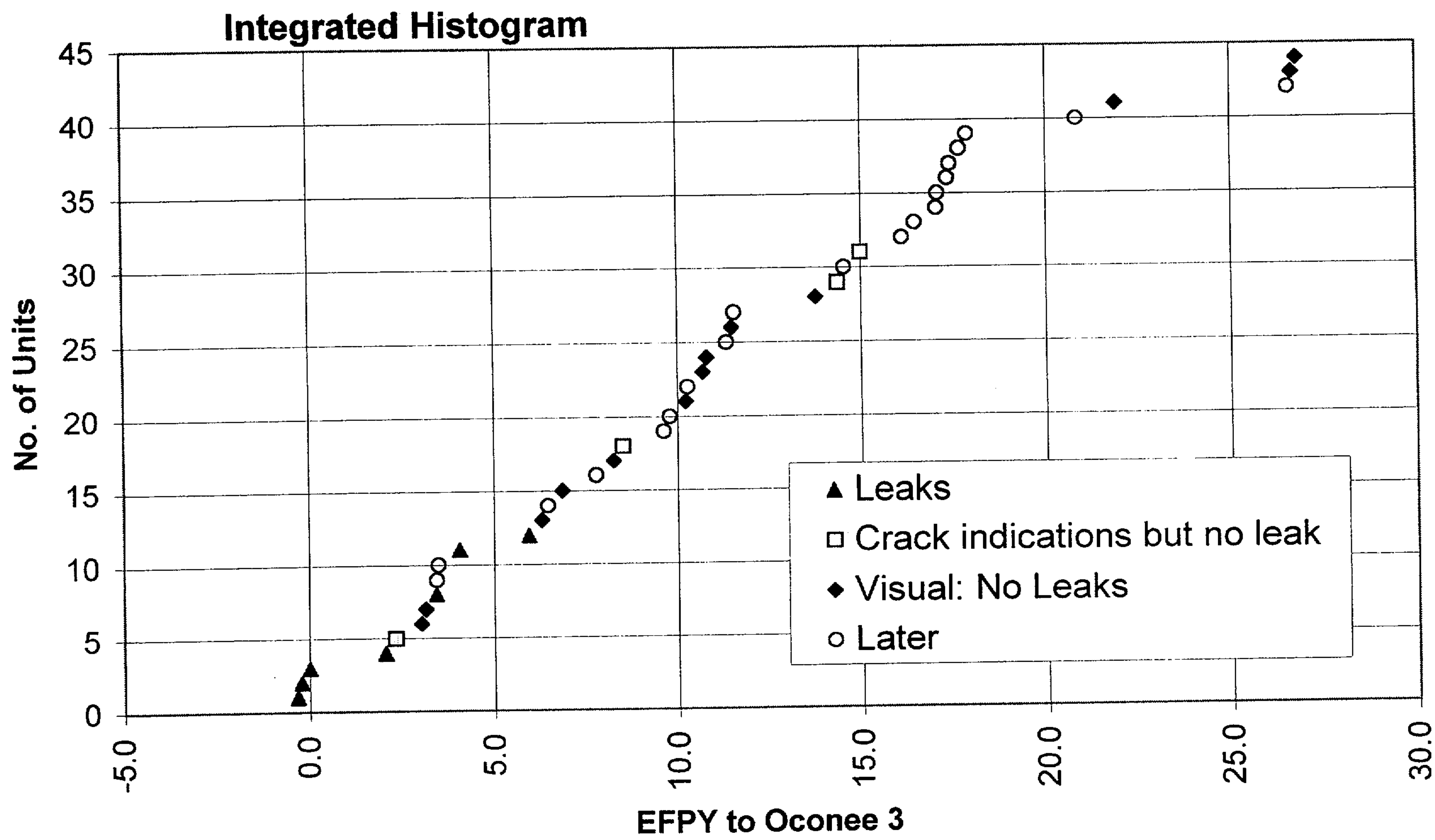
- RG&E Initially Participated in NEI AHAC Committee on Issue Starting in 1992
  - Top of Insulation Visual Inspections
  - Underhead Visual Checks Via Remote Crawler (1993)
  - Purchased As-Built Package from Manufacturer

- Following Generic Letter 97-01, RG&E volunteered for ET Penetration Inspection
  - Inspection Completed in 1999
  - All 38 Penetrations Inspected
  - Better Baseline than Effective Visual Exam

- Continued MRP Participation

Background
(continued)

- Reactor Operating Times
  - 1999 Inspection – 22.2 EFPY's
  - December 12, 2001 – 24.7 EFPY's (2.49)
  - September 15, 2003 – 26.4 EFPY's (4.16 projected)
- Ginna Ranking in Industry Histogram (MRP-48)
  - 31st, 15.0 EFPY's (NRC Group 5 to 30 years)
  - Margin to those who have found indications



Integrated Histogram
No. of Units
EFPY to Oconee 3
0
5
10
15
20
25
30
35
40
45
-5.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
Leaks
Crack indications but no leak
Visual: No Leaks
Later

Ginna 1999 Inspection

Al Butcavage
Mike Shields

Rochester Gas & Electric Corporation

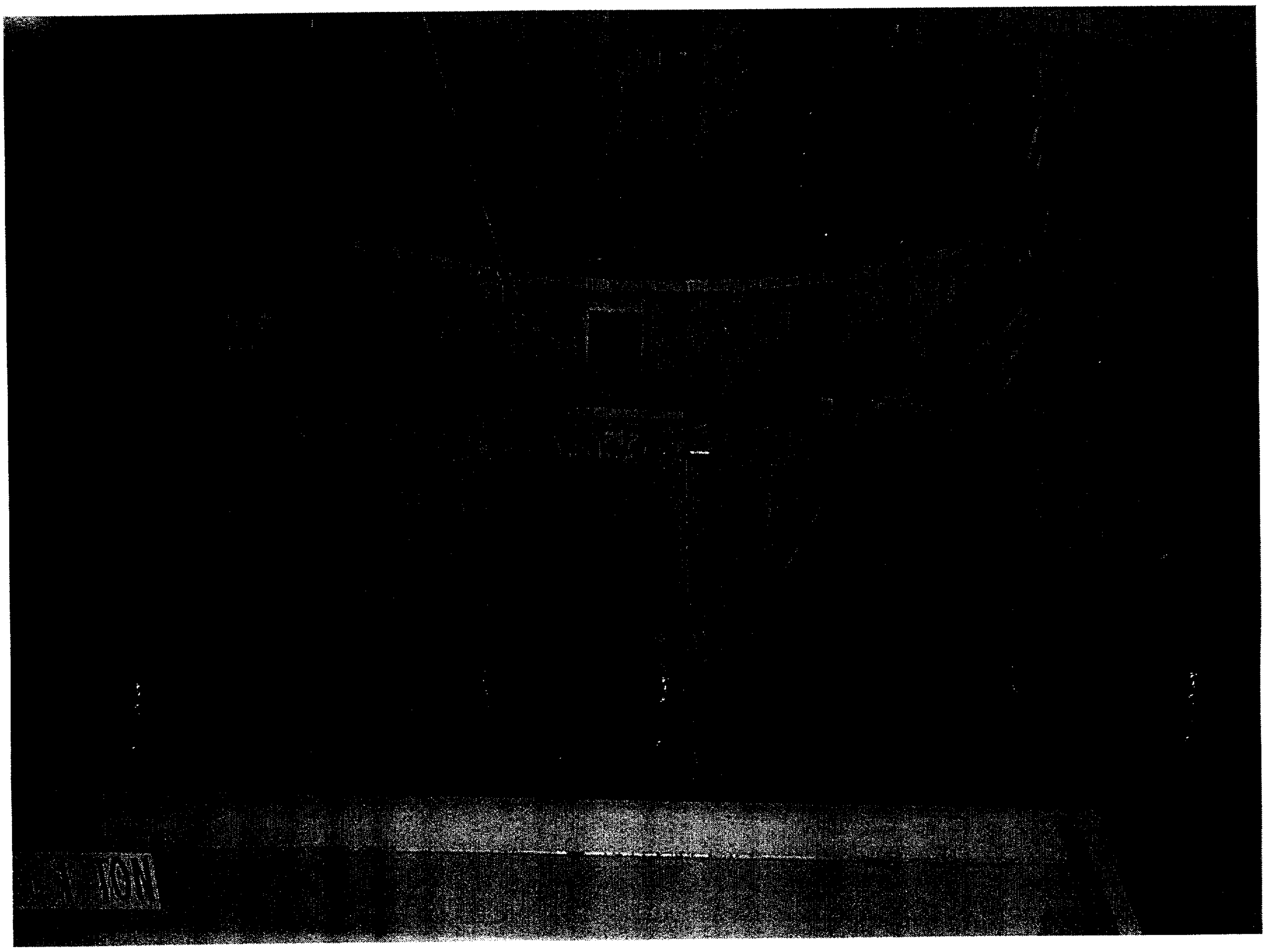
Ginna 1999 Inspection

- Purpose
  - GL 97-01 Issues
  - Primarily looking for Axial Indications
  - Equally Sensitive to Axial and Circumferential Indications
  - All nozzles not just CRDMs

Ginna 1999 Inspection

- 3 Vendors Considered
- FTI Selected
  - Experience in European Plants
  - Equipment matched our expertise (Zetec)
  - Vendor agreed to additional EPRI Blind Tests
  - Viable Repair Technique
- Method
  - Blade/Rotating Probes
  - ET Used for Detection
  - UT Used for Sizing

Ginna 1999 Inspection



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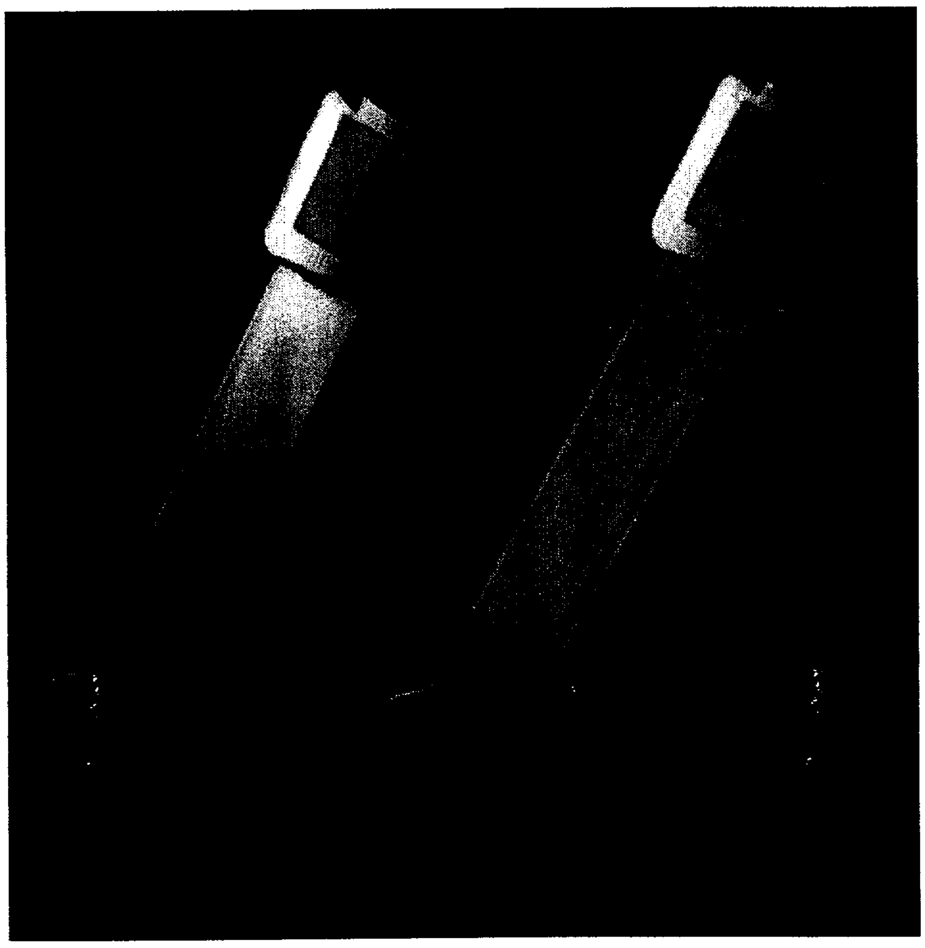
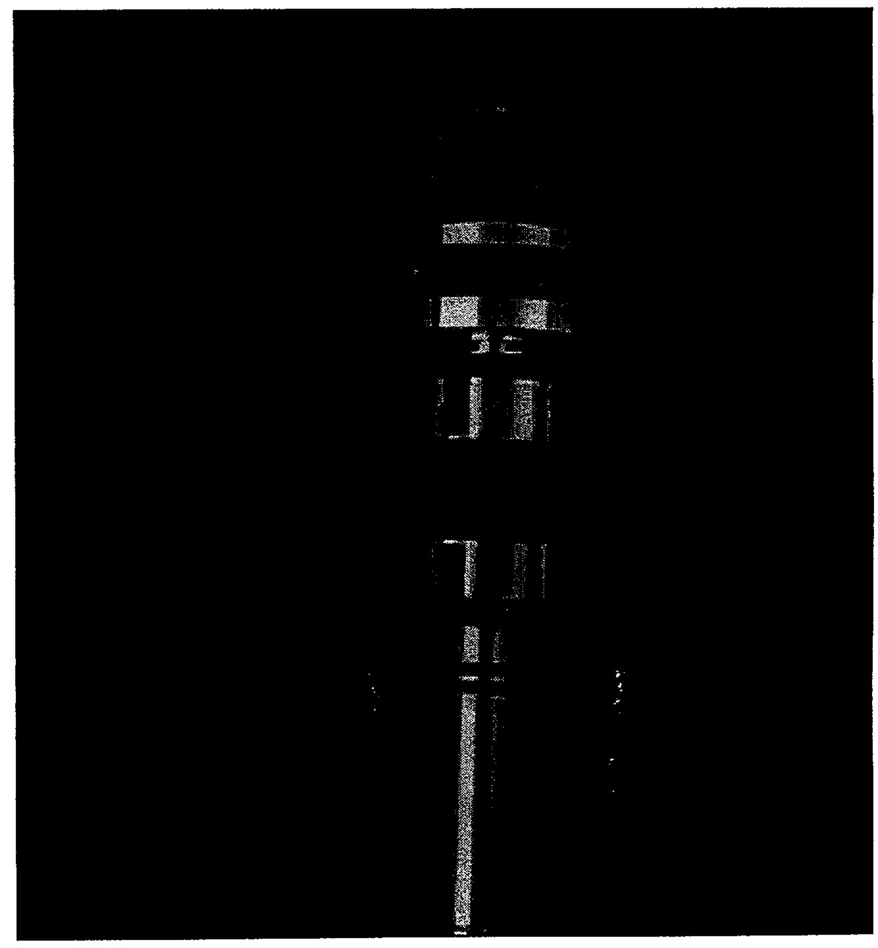
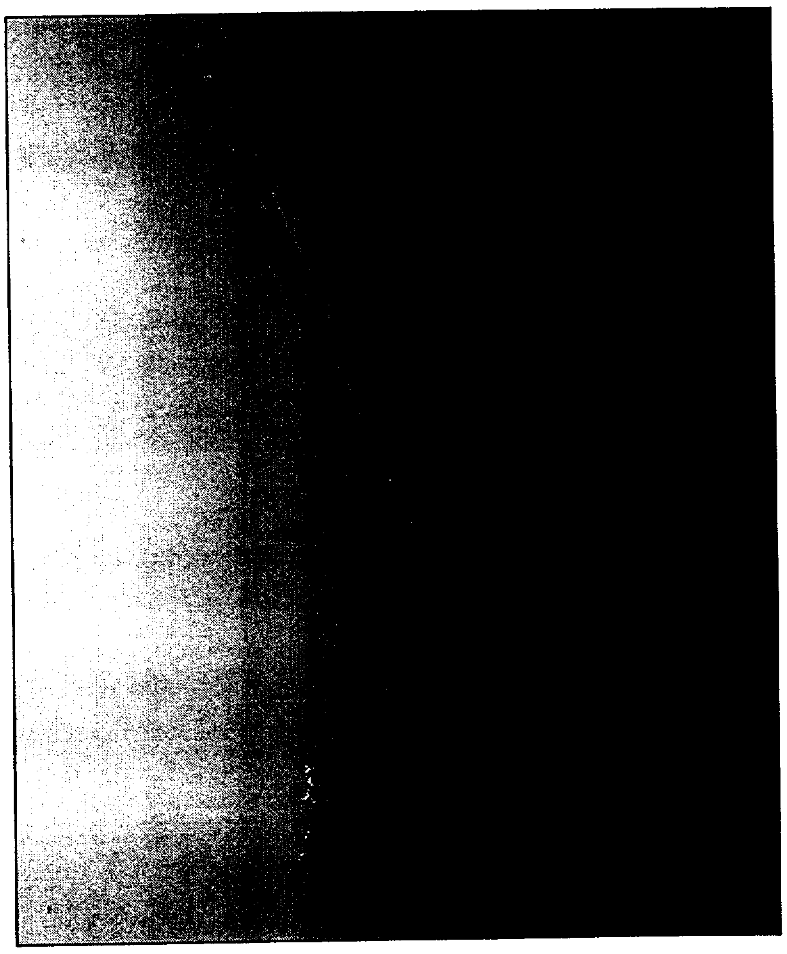
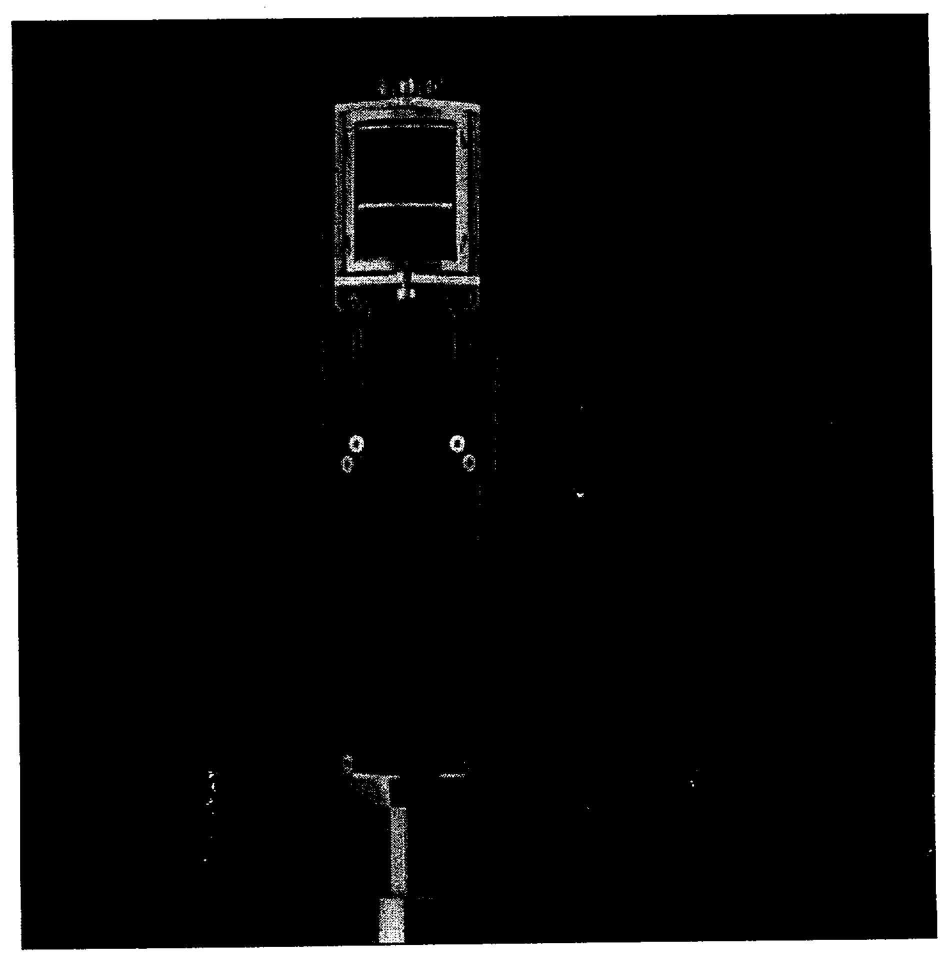
Typical Blade & Rotating Eddy Current Probes





Typical Blade & Rotating Ultrasonic Probes





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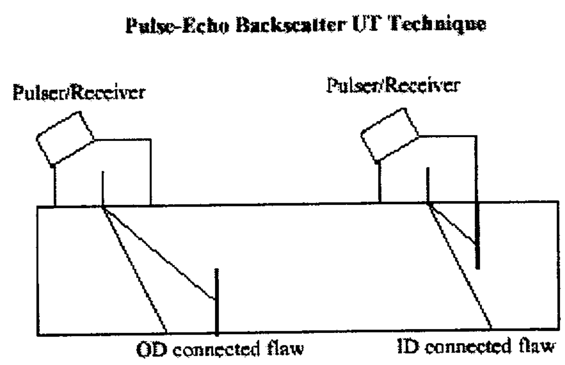
Ginna 1999 Inspection

- EPRI Blind Performance Test
  - ET/UT Qualifications
    - Axial
    - Circumferential
    - Off Axis
    - Clustered
    - Single
    - Branched
  - Equally sensitive to I.D. or O.D. circumferential or axial throughwall cracks
  - Results Detect-Size-Locate (EPRI Report TR-106260)
    - Successful in all areas

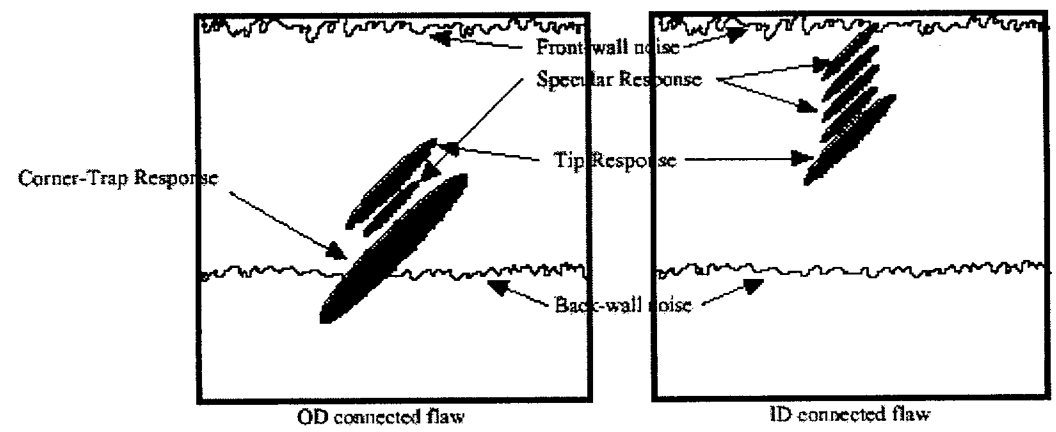
Ginna 1999 Inspection

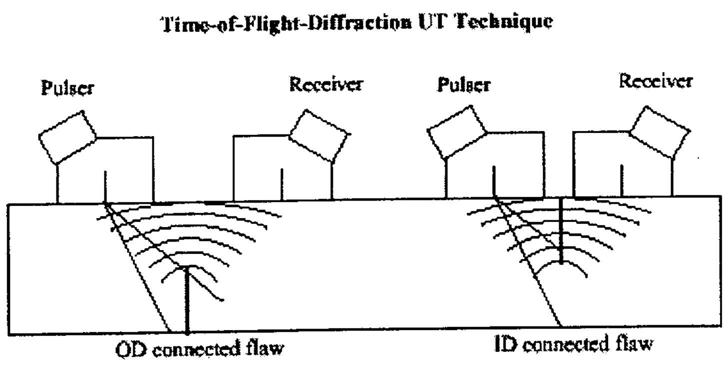
- Results
  - RG&E NDE Level III Online Review of 100% of ET and UT Data
  - The required nozzle inspection area was ±2" from weld
  - 93% of surface area covered
  - 1 nozzle (#13) with ET shallow indications
    - Shallow "craze" ID indications ≈ 5% of area
    - Random in HAZ
    - Sized with UT
    - 2 probes mid surface, near surface
    - Indications below minimum detection of UT probes (< 0.8 mm)

Ginna 1999 Inspection

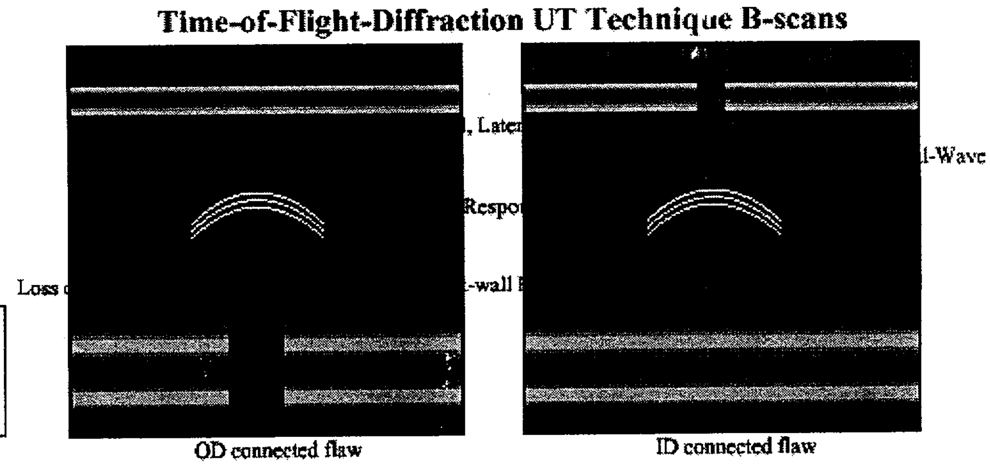


Pulse-Echo Backscatter UT Technique B-scans w/angle correction





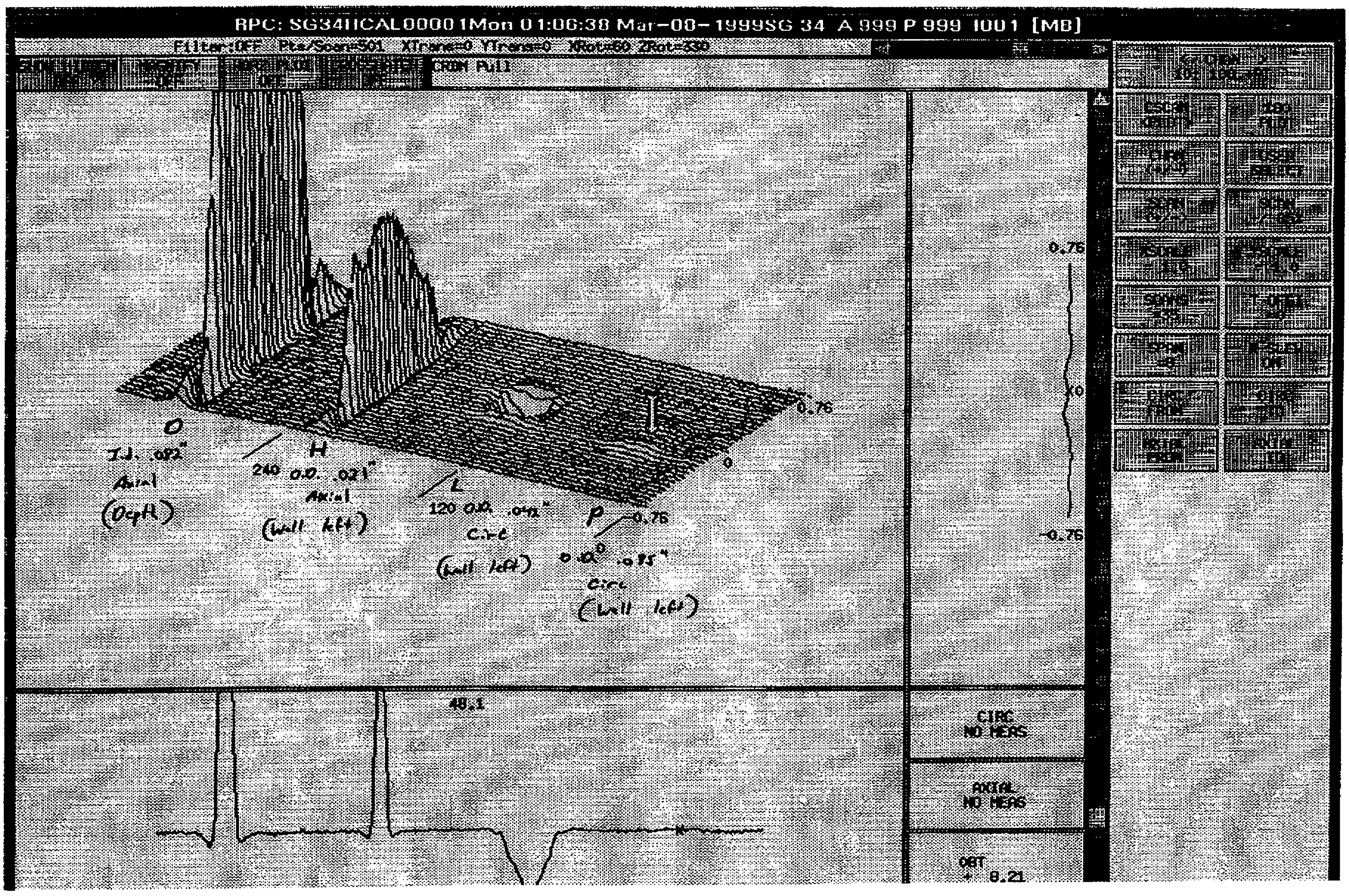
Time-of-Flight-Diffraction UT Technique B-scans



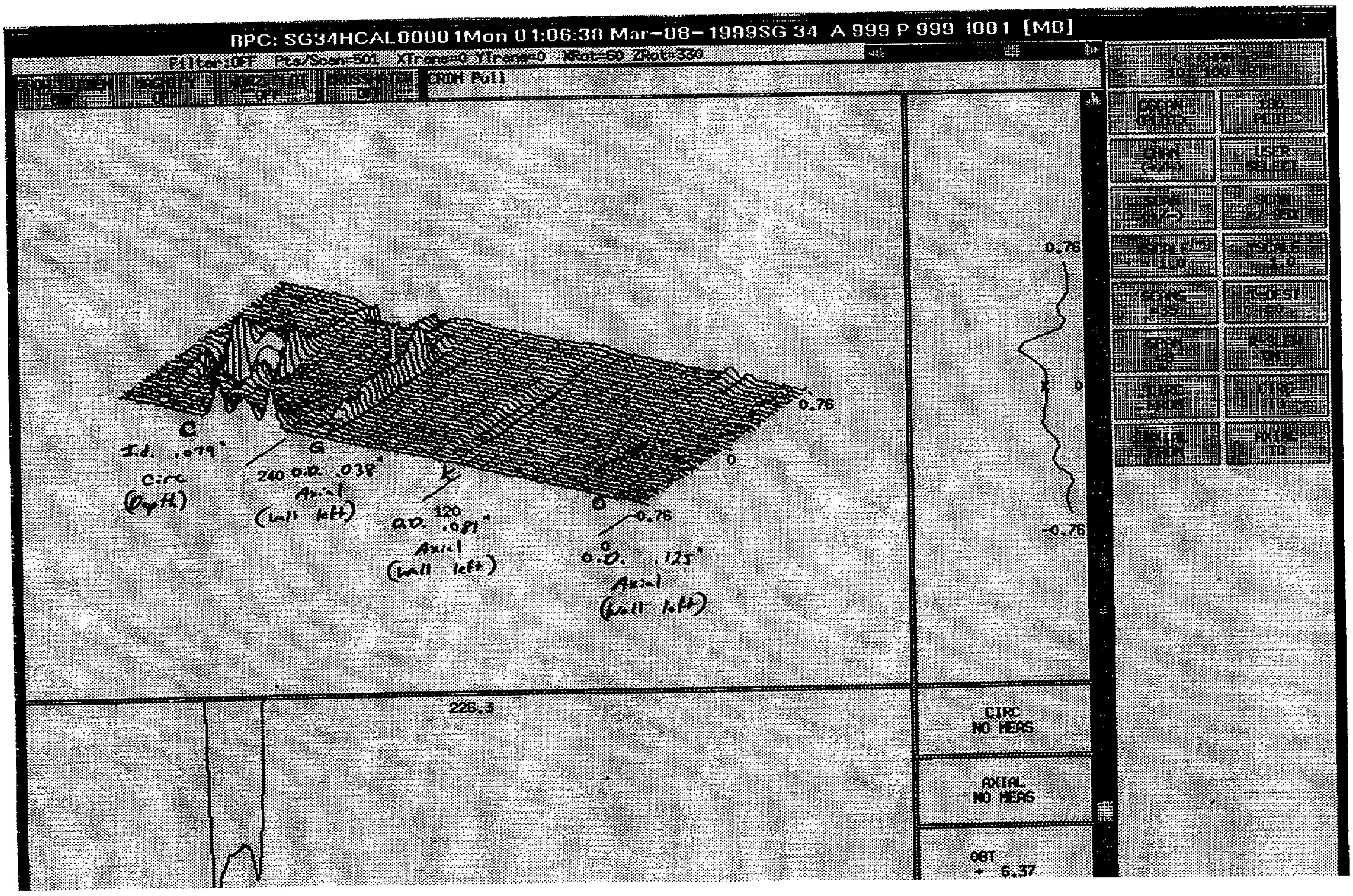
Ginna 1999 Inspection

- Post Oconee Review
  - Vendor Review of UT Data (#13)
    - No change in conclusions
  - RG&E Level 3 Review of ET Data
    - Mockup contained O.D. initiated Axial and Circumferential flaws and were detected at .042" subsurface
    - ASME Section XI considers eddy current for S/G a volumetric inspection for tube wall up to .050"
    - Data review included lower frequency deeper inspection approach
    - No change to original report

Ginna 1999 Inspection



Ginna 1999 Inspection



Reactor Vessel Head Temperature

Brian Flynn

Rochester Gas & Electric Corporation

Ginna Reactor Vessel Head Temperature

- CRDM Cracking Susceptibility and Growth Very Temperature Dependent
  - 2.25 EFPY at 580°F = 1.0 EFPY at 600°F
- Westinghouse Reactor Vessel Internals Design Provides Some Upper Head Cooling
- Two-loop Plants Inherently Cooler Upper Heads
- Temperature Utilized in MRP Ranking Conservatively Chosen

Ginna Reactor Vessel Head Temperature Operating Conditions

- 100% Power Operation

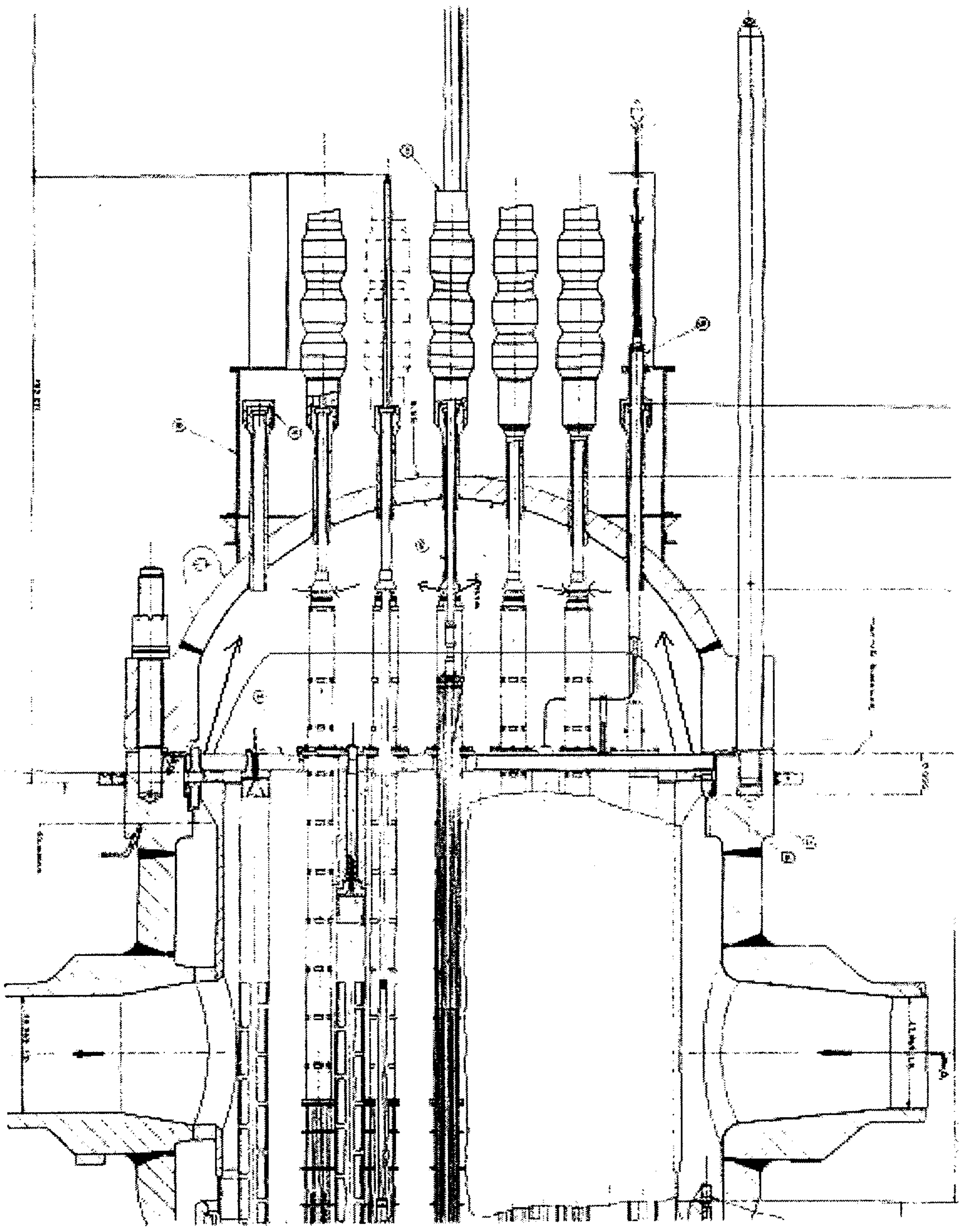
  Tcold = 532.6° F

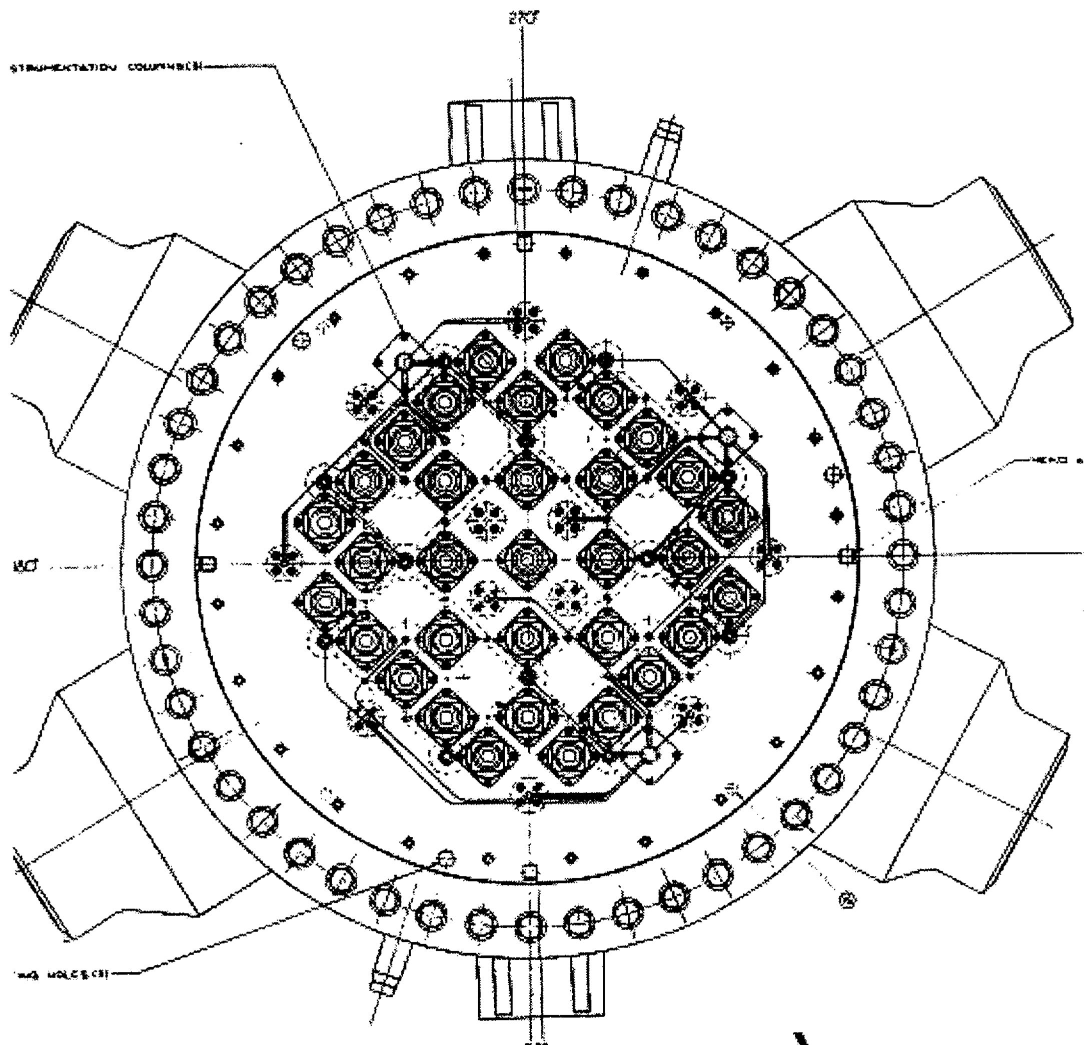
  Tavg = 561° F

  Thot = 589.5° F

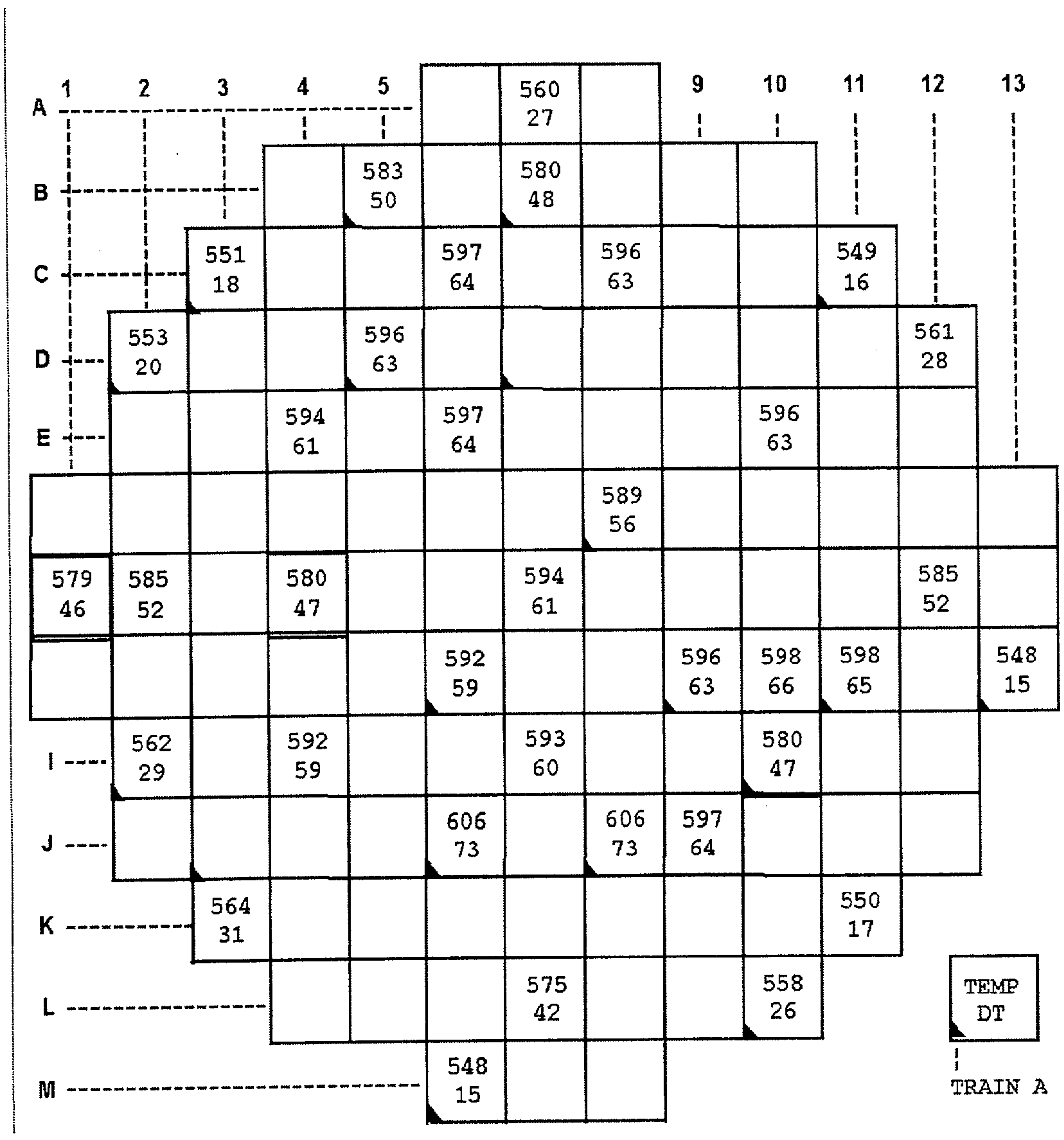
  Upper Head Bypass Flow ≈ 550 gpm (0.29%)

- Operation Since 1999 Inspections
  - 2.49 EFPY
  - 4.16 EFPY prior to proposed replacement





PLAN VIEW WITH HEAD REMOVED



1 2 3 4 5 9 10 11 12 13
A B C D E I J K L M
560 27
583 50
580 48
551 18
597 64
596 63
549 16
553 20
596 63
561 28
594 61
597 64
596 63
589 56
579 46
585 52
580 47
594 61
585 52
592 59
596 63
598 66
598 65
548 15
562 29
592 59
593 60
580 47
606 73
606 73
597 64
564 31
550 17
575 42
558 26
548 15
TEMP
DT
TRAIN A

Determining Upper Head Temperature

- WCAP - 9404 "Study of Reactor Vessel Upper Head Region Fluid Temperature", 1978
  - Analytical Modeling
  - 1/5 Scale Tests
  - In Plant Instrumentation, 5 plants installed new thermocouples
    - Ginna was 2-Loop Plant
    - Farley Under Construction, Enhanced Instrumentation

- Results
  - Analytical Model Closely Matched Scaled Tests
  - Temperatures Measured at Farley Match "Momentum Controlled" Flow Pattern
  - Two-Loop Plant Lowest Predicted Temperature
    - Low Differential Pressure in Outlet Plenum
  - Tmax in head in lower region

Ginna Upper Head Temperature Results

- Ginna Utilized Temperature Representative of Tmax in Upper Head Region
  - Average of 3 Upper Head Thermocouples 580.2° F
- Westinghouse Model Predicts Bulk Fluid Average 577.5° F
- Region of CRDM Welds Expected to be Lower
  - Particularly in Region of Outer Penetrations

Allowable Flaw Size and Flaw Growth Calculations

Hal Gustin

December 12, 2001

Structural Integrity Associates

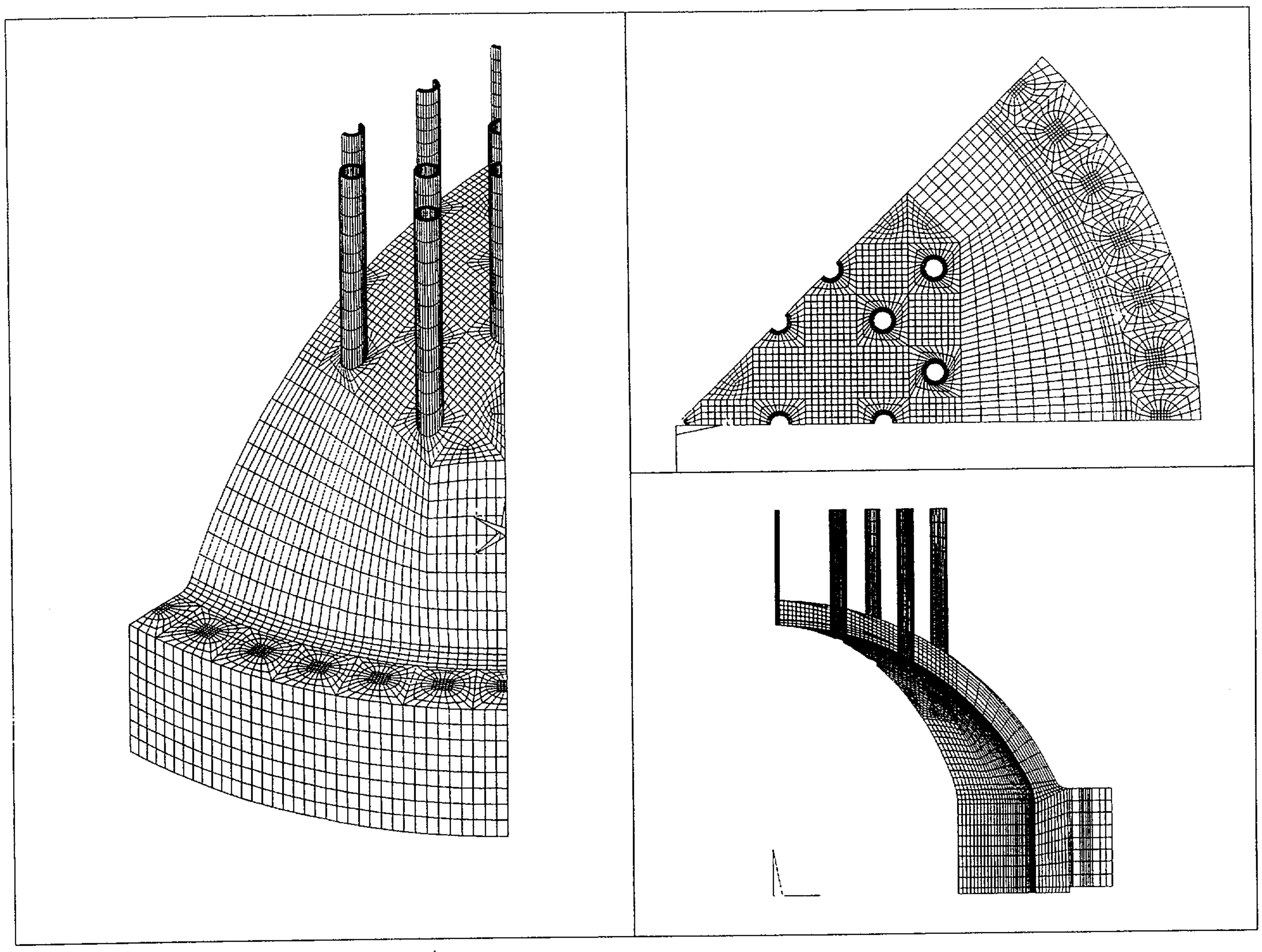
GINNA ANALYTICAL PROGRAM

- Determine maximum gap sizes for linear elastic fracture mechanics evaluations
- Determine critical/allowable circumferential through-wall flaw length for nozzle
- Perform linear elastic fracture mechanics analyses for representative set of nozzles for various flaw lengths
- Develop crack growth law by adjusting MRP 95% confidence crack growth rate to Ginna temperature (580° F)
- Determine time to reach allowable flaw length from hypothetical "large" through-wall circumferential flaw in nozzle

MAXIMUM GAP SIZES - GINNA

- **Finite element analysis of 45° of top head with nozzles**
  - Symmetric boundary conditions
  - Gap elements between nozzles and head
- **Loading conditions**
  - Normal operating pressure
  - Normal operating temperature
  - Closure bolt loads
  - Gasket/spring loads
  - Initial 0.00 inch clearance between nozzles and head
- **Maximum gap openings determined**

GINNA FINITE ELEMENT MODEL



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PRS-01-060/4

CRITICAL/ALLOWABLE FLAW LENGTH - GINNA

- **Equation 5.1 of MRP-44 utilized:**

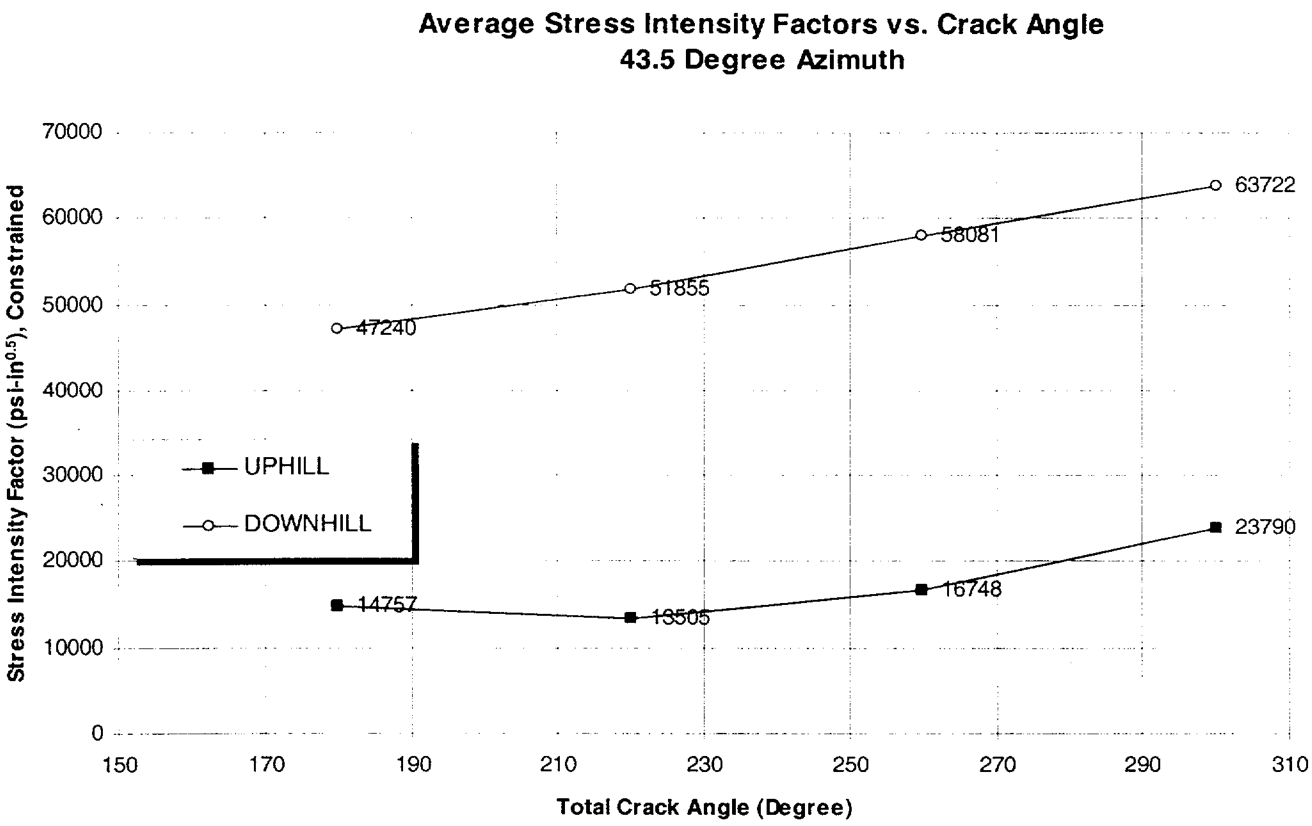
$$P = \frac{\sigma_{flow}}{FS}\left[\frac{A_{wall}\left(1-\frac{\theta}{360}\right)}{A_{bore} + A_{wall}\left(\frac{\theta}{360}\right)}\right]$$

where:	P	=	maximum normal operating pressure acting on the nozzle bore and crack face
	σ_{flow}	=	flow stress
	A_{bore}	=	cross-sectional area of the nozzle bore
	A_{wall}	=	cross-sectional area of the nozzle
	θ	=	circumferential angle of the allowable through-wall flaw
	FS	=	factor-of-safety = 3.0 for allowable flaw size

- **For Ginna, the allowable through wall flaw length is 300°, with the critical flaw length equal to 338°**

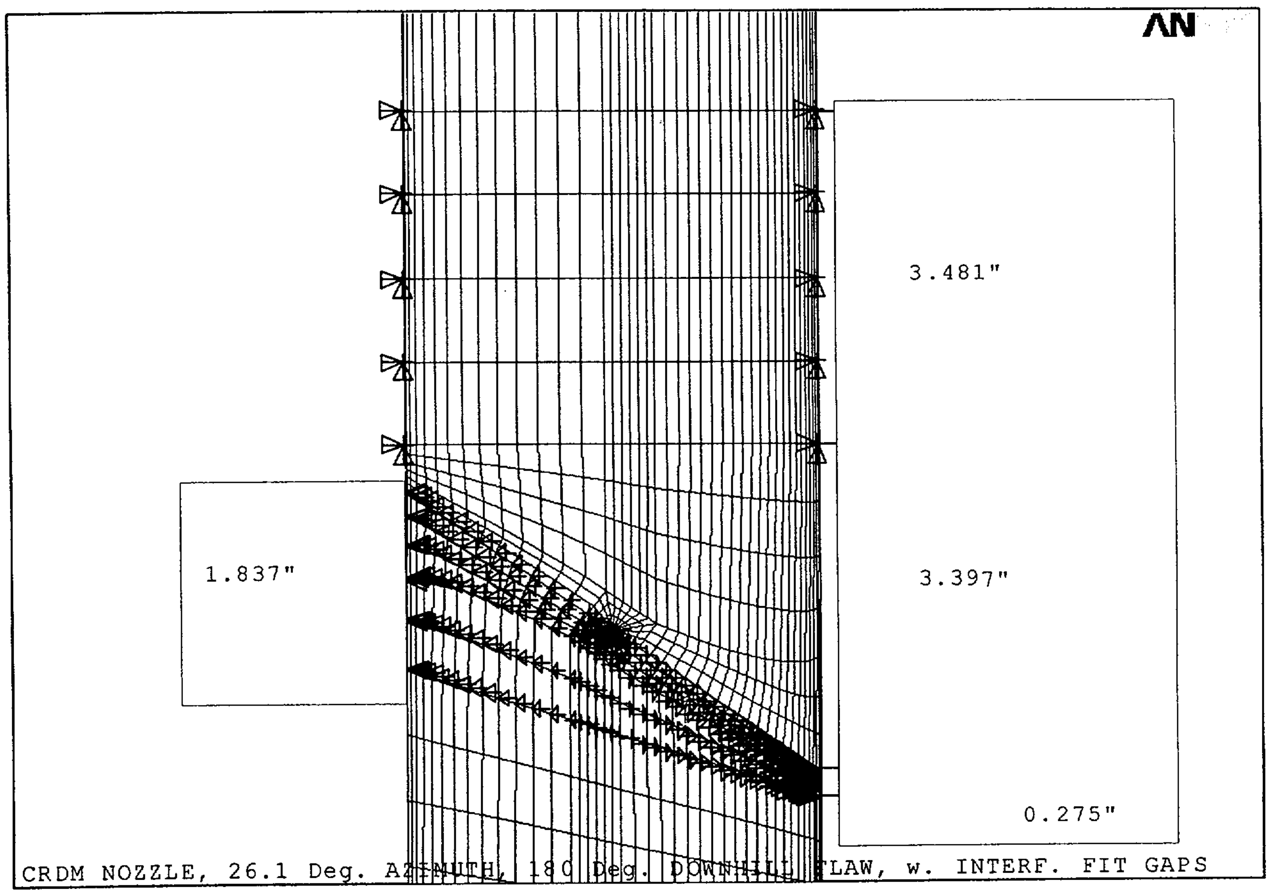
GINNA FLAW EVALUATION

- Three-dimensional finite element model developed for nozzles
  - Solid elements
  - Crack face above weld modeled with coupled double nodes
  - Circumferential through-wall flaw modeled by releasing nodes
  - Weld location modeled with radial restraint
  - Gap elements used on crack face (crack closure)
  - Gap elements used along nozzle interface with vessel
- Load combination
  - Normal operating pressure
  - Normal operating temperature
  - Weld residual stress
  - Max. gap values from gap analysis
- Loads applied as pressure on crack face
- Stress intensity factor (K) calculation performed for various flaw lengths



Average Stress Intensity Factors vs. Crack Angle
43.5 Degree Azimuth
Stress Intensity Factor (psi-In^0.5), Constrained
70000
60000
50000
40000
30000
20000
10000
0
150
170
190
210
230
250
270
290
310
Total Crack Angle (Degree)
UPHILL
DOWNHILL
47240
51855
58081
63722
14757
13505
16748
23790

SAMPLE FINITE ELEMENT MODEL BOUNDARY CONDITIONS



PRS-01-060/7

Structural Integrity Associates

GINNA CRACK GROWTH LAW

- Crack growth law developed:

$$da/dt = 5.17 \times 10^{-7} (K-8.188)^{1.11} \text{ inch/hour}$$

- Based upon MRP 95% confidence crack growth rate, adjusted for Ginna head temperature of 580°F

TIME TO REACH ALLOWABLE FLAW SIZE - EXAMPLE

- Assume the previously presented crack growth law
- Assume that the limiting location has an average applied K of about 55 ksi-(in)$^{0.5}$ between 90° and 300°
- Two cases
  - 90° circumferential through-wall flaw in the nozzle
  - 180° circumferential through-wall flaw in the nozzle
- Time to grow from an assumed flaw in the nozzle to the allowable flaw size of 300° is:
  - 9 years for Case 1
  - 5.3 years for Case 2

SUMMARY

- Finite element model consistent with industry standards
- Conservative inputs and assumptions
  - Head temperatures
  - Nozzle gaps
  - Assume initial hypothetical 90° and 180 degree throughwall crack
- Time to grow to allowable flaw size is significantly beyond 2003 RFO

Probabilistic Safety Assessment

M. Flaherty

Rochester Gas & Electric Corporation

Ginna Mitigation Design Insights

- Previous presentations demonstrate low risk of a LOCA
- Medium LOCA CCDP - 2.252E-03
  - Dominate Risk Scenarios
    - 53% - Operators Fail to Transfer to Recirc
    - 12% - RWST Suction Failures for RHR
    - 7% - Test and Maintenance of RHR, SI, CCW
    - 5% - CCFs of SI System
    - 5% - CCFs of RHR System (includes CCW)
    - 3% - Throttling Position of CCW Valves

Ginna Mitigation Design Insights

- Two Human Events Contribute 56%
  - Transfer to sump recirculation
    - Operators will be trained on this first cycle following startup from 2002 RFO
  - Throttling position of CCW valves for RHR HXs
    - Procedurally specified activity (hardened step)
    - Position verified every 31 days

Ginna Mitigation Design Insights

- Test and Maintenance Activities Contribute 7%
  - RHR and SI are “green” indicators
  - Actual maintenance unavailabilities very low
    - RHR - 91 hours in 2000 (38 hrs in 2001 to date)
    - SI - 29 hours in 2000 (21 hrs in 2001 to date)

Ginna Mitigation Design Insights

- Operators Sensitive to RCS Leakage
  - Containment particulate monitor (R-11)
    - Sensitivity to detect 0.013 gpm leak in 1 hour
    - Required operable in MODES 1 - 4 due to LBB
    - If inoperable, perform grab sample every 12 hours
      - More restrictive than Standard ITS
    - Successfully detected letdown line vent leak in 1998
      - Estimated to be 0.05 - 0.1 gpm
  - RCS leakage reviewed daily at morning meeting
    - Both upward and downward trends are discussed

PSA SUMMARY

- Ginna 1999 Inspection and Analyses
  - Low likelihood of occurrence
- If Event Were to Occur
  - Implementing steps to manage risk through training and operator awareness

Replacement Reactor Vessel Head

B. Flynn
R. Klarner

REPLACEMENT REACTOR VESSEL HEAD GINNA TIMELINE

- Spring/Summer 2001 Evaluated Options
- August 2001 Decision to Replace
  - Improve joint design and material
  - Improved insulation design for inspection
  - Address other design improvements
- September 2001 Issued Specification
- November 2001 Awarded Contract to BWC
  - Delivery August 2003

Schedule

- Head forging Purchase Order issued 12/01
- Tubing Purchase Order issued 1/02
- Award installation contract - 1/02
- Spring 2002 RFO
  - Optical templating of existing Ginna head
  - Containment laydown for changeout
  - Rigging evaluation
  - Evaluate dose projections

R. G. & E Ginna

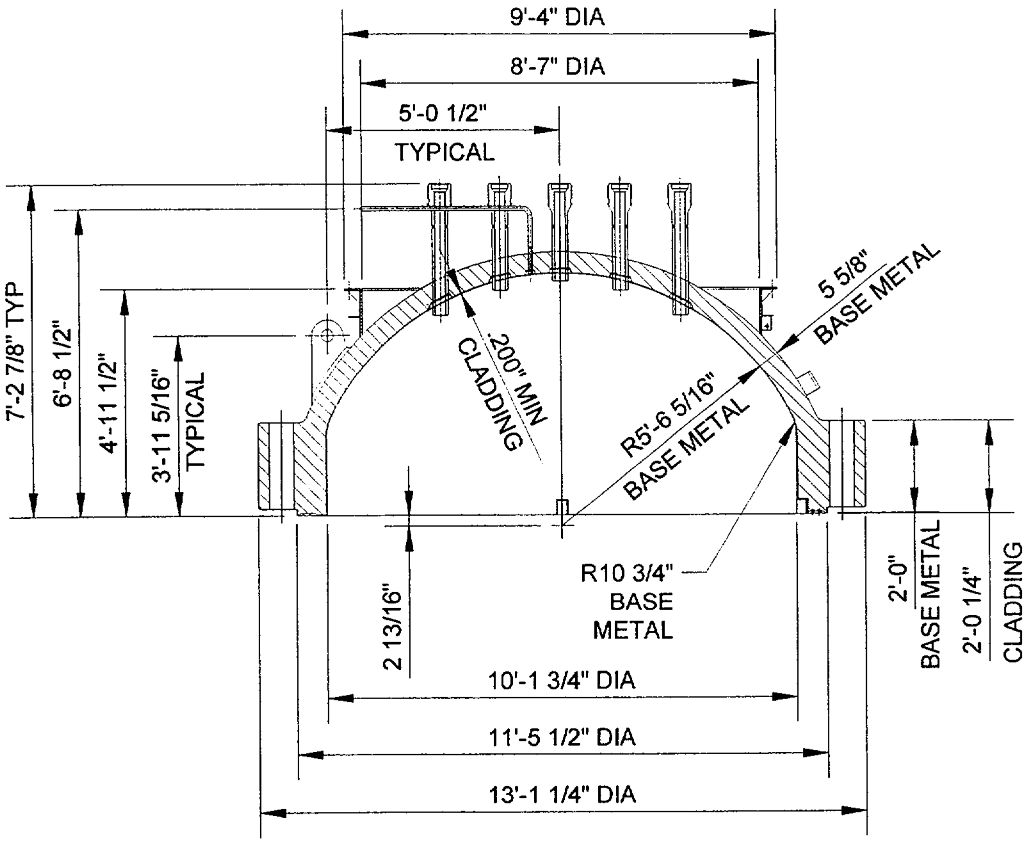
RVC Head Replacement

Presentation by Babcock & Wilcox Canada

December 12, 2001

Babcock & Wilcox Canada

Ginna Replacement Head



SECTION A-A

SEE PLAN VIEW FOR TRUE ORIENTATIONS

SCALE: 1/4"= 1'-0"

Form, Fit and Function Replacement

Dec. 12, 2001.2

Replacement RVCH Design Features

- Maximize the PWSCC integrity of CRDM guide tubes:
  - Using Alloy 690 TT materials with ESR (double melt to enhance purity and microstructure)
  - Electropolishing of guide tubes and welds to remove the cold-work surfaces induced by machining/grinding operation
  - Minimum weld volume permitted by ASME code
  - Automatic weld process to perform the "J-groove" weld
  - Weld configuration qualified by mockup testing and Finite Element Analysis to minimize residual stress in the weld joint
- Use of a single piece forged head minimizes risk of welding distortion, and eliminates potential ISI of head welds.
- Additional proprietary design features to facilitate inspections.

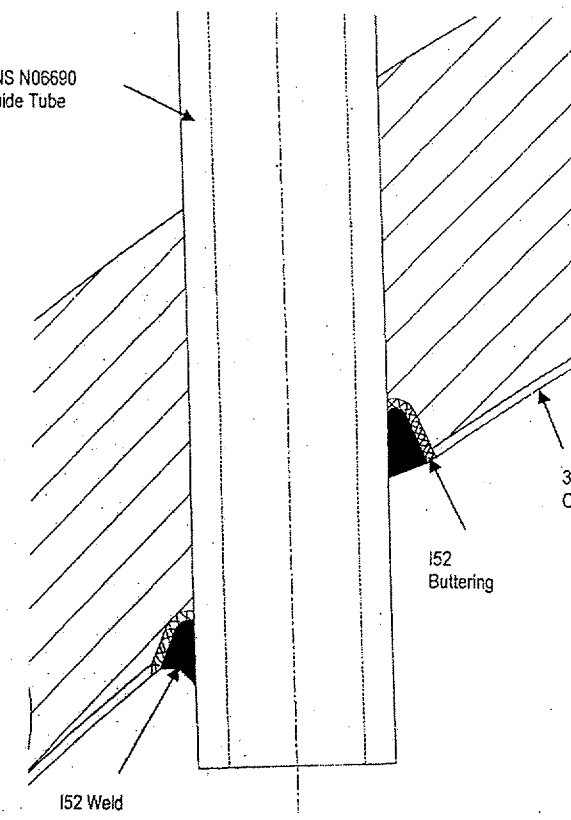
Materials

Reactor Pressure Vessel (RPV) Head - Materials of Construction

	Original RPV Head (ORPVH)	Replacement RPV Head (RRPVH)
Head	SA-336 / SA-302 Grade B	SA-508 Cl 3
Cladding	18-8 Stainless Steel	ER308L/ER309L
CRDM Guide Tubes	SB-167 Inconel 600	SB-167 Inconel 690
CRDM/Head Weld	Inconel 600	Inconel 690 (I-52)
CRDM Flange	SA-182 Tp 304	SA-182 Gr. F316LN

CRDM Nozzle Installation Sequence

- Control of cold work and residual stresses during all stages of CRDM assembly and fabrication
  - Head procured with post weld heat treated cladding
  - Machined 'J' groove over-layed with I-52 (GTAW) using a deep bore automated welding system.
  - Pockets are then machined and holes for the guide tubes are drilled.



CRDM Nozzle Installation Sequence
(Continued)

- Post weld heat treatment of head and overlayed 'J' groove
- Machine "guide tube" hole with interference fit
- Machine guide tube with controlled finishing pass, both ID and OD surfaces.
- Electropolish guide tube on ID
- Shrink fit guide tube
- I-52 partial penetration welding of guide tube to overlayed 'J' groove weld prep by GTAW process with deep bore automated welding system
- Blend grind final attachment weld profile
- Electropolish attachment weld and OD region of guide tubes

SUMMARY

- 1999 Ginna hspection is a Good Baseline
  - Cracks detectable before throughwall
- Ginna head temperatures are significantly lower than plants which have seen cracking
- Low PSA impact with selected course of action
- Replacing Reactor Vessel Head is best technical approach to this issue
  - design enhancements
  - material
  - inspectability

CONCLUSION

- Final Response to Bulletin 2001-01 Will Be Consistent with Technical Analysis Presented Here

  - Alternative evaluations justify no safety issues with our plans to not inspect in 2002

  - Current OE Supports our Conclusions

  - Proactive Head Replacement 2003