

# **Probability of Detecting Leaks by Bare-Metal Visual Inspection**

---

**Prepared for Meeting With NRC Technical Staff  
May 22, 2002**

**Dominion Engineering, Inc.  
S. Hunt  
M. Fleming**

# Contents

---

- Field Experience
- Gap Opening Displacement Analysis
- Area of Actual Metal-to-Metal Contact
- Roll Expansion Experience
- Probability of Detection

# Field Experience

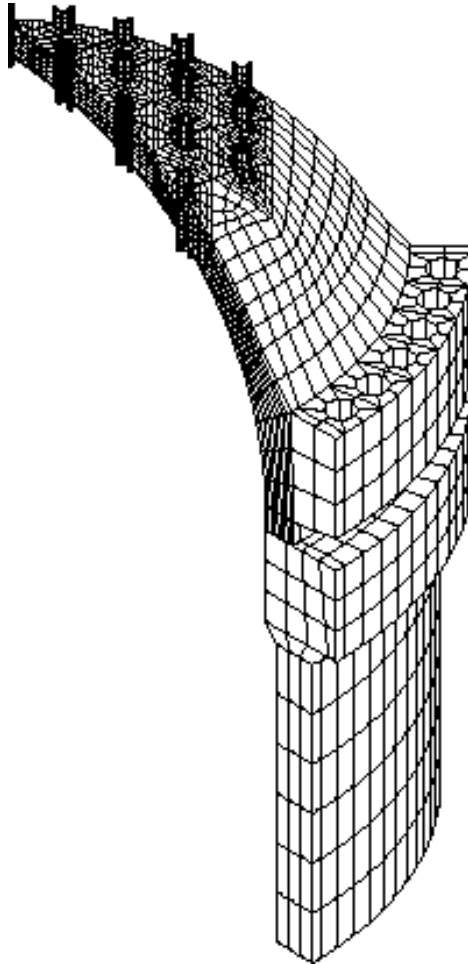
- Leaks have been found from 32 CRDM nozzles at eight plants by visual inspections
- Non-visual inspections have been performed on 481 CRDM and CEDM nozzles at fourteen plants
  - Characterization of leaking nozzles
  - Assess extent of condition at eight plants with leaking nozzles
  - Inspection of plants where insulation precludes bare metal visual inspection
- Non-visual inspections showed three nozzles with leak paths to the annulus
  - These three leaking nozzles were at Davis-Besse where leakage would have been discovered visually had head surface been clean
- Probability of Detection =  $35/35 = 1.00$

# Gap Opening Displacement Analysis

- Based on fabrication records leaks have been detected from
  - Three nozzles with 0.0014" initial interference
  - One nozzle with a 0.002" initial interference (Davis-Besse Nozzle 2)
  
- Finite element analyses have shown gap opening paths for interference fits up to 0.003" interference
  - Pressure on the nozzle OD surface after a leak reduces interference fit

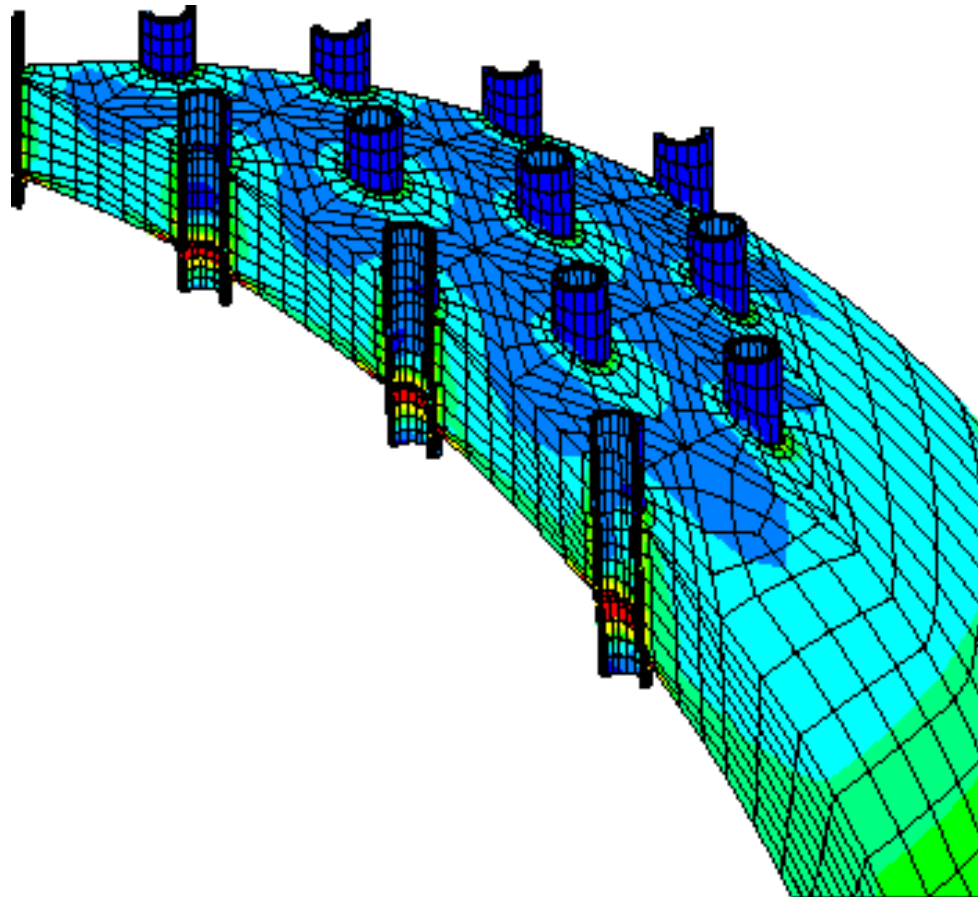
# Gap Opening Displacement Analysis

## *Typical Finite Element Model*



# Gap Opening Displacement Analysis

## *Stress Distribution in Vessel Head*



# Area of Actual Metal-to-Metal Contact

- Even for cases with a nominal interference fit, the actual area of metal-to-metal contact is small
- Based on tribology considerations
  - Contact Area = Force/(3 x yield strength)
  - Contact Area = 5% of total interface area for typical CRDM nozzle with 0.003" interference
- Over remaining 95% of the interface area
  - Flow paths equal to sum of RMS surface roughness of mating parts
  - Typically  $60-90 \times 10^{-6}$  inches
- Other factors increase flow passage sizes such as
  - Straightness
  - Out-of-Roundness

# Roll Expansion Experience

---

- There are several cases where leaks have occurred from Alloy 600 penetrations despite the penetrations having been roll expanded into the pressure boundary
  - Steam generator drain pipes
  - Pressurizer instrument nozzles (EdF plants)



# Probability of Detection

- Probability of detection (POD) for bare metal inspections
- For interference fits up to 0.002"
  - $POD = 1.00$  (provided a clean head surface)
- For interference fits up to 0.003"
  - Conservatively assumed that leaks will not be detected for interference fits greater than 0.002"
  - Assume normal distribution
  - 75% of nozzles will have fits less than 0.002" for which leakage has been confirmed
  - $POD = 1.00 \times 0.75 = 0.75$