Operational Reactor Safety

22.091/22.903

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Professor of the Practice

Lecture 21
Davis Besse - Near Miss 2002

Topics to Be Covered

- History of Davis Besse
- Review of Alloy 600 cracking
- Review of Davis Besse Vessel Head Leakage
- Contributing Factors
- Failures of Operator, NRC, INPO, Oversight
- Lessons Learned

Davis Besse - 873 Mwe
Babcock and Wilcox Design

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History of Davis Besse

- 1995 World Record of a 99.2% capacity factor
- 2001 - 99.7% capacity factor
- 2001 – 500 day run completed in October 2001
- 5.5 million hours worked without lost time accident in 2001
- Considered a good performing plant by NRC and INPO

Primary Water Stress Corrosion Cracking of Vessel Head Penetrations

- First observed in France – Bugey 3 Reactor in 1991
- Associated with PWSCC of Alloy 600 (inconel)
- PWSCC function of temperature, pressure and time
- NRC sent out information notices – required inspections
- Industry did assessment of susceptibility of reactors (BW/CE)
  - Established a scale based on full power hours of operation
  - Based on head temperature
  - Industry did not consider this a significant issue since US reactor head were built differently than French reactors.
- Inspections difficult due to access and dose

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- Perception was that if cracks occurred they would be axial not circumferential and detectable
- Carbon steel vessel degradation was considered but not judged to be significant due to flashing of steam and leaving boron crystals (>500F) – not as a liquid – 4 inches/yr if water
- Inspection of Oconee Nuclear Station 1 (Nov. 2000), Arkansas Unit 1 (Feb. 2001), Oconee Unit 3 (Feb. 2001) and Oconee Unit 3 (April 2001) showed both axial and circumferential cracks in Control Rod Drive Mechanisms.
- NRC Issues Bulletin 2001-01 ordering inspections of highly susceptible plants by December 31, 2001.
- NRC prepares a shutdown order for Davis Besse

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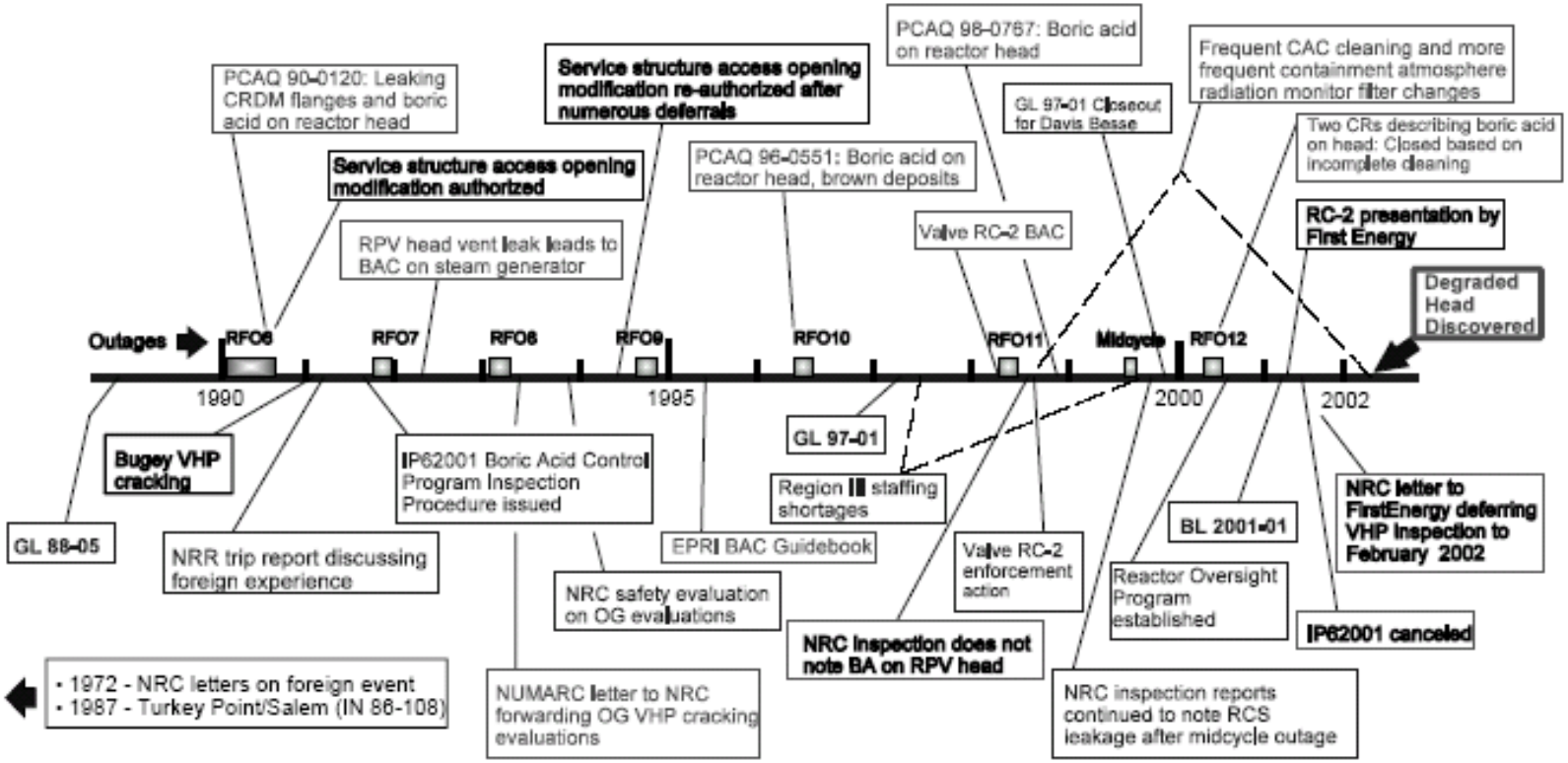
Figure 3-1 Time Line Relating Significant Items of Interest



IN (Information Notice) 86-108, "Degradation of Reactor Coolant System Pressure Boundary Resulting from Boric Acid Corrosion"
GL (Generic Letter) 88-05, "Boric Acid Corrosion of Carbon Steel Reactor Coolant Pressure Boundary Components in PWR Plants"
GL 97-01, "Degradation of Control Rod Drive Mechanism Nozzle and Other Vessel Closure Head Penetrations"
BL (Bulletin) 2001-01, "Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles"

PCAQs (Potential Condition Adverse to Quality) and CRs (Condition Reports) are issued by the licensee.

BA - Boric Acid
BAC - Boric acid corrosion
CAC- Containment air cooler
CRDM - Control rod drive mechanism
EPRI - Electric Power Research Institute
NRR - Office of Nuclear Reactor Regulation
NUMARC - Nuclear Management and Resource Council
OG - Owners Group
RCS - Reactor coolant system
RFO- Refueling outage
RPV - Reactor pressure vessel
VHP - Vessel head penetration

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Results

- Davis Besse requests an extension to next spring outage.
- NRC grants extension February to 16, 2002.

March 2002

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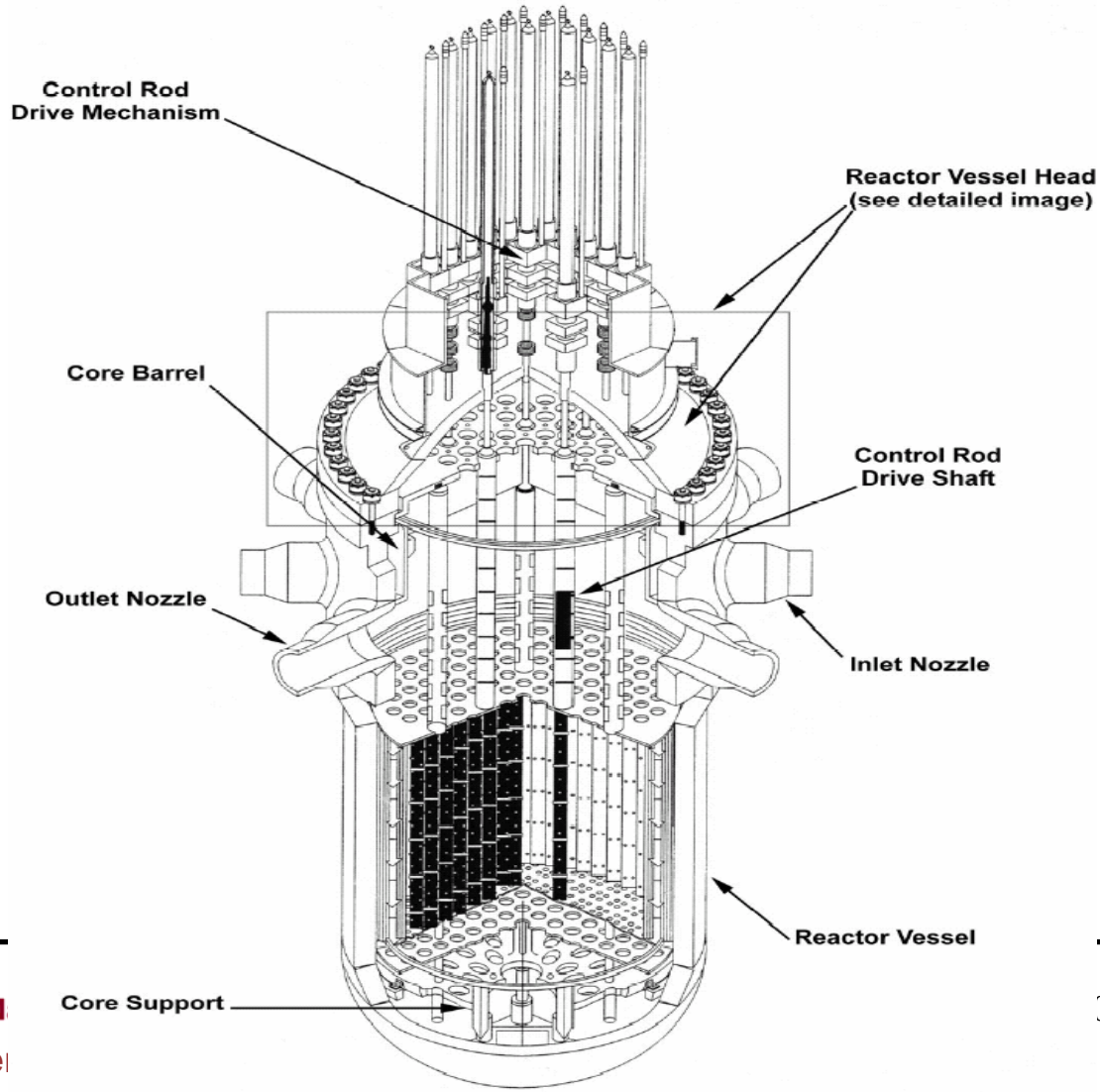
Typical PWR Reactor Vessel



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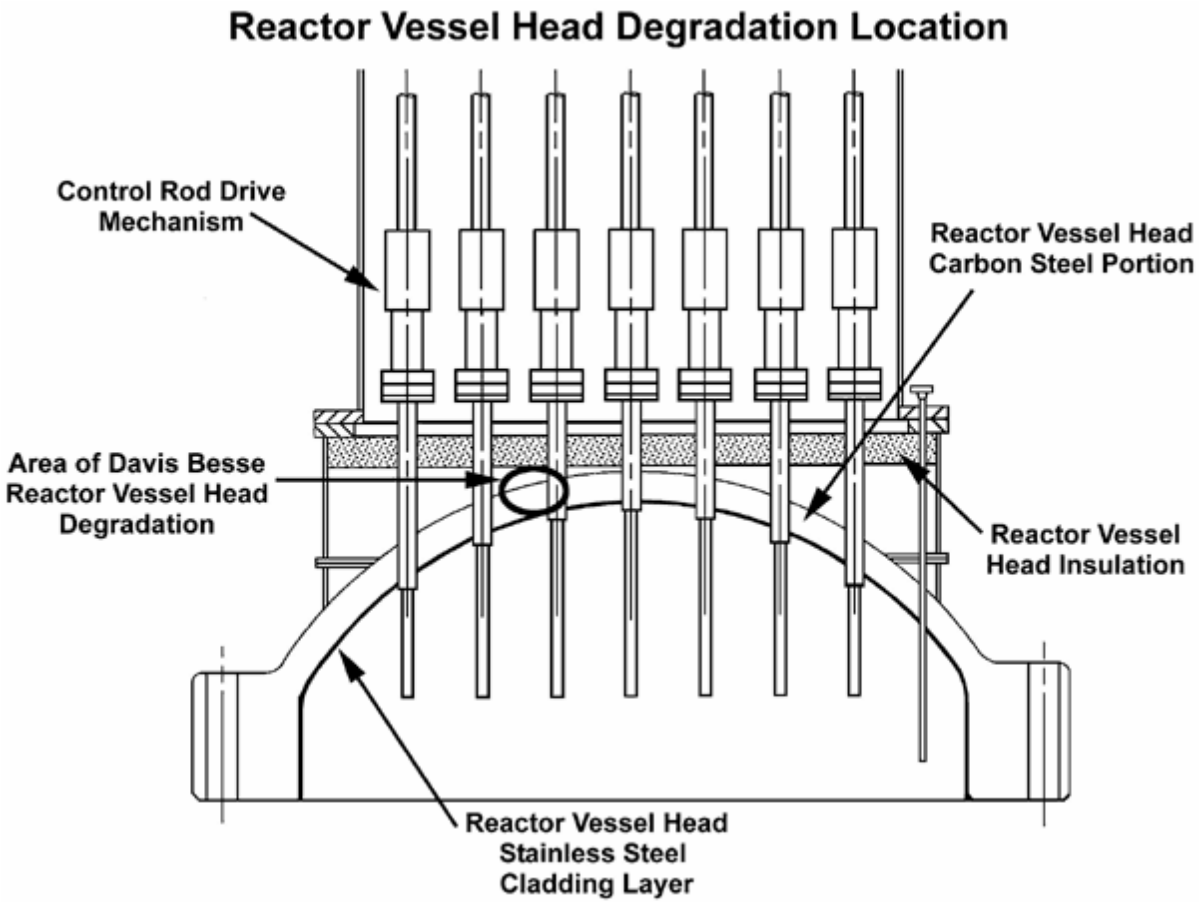

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STP Penetration # 46

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Nozzle 3 with insulation removed and shielding installed 03-16-02

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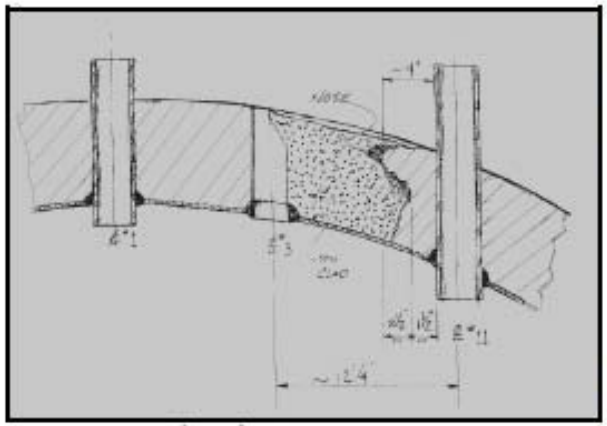
Vessel Degradation

Figure 2-4
DBNPS VHP NOZZLE NO.3 DEGRADATION CAVITY



Degradation Between Nozzle#3 and Nozzle#11.
The Sketch Provided by the Licensee

Nozzle #3 Area Cut Away From Reactor Head

Close-Up View of Cavity

Rubberized Impression of Cavity

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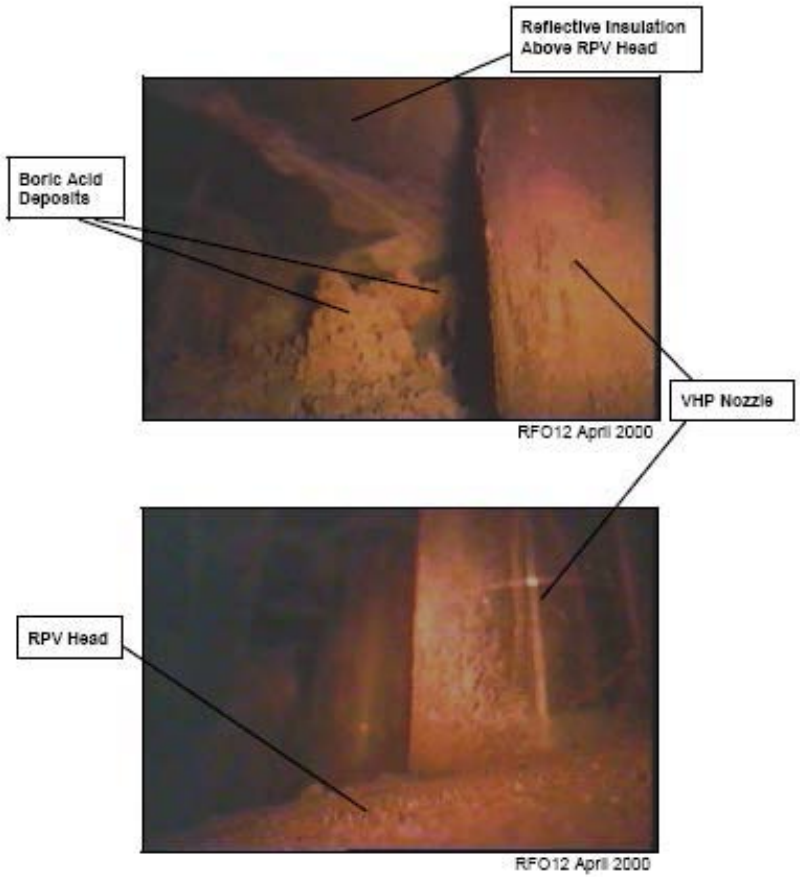
Boric Acid Deposits

Figure 2-6 BORIC ACID DEPOSITS ON THE RPV HEAD (top) AND AREA RELATIVELY FREE OF DEPOSITS (bottom)



Kadak, 2008

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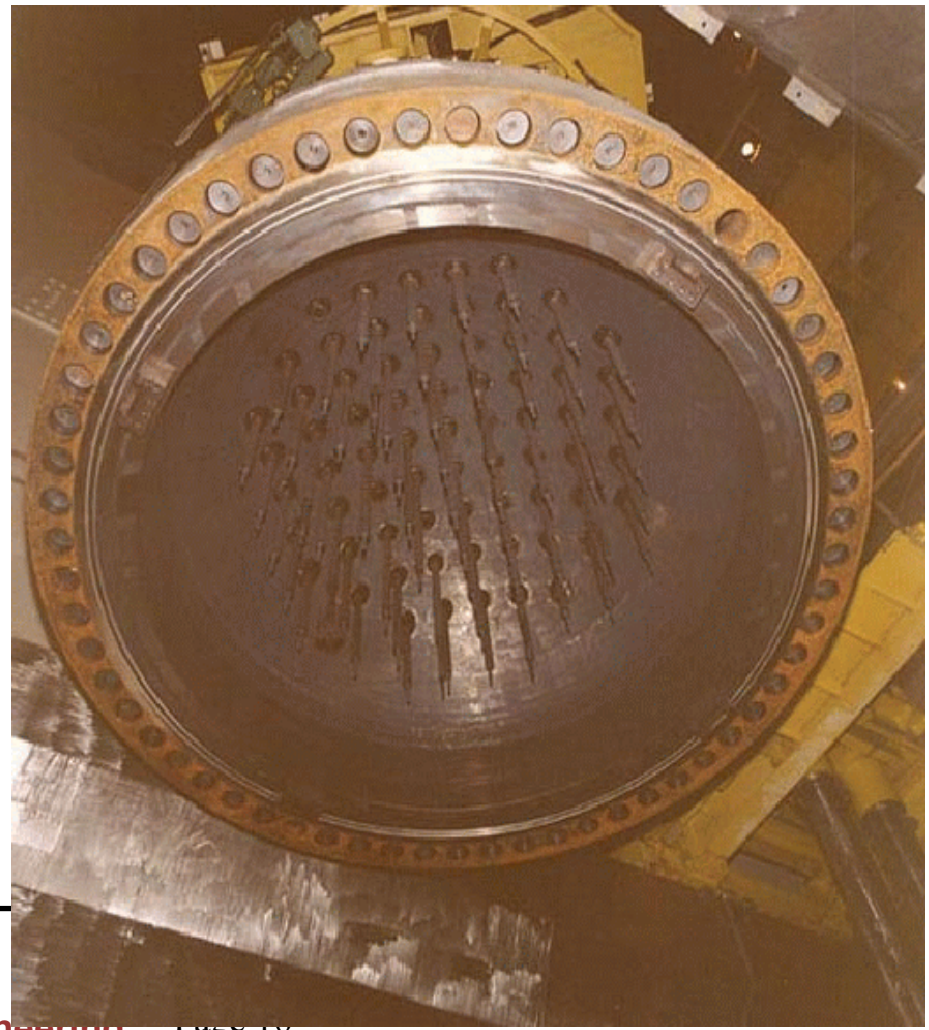
Davis-Besse Reactor Vessel



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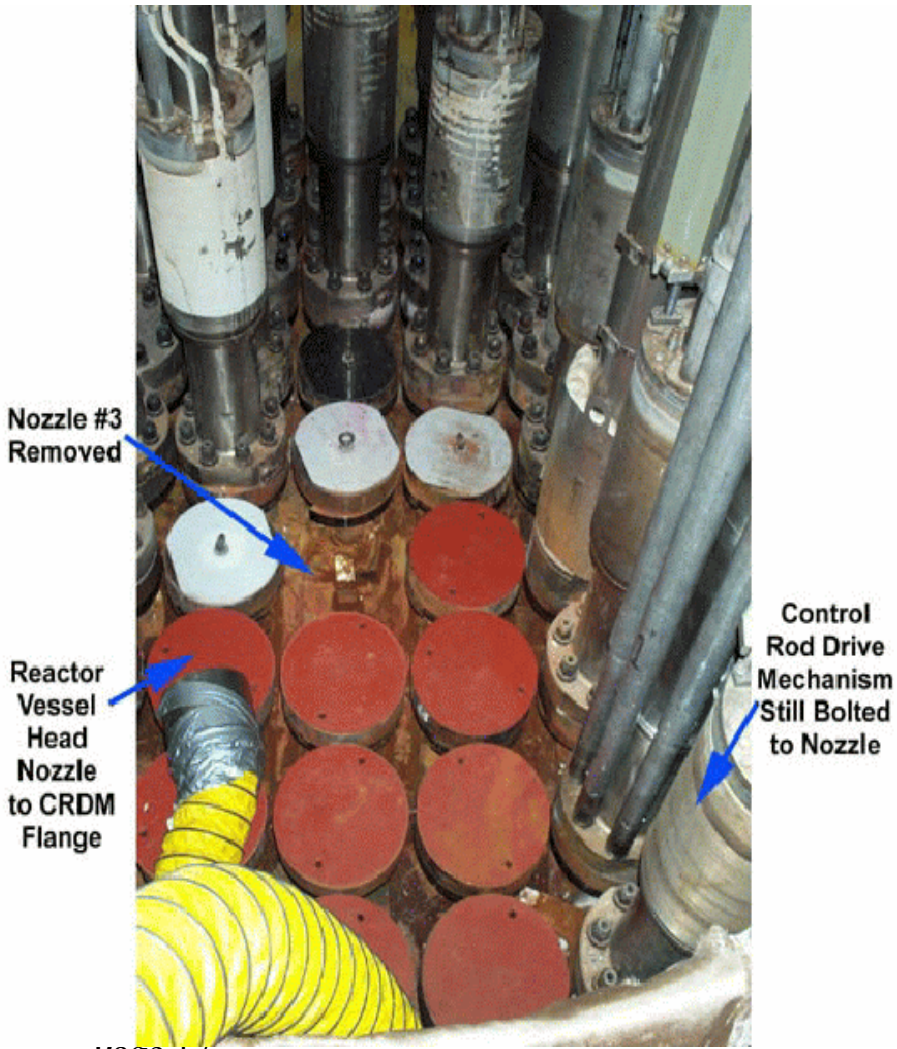
Control Rod Drive Mechanisms



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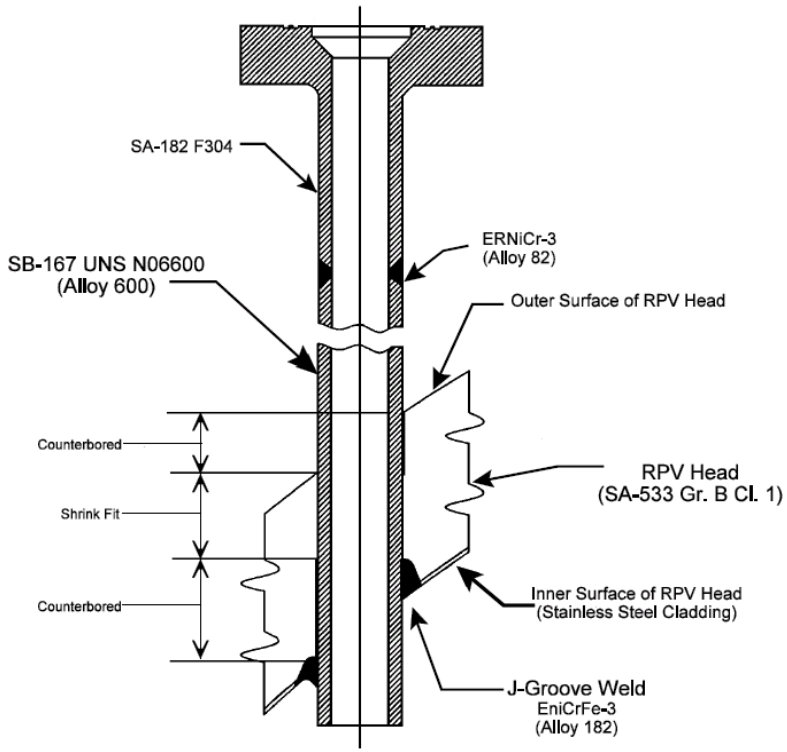
Vessel Head Penetration Nozzle

Figure 2-3 SCHEMATIC VIEW OF TYPICAL B&W VHP NOZZLE



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Davis Besse Experience with Primary Coolant Leaks

- All BW plants reported boric acid leakage problems including vessel head penetrations
- RPV head vent to steam generator (1992)
- RCS thermowells
- CRDM flange leaks
- Pressurizer spray valve
- Letdown isolation cooler isolation valve
- Pressurizer safety relief valves.

Davis Besse Indicators

- Containment Air Cooler Clogging with Boron Crystals
  - Cleaning monthly instead of yearly
- Containment radiation monitor filters (1998 -2002)
  - Ultimately required replacement every 2-3 days
  - Found brown stains with boron crystals.
- Some bolts on pressurizer spray valves corroded off due to spray valve leakage.
- Leakage increased by a factor of 10 but still within technical specification limits.

Missed Opportunities

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Breakdowns

- Utility
- Industry – NEI and EPRI
- NRC
- INPO
- Oversight Boards

Lessons Learned

- Could have set nuclear industry back (again) – major non-isolable leak – break – in reactor pressure vessel
  - We are judged by our poorest performer
- Complacency based on good record
- Poor management oversight and awareness
- You can go to jail (several charged with criminal violations – falsification of records)
- Conservative decision making is important
- Not allowing unacceptable conditions to exist.
- Strong questioning attitude needed

More lessons

- Focus should be on causes not symptoms
- Engineering organization needs to be engaged in problem resolution not just enabling management decisions.
- Mind set of it can never happen needs to be challenged.
- Oversight organizations need to be aggressive.
  - INPO should have identified the problem
  - Outside Nuclear Safety Review Boards should not only listen to management presentations
- NRC resident inspectors did not do their job
- Group think should be avoided

Even more lessons

- Failure to use experience reports and believe them
- Power production is important but if safety compromised the plant and the industry will suffer.
- Safety culture differentiates excellent performers from bad.

Consequences

- Davis Besse Replaced reactor vessel head.
- Repairs cost $ 600 million – loss of revenue
- Plant shutdown for 2 years
  - Restart issue was not of adequacy of repairs
  - ***Restart was predicated on whether or not the safety culture of the plant was acceptable for operation!***
- Fortunately this event was considered as an isolated event by the public but a failure of the regulatory and oversight process.

Homework

- Review the FENOC (Davis Besse) request for continued operation sent in late 2001 to justify operation until the spring out.
- Based on the information provided and the experience with Alloy 600, provide a technically based answer to the request – you may want to review the NRC letter granting approval to see if you agree – why and why not.

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Spring 2008

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