Use of MNSA-2 as a Contingency Repair for BMI Nozzles

Westinghouse Electric Company

September 9, 2003

Meeting Agenda

- Purpose of Meeting
- MNSA Overview & Mock-up Demonstration
- Experience
- MNSA-2 Design
- Qualification of MNSA-2 Assembly and the RPV lower head
- Preliminary Risk Analysis
- Relief Request Overview
- Wrap-up

Purpose

- Several plants are considering the use of MNSA-2 as a contingency for RPV bottom mounted nozzle (IMI/BMI) repairs
- Provide summary information relating to the technical suitability and adequacy of this repair for application to BMI nozzles
- Receive Staff feedback concerning use of MNSA on BMI nozzles

MNSA OVERVIEW

- The MNSA (Mechanical Nozzle Seal Assembly) is a mechanical device that provides both sealing and structural support for nozzle connections.
- MNSA has been accepted and installed on nozzles in the CE fleet (Hot Legs, Pressurizers and Steam Generators)
    - Previous nozzle sizes bound that of BMI's
- Design and qualification test reports were submitted to the NRC in support of MNSA installation

MNSA OVERVIEW

- There are two types of MNSAs
  - MNSA-1 seals on the outside of the pressure boundary
  - MNSA-2 seals on the flat surface at the bottom of the counterbore
- MNSA is an alternative to weld repair for leaks in J-groove welded Alloy 600 instrument nozzles.
- MNSA-2 will be employed in the BMI application

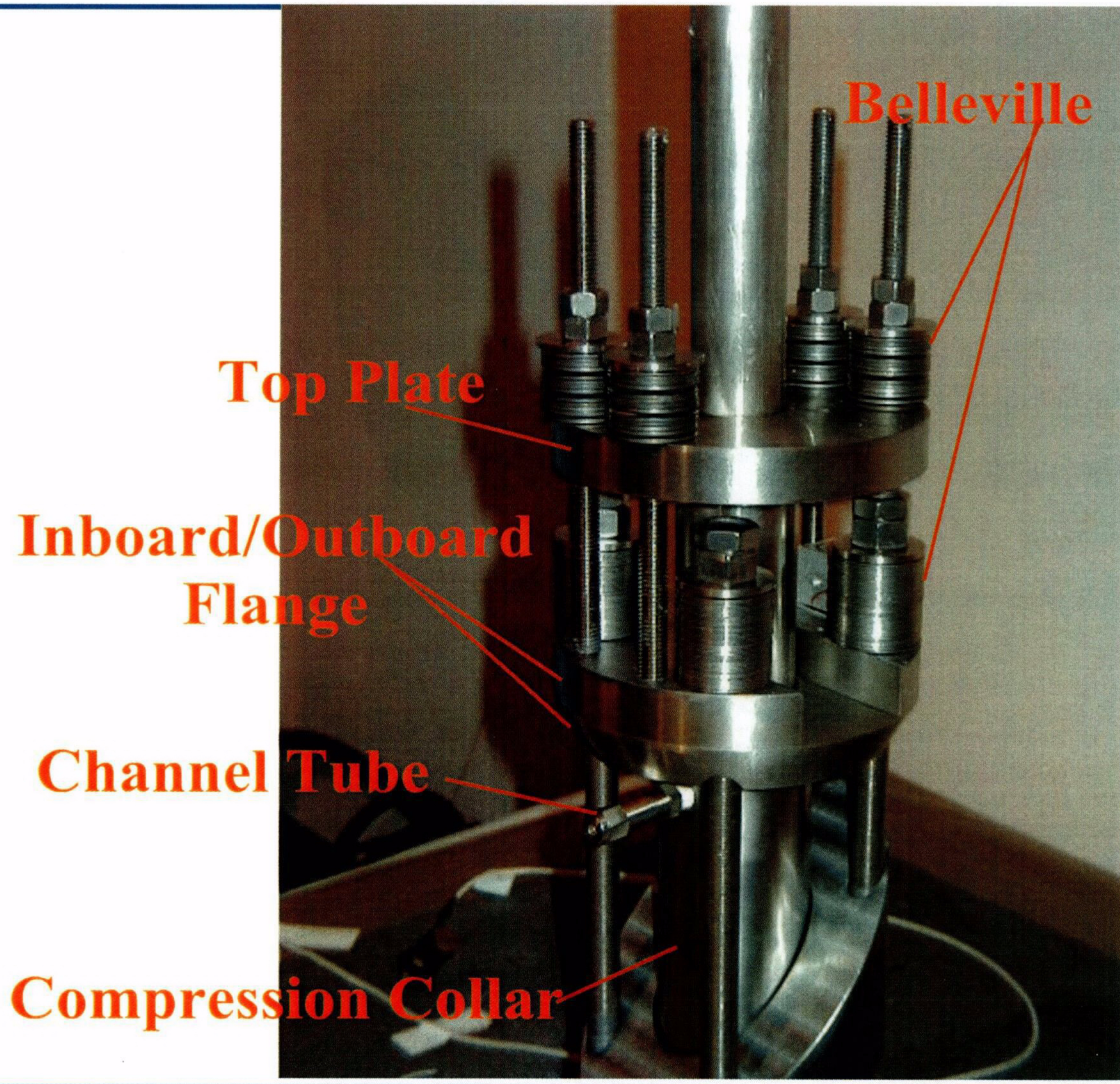
MNSA OVERVIEW

- MNSA has been designed and qualified as a permanent repair for an ASME Section III, Class1 pressure boundary for the life of the plant.
- MNSA is a repair which can be visually inspected from the vessel O.D.
  - Vessel wastage U.T. inspections can be made with MNSA in place
  - MNSA will not interfere with future volumetric NDE of the BMI nozzles
- NRC has accepted MNSA repairs for at least 2 fuel cycles

Technical Considerations for Utilization of the MNSA Contingency

- MNSA Strengths :
  - No breach of the pressure boundary required for installation
  - Lower Radiological Dose for installation
  - Does not require cutting, disposal and replacement of in-core instrumentation
  - Design accommodates wastage inspection from reactor vessel outside surface
  - Visual examination of the leak off tube can be performed at subsequent outages to confirm primary seal integrity
  - Not a new method - successfully used in primary system pressure boundary applications (ASME III Class 1)
  - The anti-ejection feature provides a second barrier to nozzle ejection and the potential for a LOCA

MNSA-2 Mock-up Demonstration



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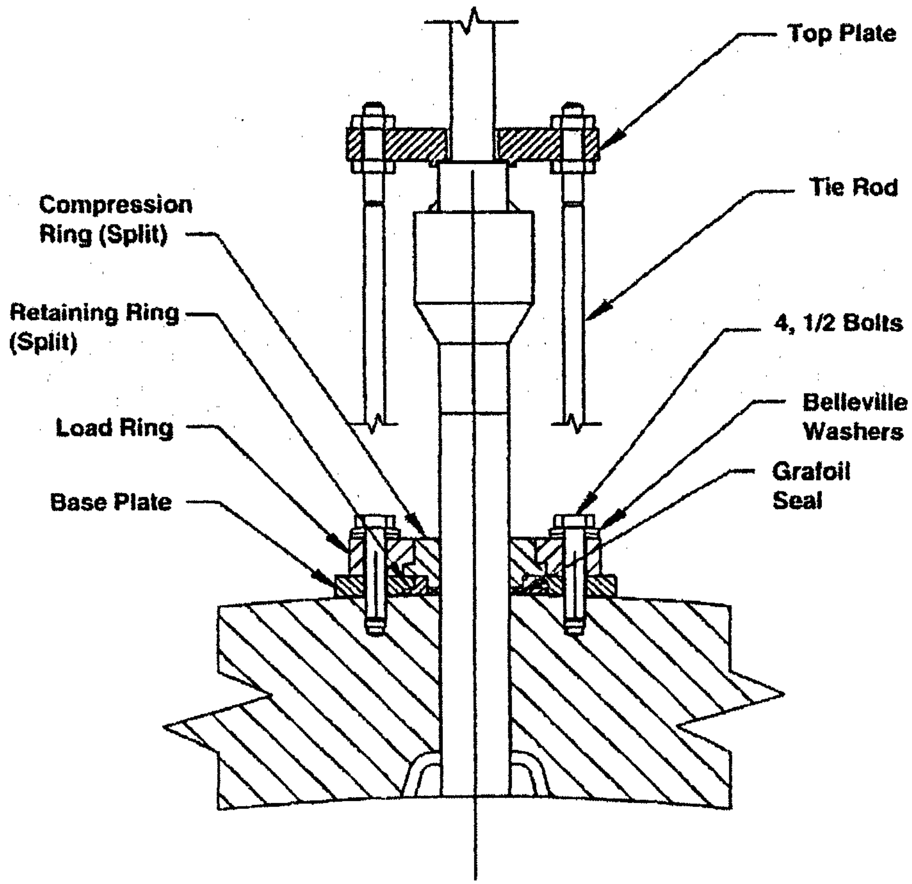
MNSA Experience Summary

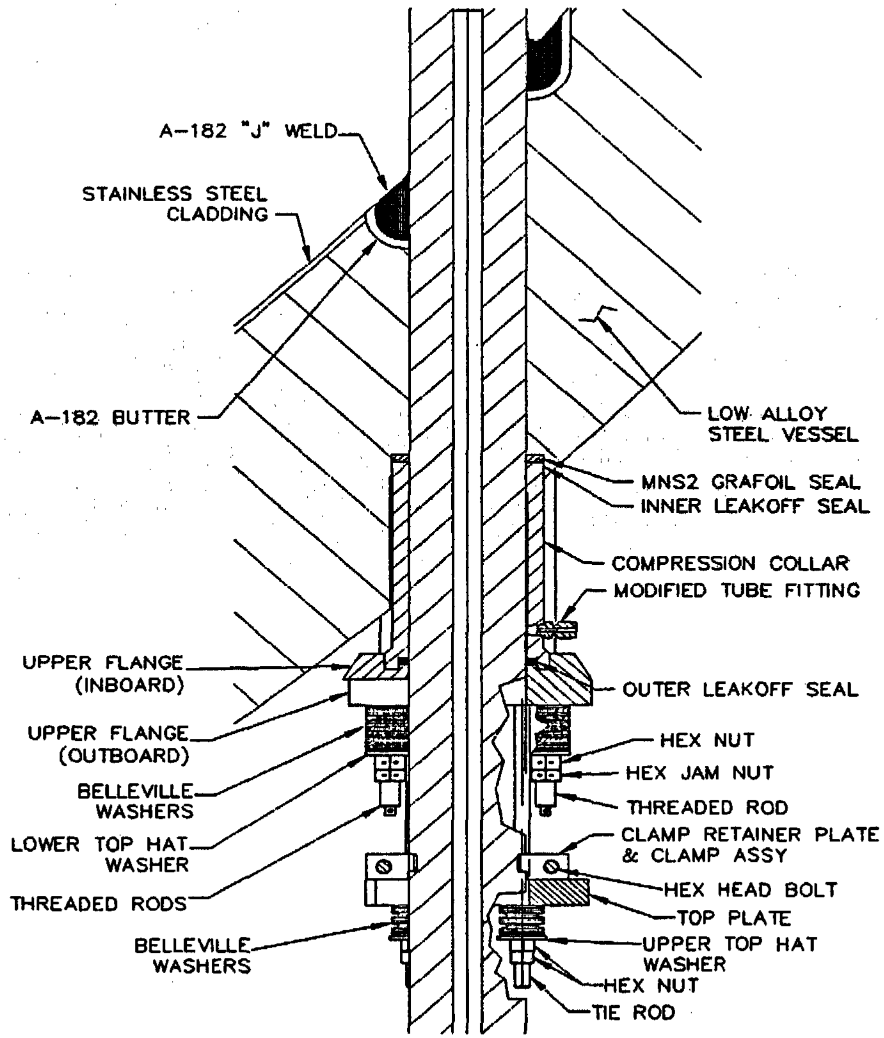
INSTALLED MNSAS					
Plant Name		**# installed**	**Location**	**When installed**	**When removed**
Maine Yankee		1	Pzr RTD nozzle	1995	Plant shut down
SONGS 2		2	Lower Pzr Hd	Feb-98	Still on
SONGS 2		2	Hot Leg RTD	Feb-98	Jan-99
SONGS 2		2	Stm Gen PDT	Feb-98	Still on
SONGS 3		1	Side Pzr RTD	Mar-98	Still on
SONGS 3		2	Lower Pzr Hd	Mar-98	Still on
Calvert Cliffs 1		1	Side Pzr RTD	Mar-00	Still on
Calvert Cliffs 1		2	Lower Pzr Hd	Mar-00	Still on
Calvert Cliffs 1		4	Upper Pzr Head	Mar-00	Still on
Calvert Cliffs 2		1	Side Pzr RTD	Mar-01	Still on
Calvert Cliffs 2		2	Lower Pzr Hd	Mar-01	Still on
Palo Verde 3		1	Hot Leg RTD	Oct-01	Apr-03
Palo Verde 3		2	Pzr Htr Slv	Apr-03	Still on
Millstone 2		2	Pzr Htr Slv	Feb-02	Still on
ANO2 (MNSA2)		6	Pzr Htr Slv	Mar-02	Still on
Fort Calhoun		1	Upper Pzr Head	Oct-00	Feb-03
Waterford 3		3	Hot Leg Inst Noz	Mar-99	Oct-00

MNSA-1 Design

- Grafoil seats against nozzle OD and vessel OD
- 4 bolts load compression ring
- Belleville Washers
- Tie Rods prevent ejection if loss of weld



MNSA-2 BMI Design

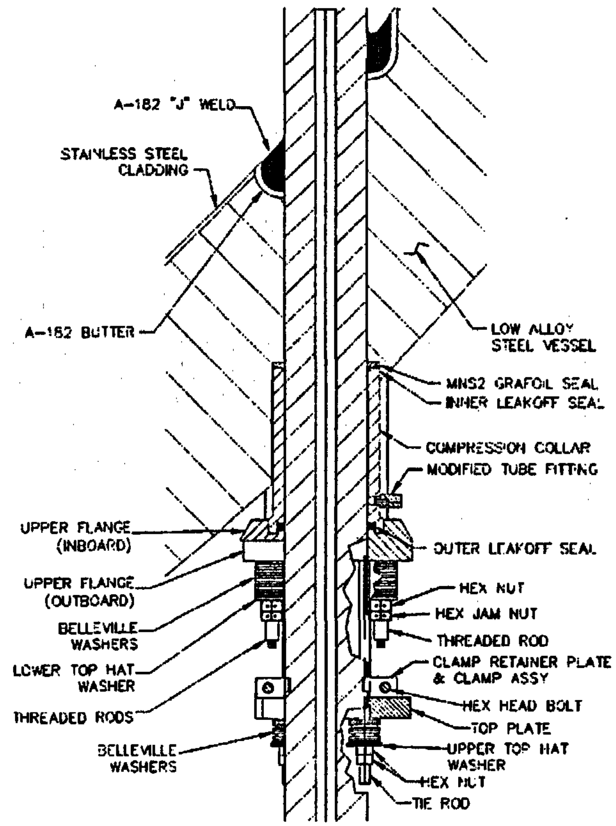


Similarities Between MNSA-1 and MNSA-2

- 4 bolt pattern
- Grafoil primary seal
- Same materials
- Same bolt torque values or less
- Seal seats on OD of nozzle
- Qualified to ASME NB 3200
- Prototype tested

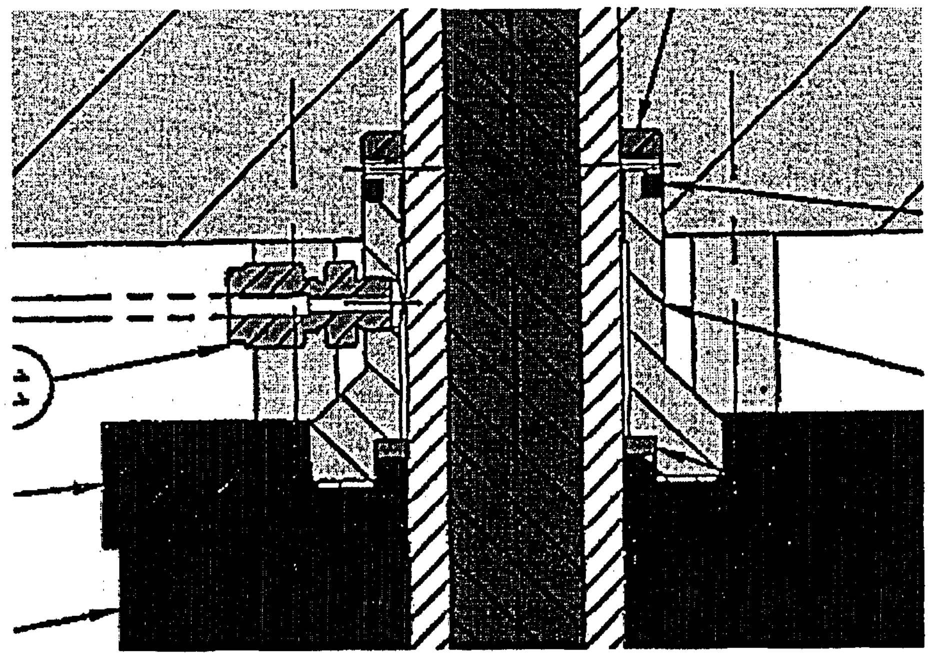
MNSA-2 Design Features

- Standardized design
- No system breach required
- Seal - packing gland type, live loading
- Seal is NOT dependent on existing surface condition
- Compression load normal to seal
- Secondary seals provide leak-off control (visual ;confirmation of primary seal integrity)
- Anti-ejection feature
- Existing J weld not required for structural integrity



MNSA-2 Primary and Secondary Seal Design

- Primary Seals Prevents Reactor Coolant (RC) Leakage
- The secondary seal diverts Reactor Coolant away from any vessel and prevents any damage to base material in the unlikely event of a primary seal leak



Installation Process to Ensure Proper Alignment

- Tapped holes for tie rods are drilled with a precision jig that is clamped to the nozzle. Jig has drill bushings that align drill parallel to nozzle axis.
- If holes were drilled skewed to nozzle, the MNSA could not be assembled.
- Tie rods are tensioned evenly using crisscross pattern.
- Tie rods are tightened to a specified torque value using calibrated torque wrench.

Installation Process to Ensure Proper Alignment (cont.)

- Bottom of counterbore is machined perpendicular to nozzle axis. Grafoil seal provides some compliance.
- Compression collar is relieved on inner surface to provide clearance.
- If counterbore is machined eccentric to nozzle, clamp cannot be assembled.
- Hence, no side load is imparted to BMI nozzle.

Qualification of the MNSA-2 Assembly and the RPV Lower Head

Qualification Status

- MNSA-2 was previously qualified for use on the pressurizer lower head to repair heater sleeve leaks
- Qualification is being extended to apply to the RPVLH BMI locations
  - Generic evaluations currently being completed to support a relief request submittal at the end of September
    - » Stress analysis
    - » Tooling Demonstration
    - » Installation procedures
    - » NDE methods
  - Plant specific documentation to be completed when a specific leak is identified

Qualification Criteria

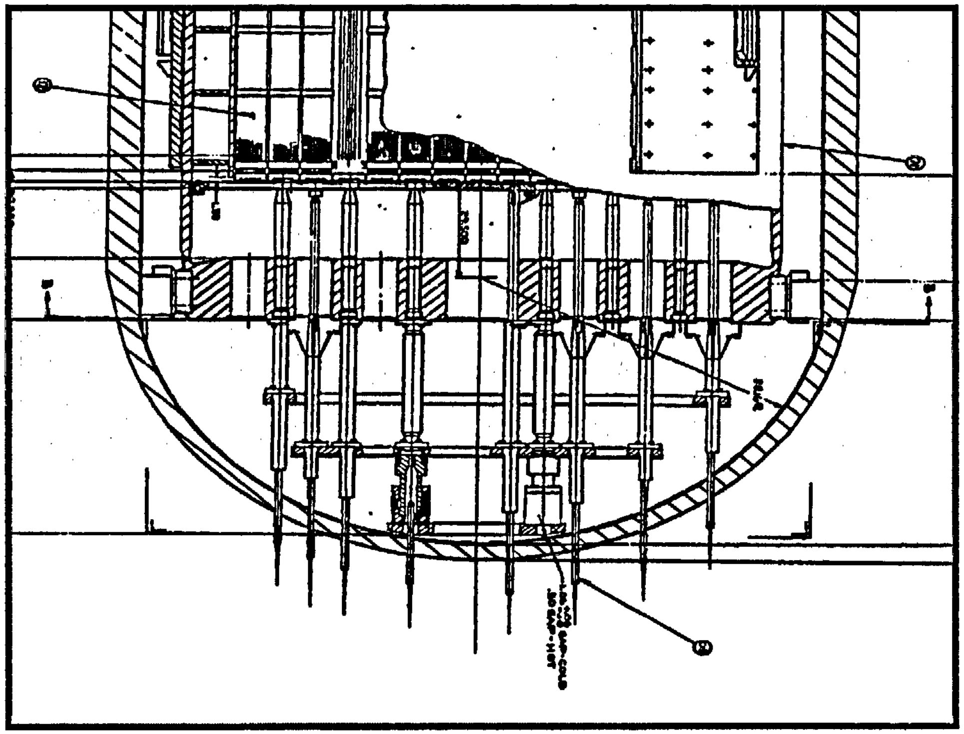
- **Analysis as an ASME Code Section III Class 1 Pressure Boundary Component (RPVLH and MNSA) in accordance with the RV Design Specification**
  - Primary Stresses (Local & General)
  - Primary + Secondary Stresses
  - Fatigue Usage
- **Functional Tests to confirm sealing effectiveness**
  - Leakage Tests
    - » Pressure, Seismic, Thermal Cycling
  - Bellville Washer Compression Test
- **Corrosion Evaluation of RPVLH BMI nozzle bore**
- **Flaw Evaluation of remaining leakage crack in J-weld**

Loading Conditions

- Loads covering all design transients are evaluated prior to and after an assumed nozzle ejection (Levels A, B, C and D)
  - Installation preload
  - Internal pressure
  - Steady-state and transient thermal conditions
  - Seismic Loads
  - Design Mechanical Loads
  - Impact load on the anti-ejection device

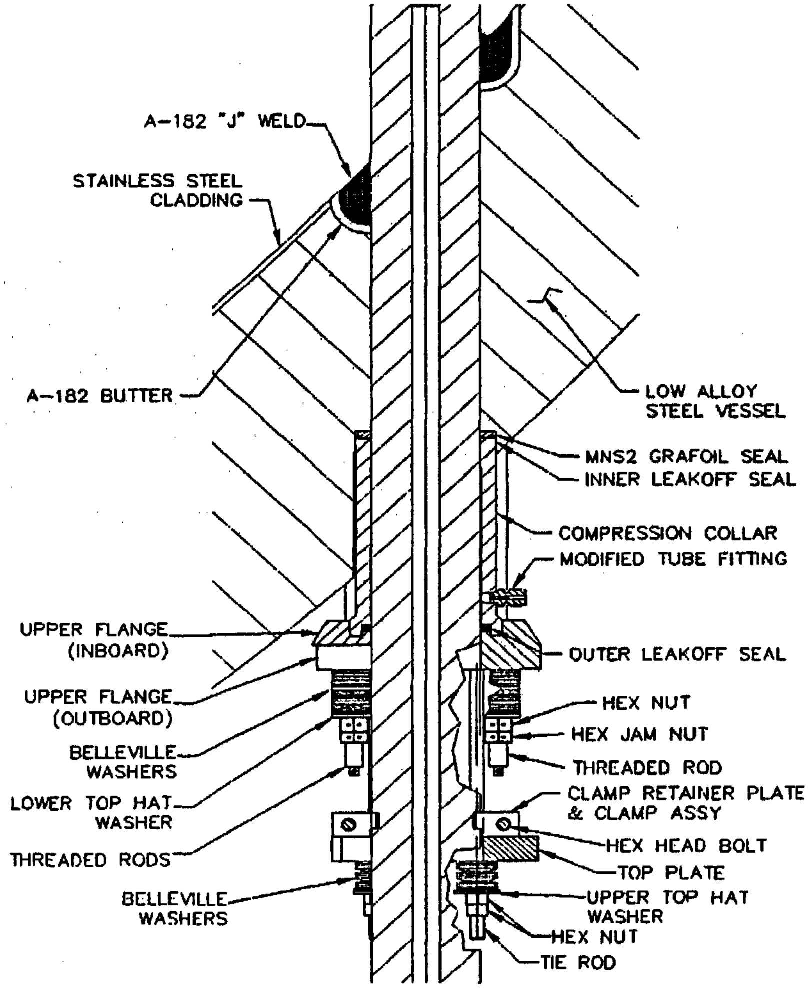
Locations Evaluated

- RPVLH Evaluation
  - Typical innermost and outermost locations are analyzed
    - Intermediate locations are bounded
  - Counterbore
  - Tapped attachment holes



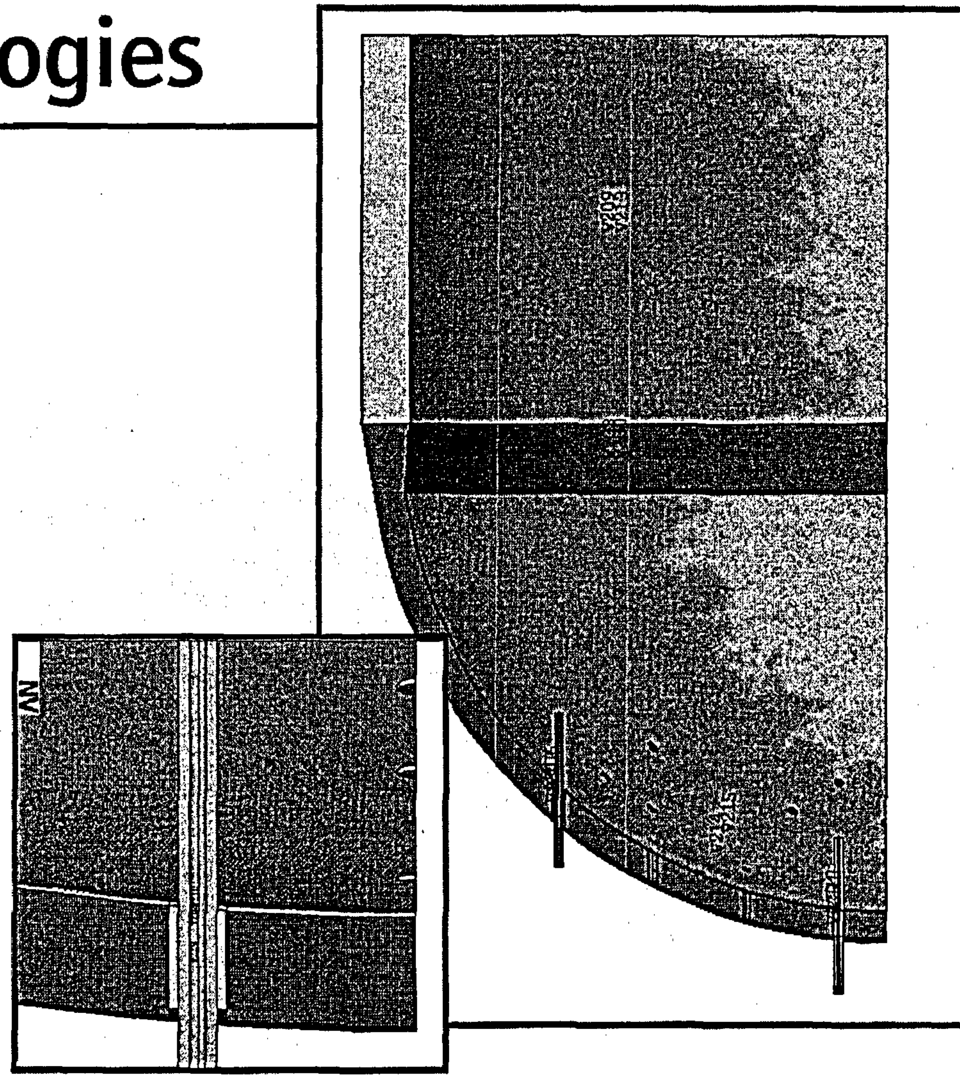
All Portions of the MNSA-2 are Evaluated

- Per the ASME Code including:
  - Threaded rods to vessel shell
  - Tie rods for preventing nozzle ejection
  - Compression collar
  - Flanges and impact plate
  - Belleville washers, flat washers and nuts

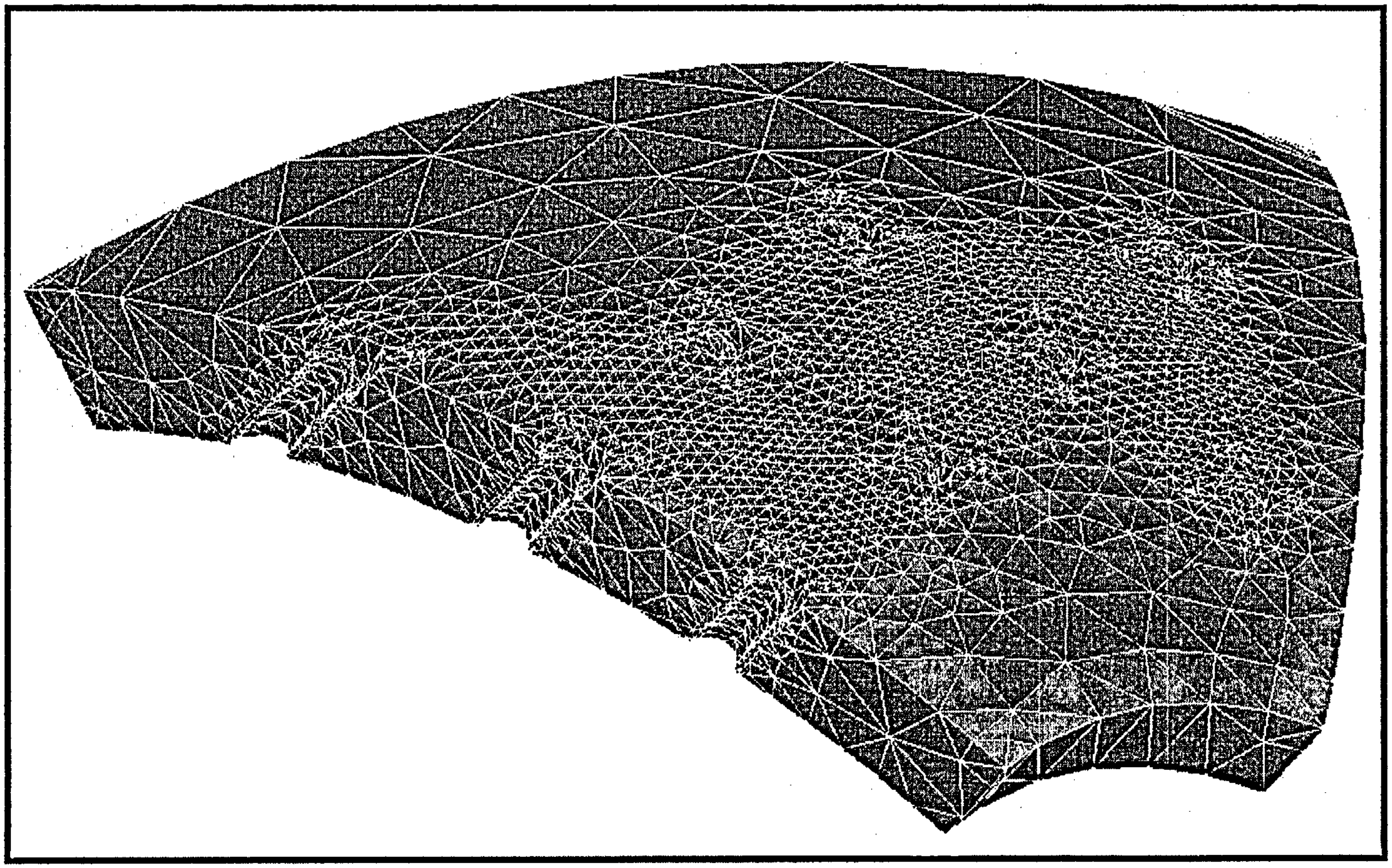


Analysis Methodologies

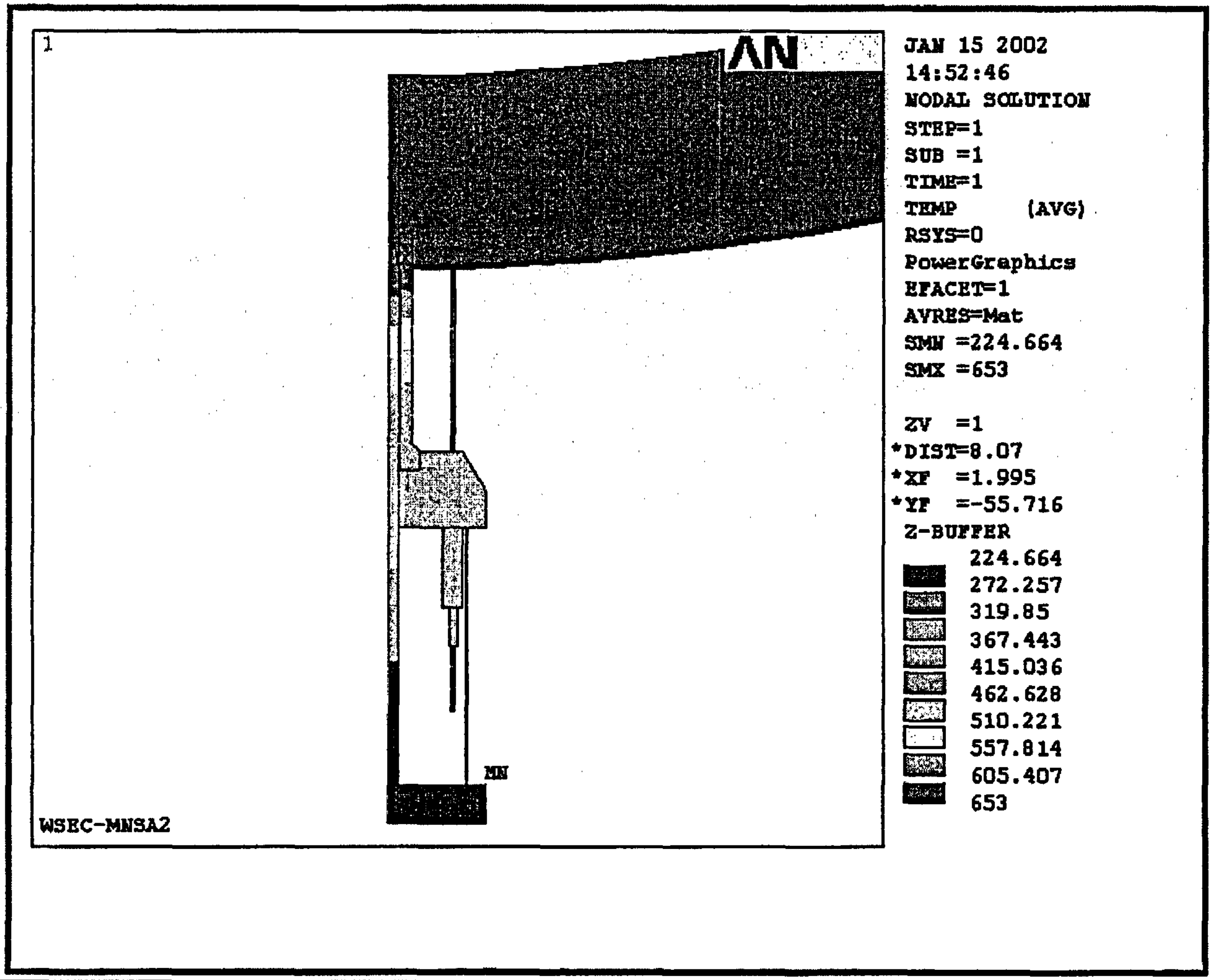
- 3-D Finite Element Analysis (ANSYS)
  - –Temperatures and Stresses
- Handbooks and classical methods
  - –Stress concentration factors and fatigue strength reduction factors



Typical model for evaluation of PM, PL and P + Q stresses



Typical FEA model for Steady State and Transient Thermal Analyses of Lower Head (Pressurizer) and MNSA-2 Temperatures



Analysis Results ASME III Code

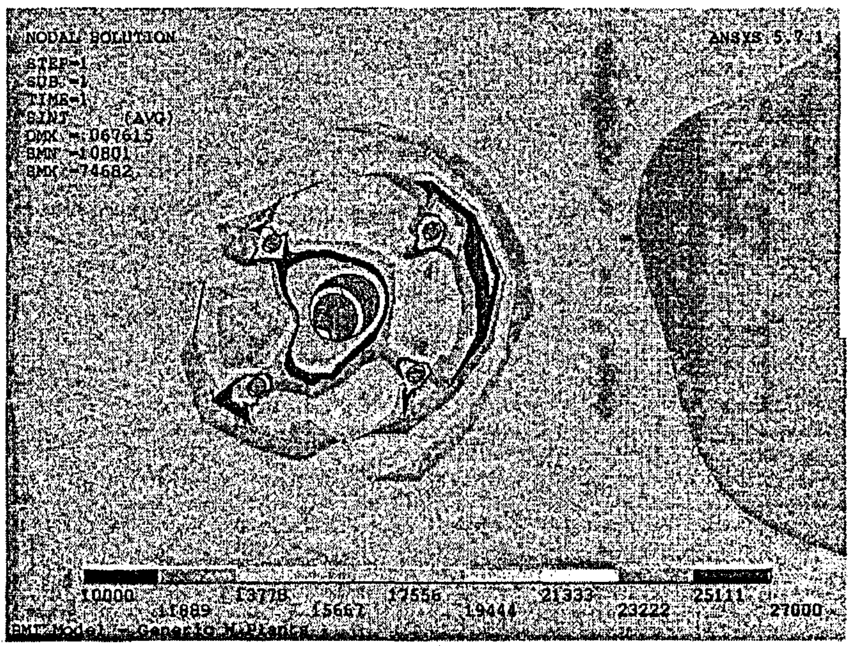
- Pressurizer Lower Head and MNSA-2 components meet all ASME Code Criteria for the pressurizer application
- Preliminary Pressure load case results for the RPVLH are consistent with the pressurizer results

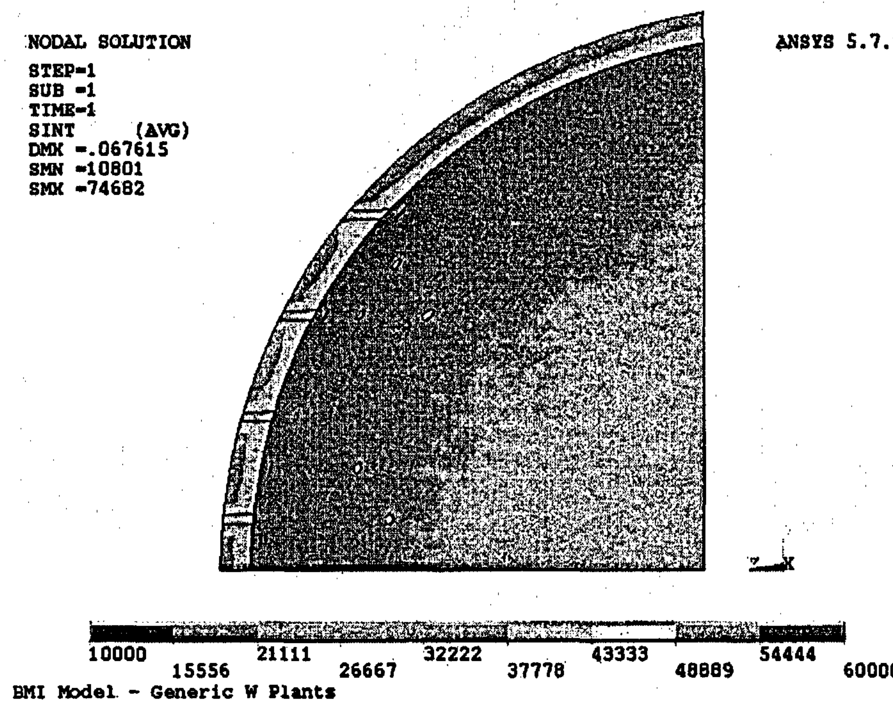
Preliminary Analysis Results for RV Lower Head

- Pressure Load Case
  - General Primary Membrane Stress
    - » Allowable is S_m = 26.7 ksi (SA 533 Gr. B @ 550°F)
    - » Pm = PR/2T + P/2 = ~22 ksi (Hand calculation based on NB-3324.2)
    - » FEA P_m = ~ 21 ksi w/o MNSA
    - » FEA P_m = ~ 21 ksi w/MNSA
  - Local Primary Membrane Stress
    - » Allowable is $1.5S_m$ = 40.05 ksi
    - » FEA P_l = ~ 24 ksi w/o MNSA
    - » FEA P_l = ~ 27 ksi w/MNSA

Preliminary Results for RPV Lower Head

Stress distribution around MNSA attachment points





Stress distribution in RPV Lower Head

Qualification Testing

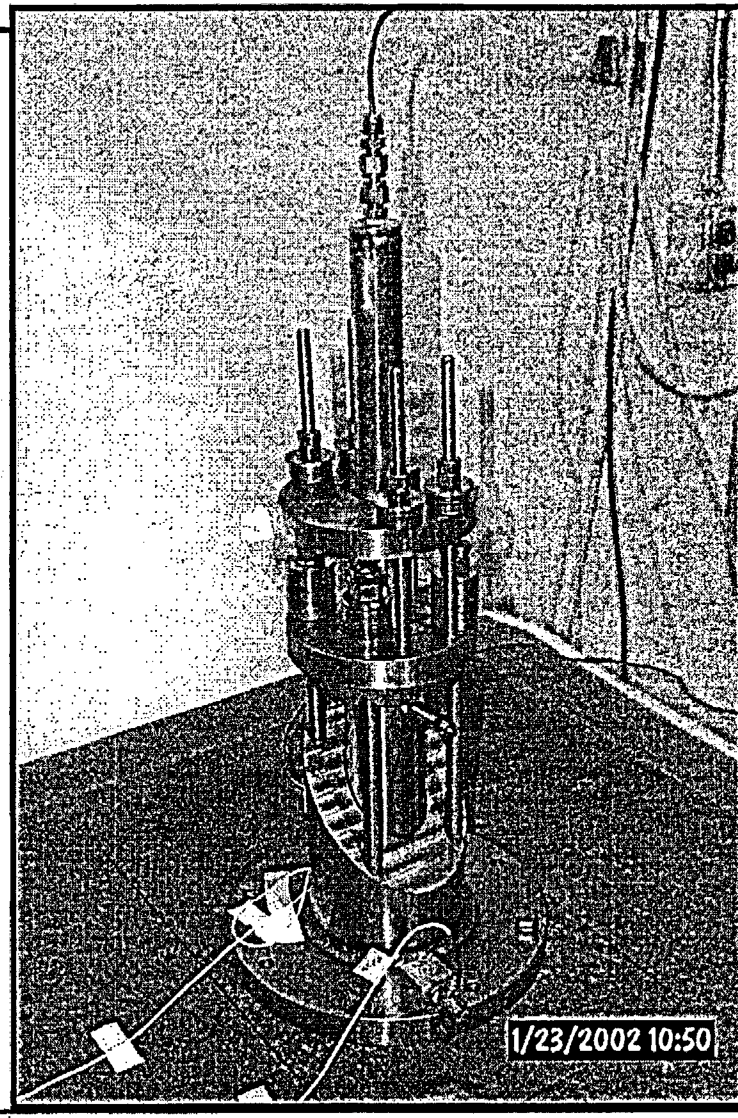
- Functional testing previously completed for the pressurizer application
- These tests are applicable to the BMI application, because
  - The Pressurizer heater sleeves envelope the BMI nozzle sizes
  - Hillside effects are more severe in the pressurizer
  - Temperatures are higher in the pressurizer
  - Thermal transient rates are more severe in the pressurizer

Qualification Testing (cont.)

- Leak testing
  - Hydrostatic Test
    - » Test in accordance with ASME Code demonstrates zero leakage
  - Thermal Cycle Test
    - » 3 Heat-up/Cool-down Cycles demonstrates zero leakage
  - Seismic Load Test
    - » Demonstrates zero leakage
    - » Establishes rigidity
- Axial Compression Test on Belleville Washer Packs
  - Determines stiffness values for FEA model

Seismic Qualification Setup

- MNSA-2 is "Rigid"
- Frequency is > 50 Hz
- Sine sweep testing performed pressurized to 3000 psi

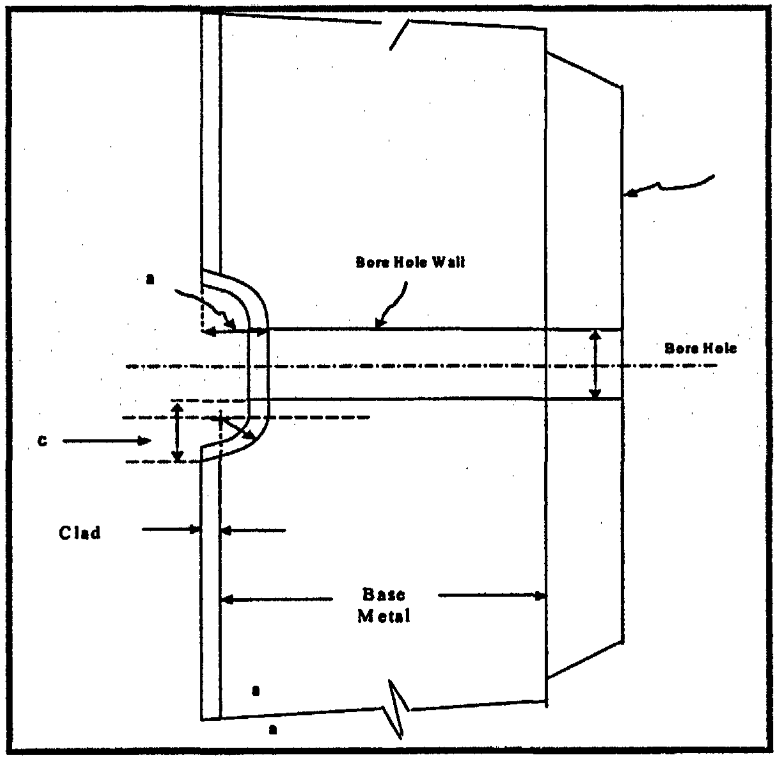


Corrosion Evaluation of Nozzle Bore

- Primary coolant will leak through cracks and fill annulus between nozzle and vessel
  - Unclad low alloy steel exposed to primary coolant
  - Some general corrosion of the steel will occur during operation, outages, startups
  - Calculate an overall corrosion rate
  - Estimate total corrosion (increase in hole diameter) to end-of-life
  - Calculate maximum increase in hole diameter before Code rules exceeded
  - Compare total lifetime corrosion with the maximum increase in hole size to demonstrate acceptability to EOL

Flaw Evaluation

- Flaw evaluation performed in accordance with ASME Code Section XI
- Free field stresses in RPVLH determined with 3-D FEA model
  - –Maximum combined pressure + thermal stress
- Assumed flaw
  - –Through cladding, butter and J-weld
- Stress intensity factors determined using Raju-Newman correlations



Preliminary Risk Analysis

Preliminary Risk Analysis Results

- A risk model was prepared in terms of an event tree which is quantified for a spectrum of cases to simulate the uncertainty in the j-weld flaw probabilities.
- All reasonably realistic cases meet the risk acceptance criteria of CDF < 1.0E-06/year comfortably, for one or more MNSAs installed for both Westinghouse and B&W designed plants.

Preliminary Risk Analysis Results

- For Westinghouse designed plants, the best estimate case, results in a CDF of 1.56E-10/year. The upper bound estimate results in a CDF of 1.56E-09/year.
- For B&W designed plants, the calculated CDF values are 2.14E-10/year (best estimate), and 2.14E-09/year (upper bound).
- With these small values of CDF, the LERF criteria are also met.
- The risk of vessel failure due to MNSA installation is essentially unchanged.

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MNSA-2 Relief Request Overview

MNSA-2 Relief Request

- This section discusses the Relief Request for the MNSA-2.
- In the event of a leaking BMI, it is recognized that additional information will be required for return to power such as:
  - NDE results of all penetrations
  - Root Cause analysis
  - Failure Modes & Effects Analysis
  - Future plans for inspection & monitoring

MNSA-2 Relief Request

- System
  - Reactor Coolant System (RCS)
- Components
  - Will identify specific nozzle locations
- ASME Code Applicability
  - Will identify year/addenda for each site
  - Section XI applicability
  - Section III applicability

MNSA-2 Relief Request

- Code Requirements
  - Rules for replacing ASME Sect. III Class 1 welded nozzle integrity with mechanical clamps are not clearly defined in ASME Section III
  - Code interpretation allows mechanical connections if designed to ASME Section III
- MNSA-2 a proposed alternative to welded connection
- Basis for Relief
  - Cite regulatory provisions for relief [10 CFR 50.55(a)(3)(i)]
  - The MNSA-2 will provide an acceptable level of quality & safety

MNSA-2 Relief Request

- Basis for proposed alternative
  - Current design of nozzle
  - MNSA-2 Application, Description, & Design
    - Design
    - Materials of construction
    - Structural analysis of MNSA
    - Structural analysis of vessel with MNSA
    - Flaw evaluation
    - Corrosion evaluation
    - Qualification Testing

MNSA-2 Relief Request

- Pre-service Testing & Inspection in accordance with ASME Section XI
  - VT-1 on bolting in accordance with IWA-4820
  - Pressure test & VT-2 inspection performed as part of plant restart at normal operating pressure in accordance with IWA-4710(c) & Code Case N-416
- In-service Testing & Inspection in accordance with ASME Section XI
  - VT-2 inspection performed prior to plant start-up following each refueling outage
  - VT-1 in-service inspection for category B-G-2

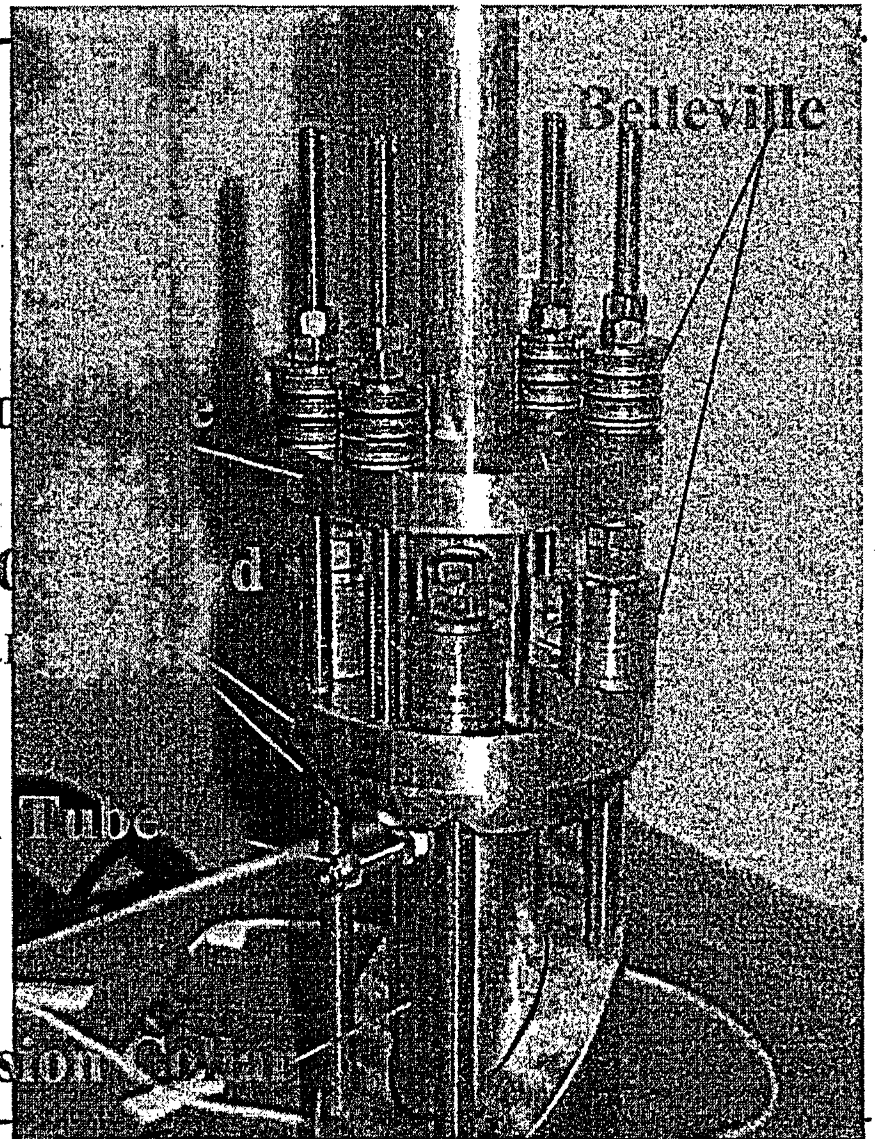
Wrap-Up

- This presentation has covered
  - MNSA-2 design details
  - Operating experience
  - Status and discussion of structural analysis being performed
  - Corroborating test information
  - Preliminary risk analysis results
  - Format of relief request
- Are there any other issues associated with the use of MNSA for the BMI application?

Back-Up Slides

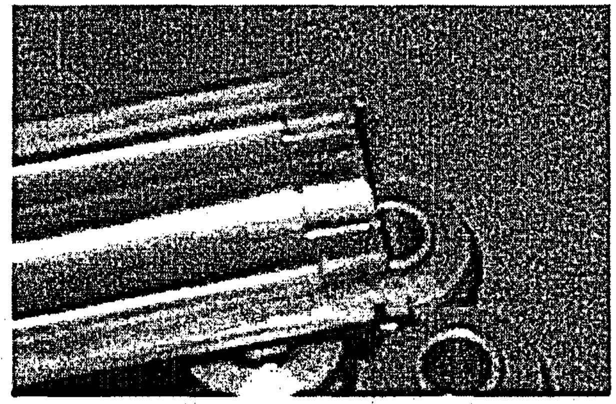
MNSA-2

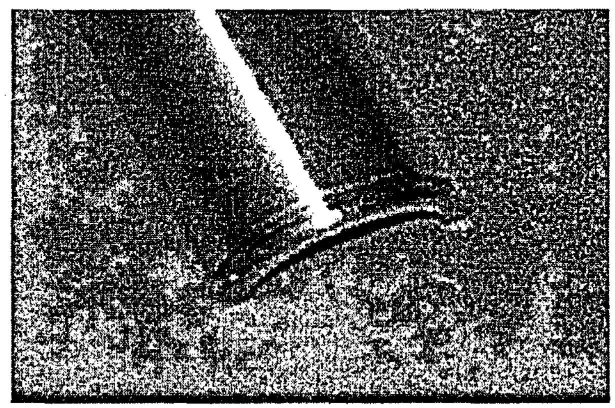
- Seismic Test MNSA-2



Compression Collar

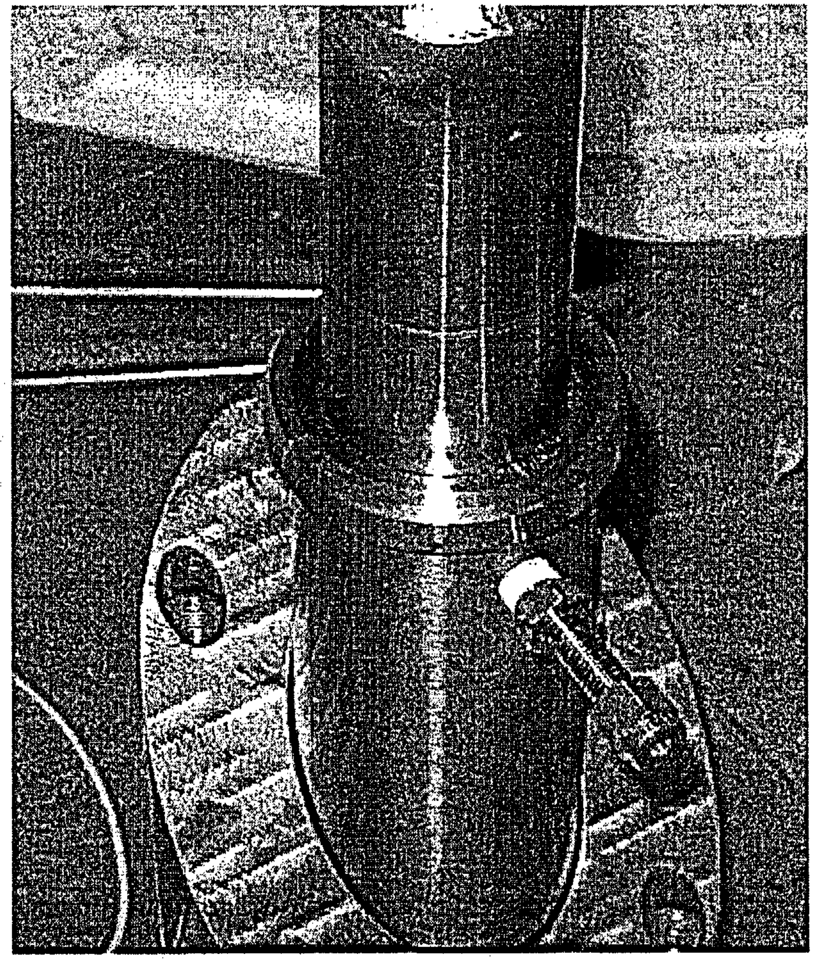
- Split Compression Collar
  - –Weep holes allows fluid to be channeled away from vessel in event of primary seal leakage





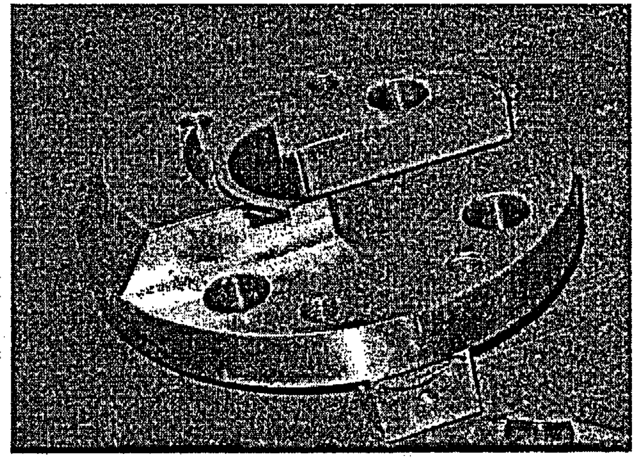
Channel Tube

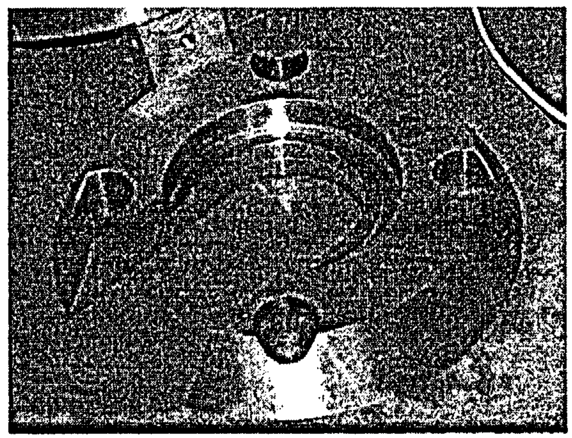
- RC is diverted away from vessel in the event that the primary seal developed a leak
- Provides a visual confirmation of the primary seal integrity



Upper Inboard and Outboard Flange

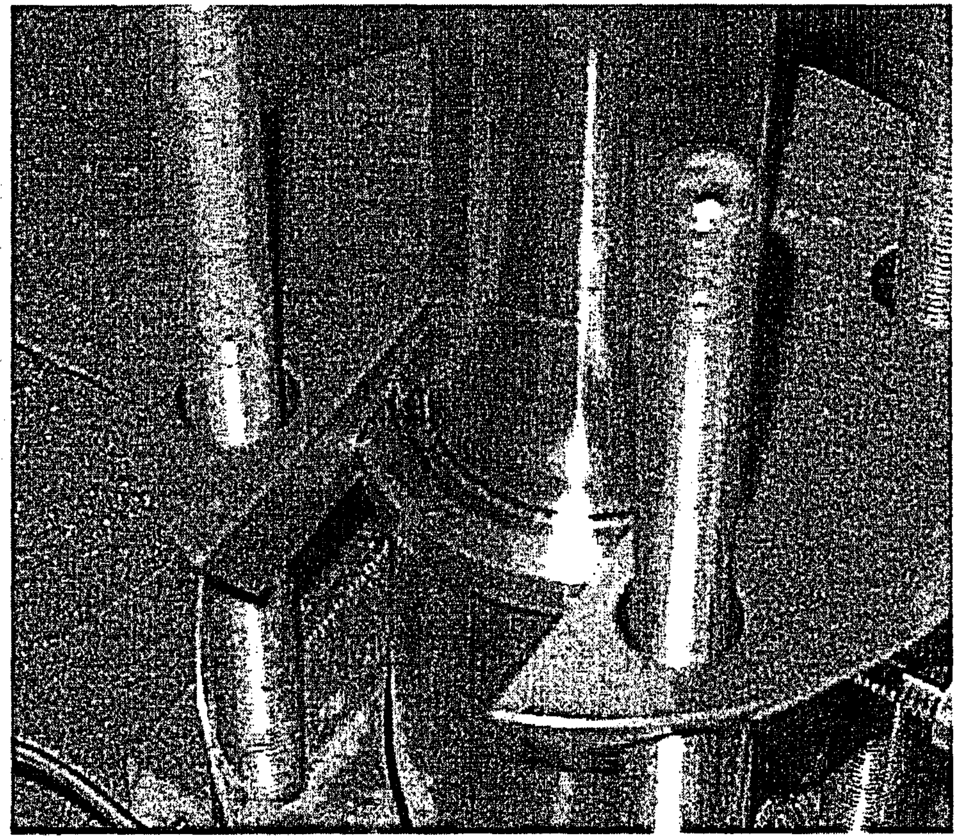
- Holds compression collar together and loads seal through the collar, threaded rods, and nuts





Inboard Upper Flange

- Inboard flange assembled onto compression collar
- Outboard flange fits over the top of inboard flange forming a continuous solid flange



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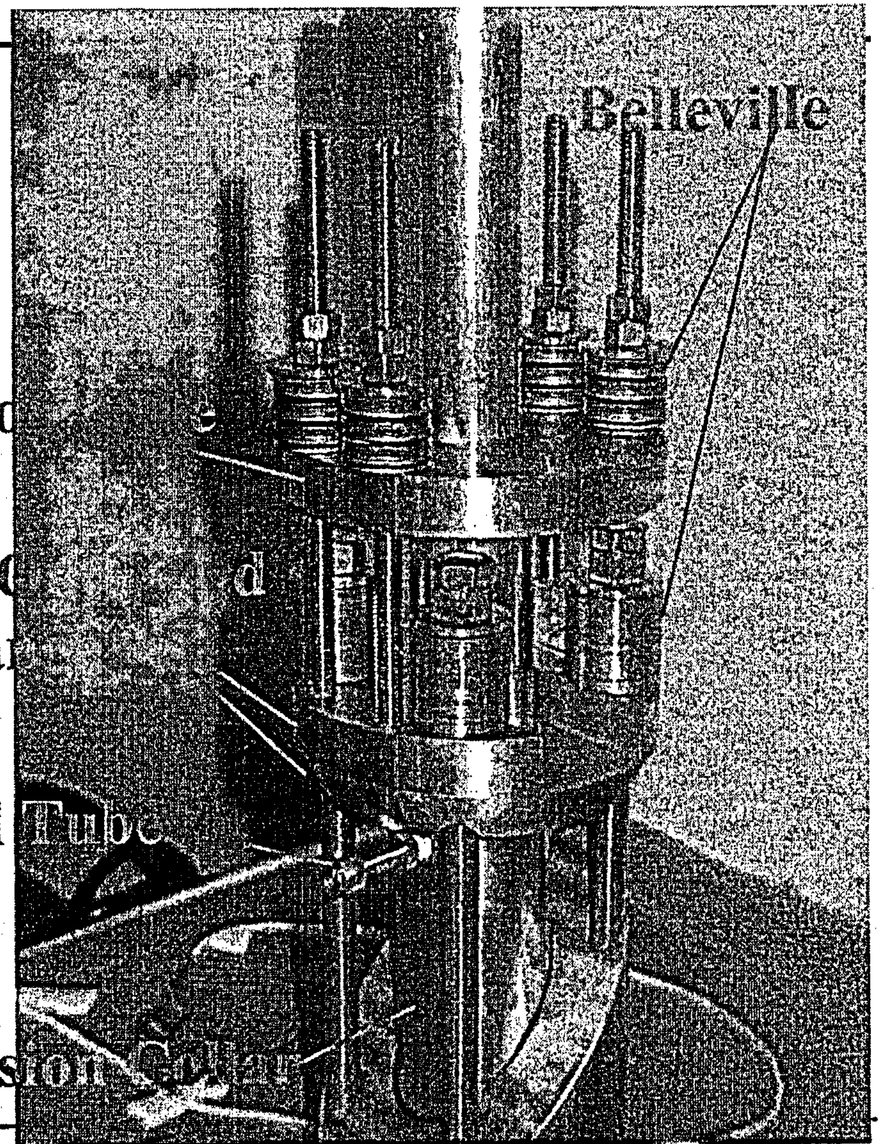

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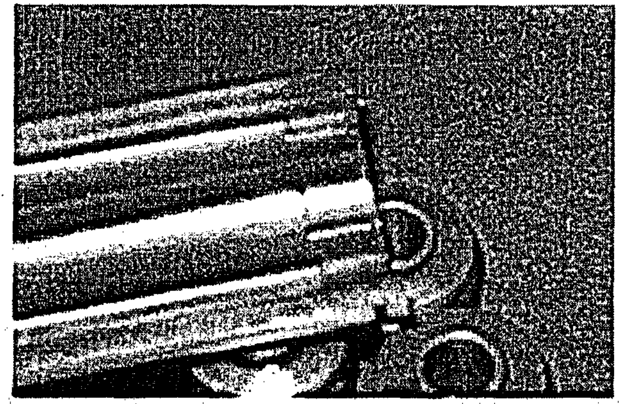

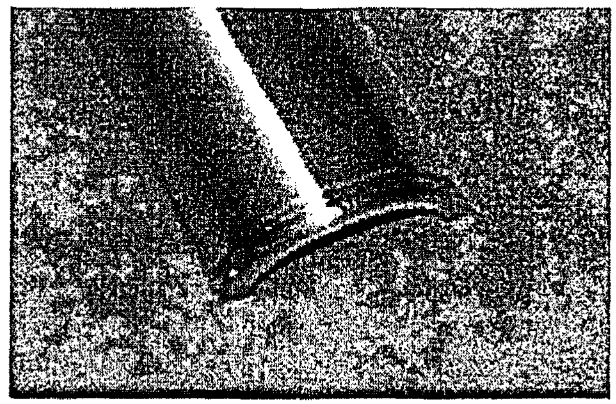

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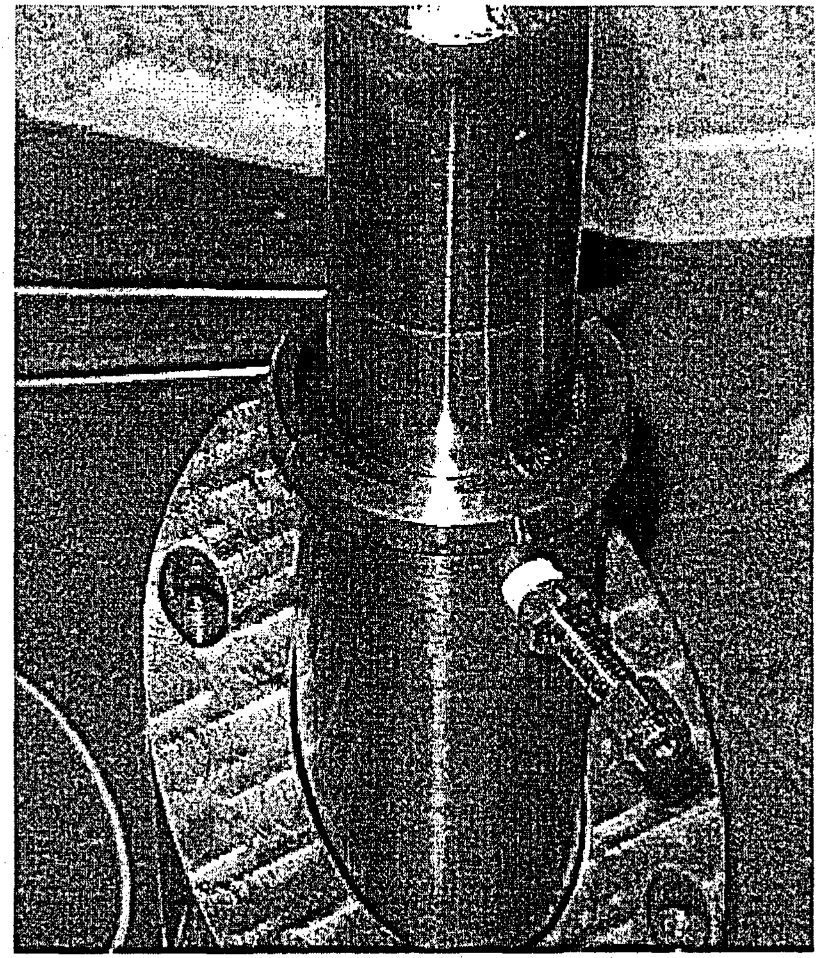

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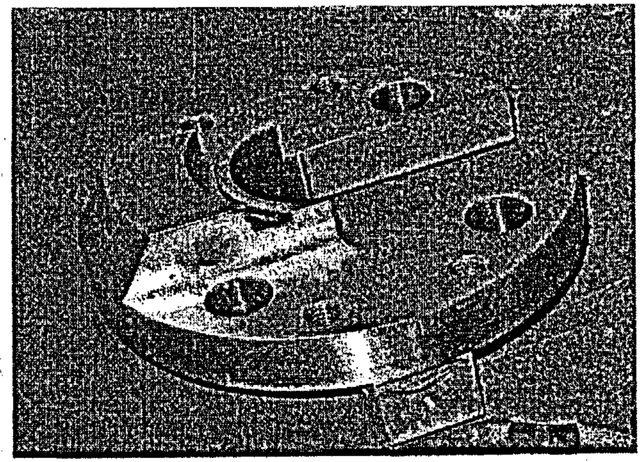

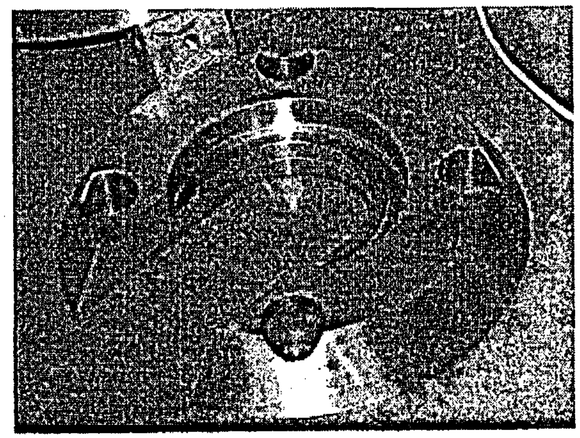

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