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<table>
<thead>
<tr>
<th>DATE OF MEETING</th>
<th>10/21/2003</th>
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- **Docket Number(s)**: 50-346
- **Plant/Facility Name**: Davis-Besse
- **TAC Number(s) (if available)**: 
- **Reference Meeting Notice**: 2003-0761
- **Purpose of Meeting (copy from meeting notice)**: Discuss the modification of the high pressure injection pumps.

<table>
<thead>
<tr>
<th>NAME OF PERSON WHO ISSUED MEETING NOTICE</th>
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<tbody>
<tr>
<td>Jon Hopkins</td>
<td>Senior Project Manager</td>
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<tr>
<th>OFFICE</th>
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DFO1
**FirstEnergy**

**Davis-Besse Nuclear Power Station**

Modification of High Pressure Injection Pumps

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**FirstEnergy**

**Agenda**

- Opening Remarks...................... Gary Leidich
- Modification Design................... Bob Schrauder
- Analysis and Qualification Testing ....Bob Coward, MPR
- Conclusion................................ Gary Leidich

Gary Leidich  
President and Chief Nuclear Officer - FENOC
Opening Remarks

Gary Leidich
President and Chief Nuclear Officer - FENOC

Desired Outcome

- NRC and the public gain confidence that pump modifications and associated testing and analysis ensure the HPI pumps will perform their required safety functions under all design conditions
Overview

• Background
  – Implemented Building Block approach in 2002 that included assuring the health of plant systems
  – System Health Assurance identified the High Pressure Injection Pumps as an original design issue since fine particles from the Containment Emergency Sump could potentially damage the pumps during the loss-of-coolant accident (LOCA) recirculation mode

• Today
  – Present how these findings were resolved and provide assurance the HPI Pumps are capable of performing their design function
Modification Design

Bob Schrauder
Director - Support Services

High Pressure Injection Pumps

- Manufacturer
  - Babcock and Wilcox Canada
- Type
  - Horizontal, eleven stage centrifugal pumps
  - 600 HP electric motors
  - Hydrostatic bearing
- Design Pressure/ Temperature
  - 2000 psig/ 300°F
- Design/ Manufacture Code
  - ASME Pump & Valve Code, Class II, November 1968
- Surveillance Test/ Inservice Testing
- This design is unique to Davis-Besse in domestic nuclear industry
HPI Pump Operational Environment

• Borated Water Storage Tank Operation
  – Surveillance Testing
  – Initial Post-LOCA mode

• Sump Recirculation Operation
  – In post-LOCA recirculation mode operation, HPI pump suction is from Containment Emergency Sump through LPI pumps
  – Sump may contain debris from LOCA blowdown and containment spray actuation
  – HPI Pumps must be capable of operating with debris in the pump flow

HPI Pump Original Design Issues

• System Health Assurance identified design issues
  – Hydrostatic bearing plugging
    – Bearing orifices are smaller than emergency sump strainer and could become plugged
    – Bearing pocket clearances are smaller than sump strainer
  – Close clearance wear
    – Preliminary rotordynamics analyses suggested increases in clearances due to wear by debris could lead to operation at critical speeds
    – Increased clearances will degrade pump hydraulic performance
  – Supply path to cyclone separator (seal water) could be smaller than sump strainer and may become plugged
Original Hydrostatic Bearing

- Orifices in supply to hydrostatic bearing pockets are 0.109 inch diameter
- New containment emergency sump strainer has 0.188 inch diameter openings
- Orifices may plug with debris that passed through sump strainer, degrading bearing performance

Original Hydrostatic Bearing

- Bearing includes tight clearances (0.006 inch to 0.007 inch) at edges of pockets
- Debris in supply water may be larger than clearance and accumulate in the bearing pocket
- Degradation of bearing performance may impact pump operation
Close Clearances Wear

- Pump design includes tight clearances
  - Central volute bushing (0.006 inch to 0.007 inch)
  - Hydrostatic bearing (0.006 inch to 0.008 inch)
  - Wear rings (0.009 inch to 0.010 inch)
- Debris in water may increase rate of wear of the fine clearances
  - Increased clearances could result in operation at critical speeds
  - Increased clearances could decrease hydraulic performance capability

HPI Pump Configuration
HPI Pump Internal Assembly

HPI Pump Volute
Resolution Objective

• Implement a resolution plan that fully resolves HPI pump debris issue that
  - Modifies only the HPI pump
  - Assures compliance with existing licensing basis, procedures, Updated Safety Analysis Report, and design basis documents
  - Meets requirements of Technical Specifications
Initial Modification Approach

• Modifications
  – Install self-flushing strainer on volute to prevent plugging of hydrostatic bearing supply line orifice
  – Move supply line take-off to suction side of volute

Initial Modification Approach

• Key Assumptions to be verified
  – Strainer would be self-flushing and remain clear of debris
  – Debris larger than bearing clearance would be crushed by bearing and pass through clearance
  – Wear of close clearances would be minimal and uniform
  – Pump operation at critical speeds would not cause vibration or other operational challenges
Developmental Test Results

- The original test conditions were unrealistic – LBLOCA debris for SBLOCA operating conditions
- Several key assumptions proved invalid
  - Soft, larger debris became lodged in bearing pockets and orifices
  - Velocities in volute were not sufficient to keep finer strainers clear
  - Wear was greater than anticipated, particularly for soft components
  - Close clearances are subject to plugging

Revised Design Concept

- Three primary load carrying components: hydrostatic bearing, wear rings, and central volute bushing
- Rotordynamic analyses show several acceptable conditions
  - Functional hydrostatic bearing and bushing
  - Functional hydrostatic bearing and wear rings
  - Functional wear rings and bushing
- Use defense-in-depth approach and address all three components to ensure they function under debris loading
Revised Design Concept (Continued)

- Use 50 mil strainer to protect hydrostatic bearing orifices
- Locate strainer on discharge side of impeller, close to wear ring to reduce concentration and size of debris reaching hydrostatic bearing
  - Wear ring acts as a strainer
  - Centrifugal effect on heavier debris maximized
  - Discharge side of volute maintains high velocity for all pump flows
  - Standard approach used by Pump Guinard for French PWRs

Volute Modifications
Revised Design Concept
(Continued)

• Modify hydrostatic bearing to improve debris tolerance
  - Add "escape" grooves to pocket
  - Change rectangular pocket to "8" pocket based on Pump Guinard design

“8” Pocket Hydrostatic Bearing

Revised Design Concept
(Continued)

• Hardface all critical wear surfaces: wear rings, bushing and shaft sleeve, hydrostatic bearing and sleeve

Suction and Discharge Wear Rings
Analysis and Qualification Testing

Bob Coward
MPR Associates

Modification Design Analyses

• Volute stress analysis
• Strainer stress analysis
• Hydrostatic bearing load carrying capability and stiffness
• Failure modes and effects analysis
• Hardfaced parts equivalency evaluations
Volute Finite Element Model

Strainer Finite Element Analysis
Stress
Hydrostatic Bearing Analysis

Failure Mode and Effects Analysis

- Considered all modifications to pump
- Evaluated potential failure modes for modification design
- Concluded no new failure modes are introduced
Qualification Testing Overview

- Use separate effects testing to evaluate pump internal components individually
  - Avoids contamination concerns
  - Addresses parts availability concerns
  - More flexible than full pump test
- Key elements of program included:
  - Fixture designs match critical characteristics of HPI pump
  - Full scale components
  - Debris characterization based on Davis-Besse containment
  - All testing in accordance with MPR's Quality Assurance Program

Qualification Testing Configuration

- Five test loops
  - Loop 1 - Suction Wear Ring
  - Loop 2 - Discharge Wear Ring
  - Loop 3 - Hydrostatic Bearing
  - Loop 4 - Central Volute Bushing
  - Loop 5 - Hydrostatic Bearing Supply Strainer
- 8000 gallon supply tank simulating sump (including debris) supplied Loops 1, 2, 4, 5
- Loop 3 (hydrostatic bearing) supplied through Loop 5 strainer
Qualification Testing Objectives

<table>
<thead>
<tr>
<th>Loop</th>
<th>Objectives</th>
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<tbody>
<tr>
<td>Suction Wear Ring &amp; Discharge Wear Ring</td>
<td>Measure Clearance Increase and Measure Flow Rates</td>
</tr>
<tr>
<td>Hydrostatic Bearing</td>
<td>Measure Clearance Increase and Confirm Adequate Flow</td>
</tr>
<tr>
<td>Central Volute Bushing</td>
<td>Measure Clearance Increase and Measure Flow Rates</td>
</tr>
<tr>
<td>Hydrostatic Bearing Supply Strainer</td>
<td>Confirm Adequate Flow</td>
</tr>
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Typical Test Loop

![Diagram of a typical test loop](image-url)
Suction Wear Ring Test Fixture

(Continued)
Test Fixture Equivalency Evaluation

• Design Configuration
  – Verify test fixture dimensions and materials match the HPI pump internals

• Flow Fields
  – Hydraulic and Computational Fluid Dynamics (CFD) analysis of test fixtures compared to HPI pump

• Operating Conditions
  – Test flow rates and pressures consistent with HPI pump functions

• Debris Characteristics
  – Use types, sizes and quantities of the debris expected in LOCA

CFD Modeling HPI and Loop 5 Pumps

HPI Pump

Loop 5 Pump
HPI Pump Operating Conditions

- SBLOCA operating conditions most challenging, but minimal debris
- LBLOCA most challenging debris, but not needed for short term cooling
- LBLOCA long term cooling (boron precipitation control) combines worst case debris with low flow/high head operation – testing performed for these operating conditions
Debris Characterization Approach

- Analyses based on debris generation and debris transport analyses for containment sump modification, as well as NRC-sponsored research
- Critical parameters, and their acceptance ranges, are defined for each debris type
- Commercial-off-the-shelf (COTS) materials selected to match critical characteristics
- Debris handling procedure addresses initial loading, sampling, and re-loading

Debris Characterization Analysis

- Considered short term and long term debris generation
- Considered debris transport to sump strainer
- Particle sizes selected to increase pump degradation
- Debris "recipe" includes:
  - Fiber (based on quantities after removal from containment)
  - Rust
  - Qualified and unqualified coatings
  - Dirt and dust
  - Concrete particles
Conservatisms in Analysis

- No credit for filtering of small debris on sump strainer surfaces
- Particle/fiber sizes biased toward increasing potential for pump degradation
- All miscellaneous fibers assumed to transport to sump
- All unqualified coatings are assumed to fail and become debris in post-LOCA environment

Suction Wear Ring Test Results
Central Volute Bushing Test Results
Hydrostatic Bearing Test Results

21 Days Testing
Hydrostatic Bearing Test Results

Strainer Test Results
Qualification Testing Results Summary

- **Suction Wear Ring**
  - Minimal wear on wear ring and impeller hub
  - Little impact on leakage flow

- **Discharge Wear Ring**
  - Minimal wear on wear ring
  - Abrasive "grooving" on impeller hub from plugging, small wear elsewhere on hub
  - Essentially no impact on pump performance

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Qualification Testing Results Summary (Continued)

- **Central Volute Bushing**
  - Minimal wear on bushing
  - Abrasive wear on shaft sleeve from plugging
  - Leakage flow depends on plugging and axial extent of abrasive wear

- **Hydrostatic Bearing**
  - Minimal wear on bearing
  - Abrasive wear on shaft sleeve
  - Bearing flow remained adequate (~ 5% decrease)

- **Strainers**
  - Essentially constant flow throughout test
Performance Analyses

• Rotordynamics Analysis
  - To demonstrate that vibration levels for the worn condition of all pump parts are acceptable
  - Preliminary analysis results show acceptable results

• Hydraulic Analysis
  - To demonstrate the pump hydraulic performance in the worn condition is acceptable
  - Preliminary analysis results show considerable margin
Critical Speed Analysis

Original Hydrostatic Bearing

Replacement Hydrostatic Bearing

Forced Response Analysis

75% Central Volute Bushing Length

50% Central Volute Bushing Length
Hydraulic Performance Analysis

French Experience

- French PWRs use similar class pump for make-up/HPI
- Nuclear Safety Authority requested validation pumps would operate satisfactorily in emergency conditions
  - Comprehensive testing performed in 1980-1981
  - Pump design modified to increase debris tolerance
- Main design features were:
  - Moved hydrostatic bearing take-off to discharge side of volute
  - Hardfaced close clearances
  - Modified hydrostatic bearing pocket design to "H" bearing
  - Replaced central volute bushing with hydrostatic bearing
French Experience (Continued)

- Davis-Besse HPI Pump modifications comparable to French modifications, with additional measures to improve debris tolerance.

Overall Approach Summary

<table>
<thead>
<tr>
<th>Concern</th>
<th>Modifications</th>
<th>Testing</th>
<th>Analysis</th>
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<tbody>
<tr>
<td>HSB orifice and pocket plugging</td>
<td>• Installed strainer to filter debris</td>
<td>• Mock-up testing of strainer demonstrated adequate flow</td>
<td>• Completed structural analysis of volute/strainer</td>
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<tr>
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<td>• Moved HSB take-off to low debris location</td>
<td>• Mock-up testing of HSB demonstrated adequate flow</td>
<td>• Completed HSB hydraulic analysis</td>
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<tr>
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<td>• Included debris escape grooves in HSB pockets</td>
<td></td>
<td>• FMEA</td>
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<tr>
<td>Close clearance wear</td>
<td>• Installed replacement hardfaced parts to minimize wear</td>
<td>• Mock-up testing of new parts determined worn condition</td>
<td>• Completed evaluation of mock-up fixtures</td>
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<td>• In-plant testing of worn pump demonstrated acceptable performance</td>
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October 21, 2003
Major Project Conservatisms

- Defense-in-depth approach to ensure satisfactory pump performance
- Mock-up testing did not include filtering effect of discharge wear ring for hydrostatic bearing flow
- Mock-up testing maintained initial debris concentrations for entire test – extreme measures were required to prevent settling and hideout
- All miscellaneous debris assumed to be transportable fiber
- Simulated coating materials in mock-up testing significantly stronger than containment coatings

Project Status

- Modification design completed, finalizing design change package
- Mock-up testing completed, finalizing data analysis
- Preliminary rotordynamic and hydraulic analysis completed, awaiting finalization of test report
- Pump modifications in progress
Conclusion

Gary Leidich
President and Chief Nuclear Officer - FENOC

- Modifications, along with associated analysis and testing, demonstrates that the HPI pumps will perform their safety functions