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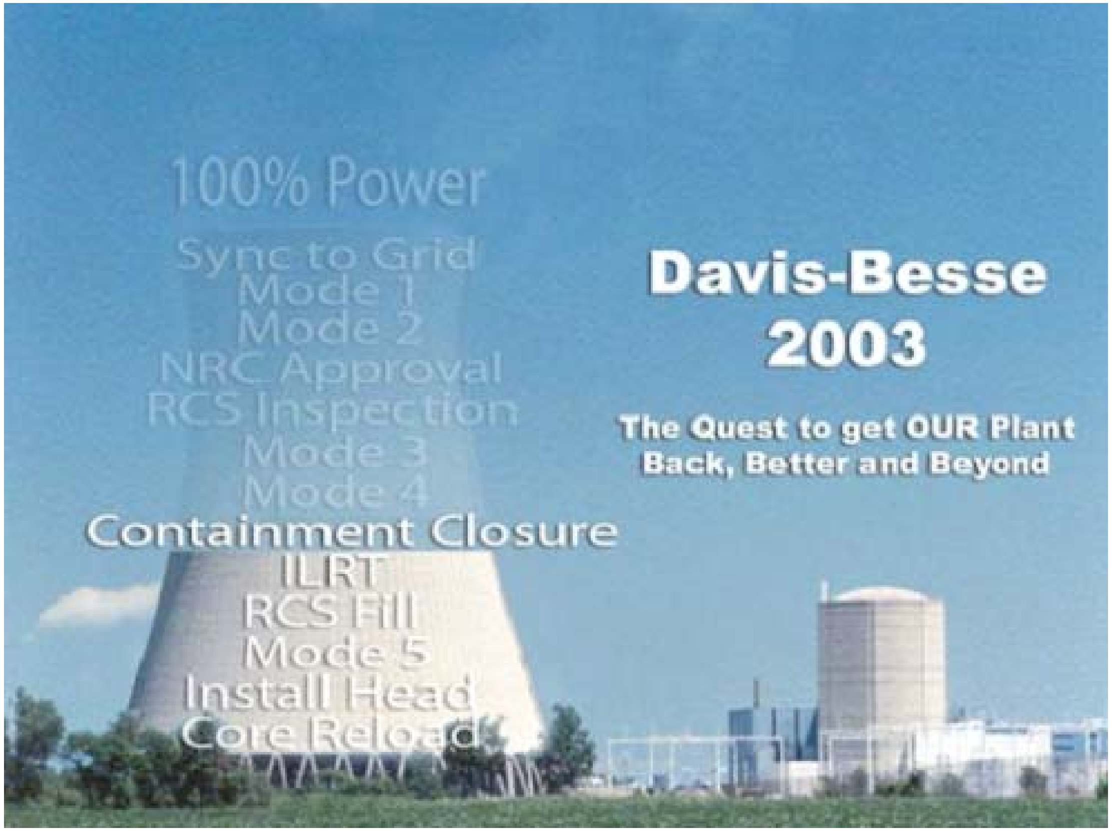
Davis-Besse Nuclear Power Station



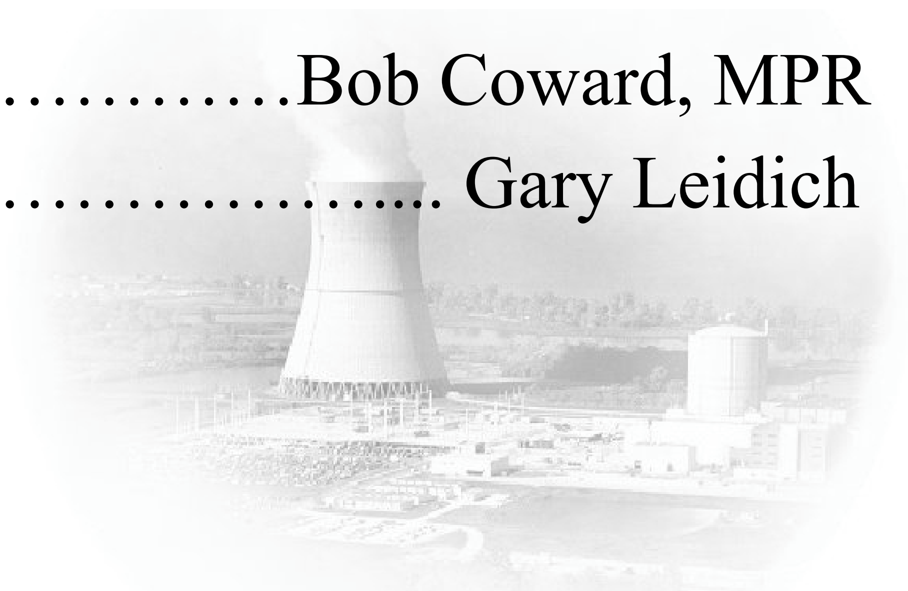
Modification of High Pressure Injection Pumps

Agenda

Opening Remarks . . . . Gary Leidich

- HPI Pump Design..…………………………… Jim Powers
- HPI Pump Modifications……………Bob Coward, MPR

Closing Comments…………………………..... Gary Leidich



Opening Remarks

Gary Leidich
Executive Vice President - FENOC

Overview

- Background
  - Implemented Building Block approach in the summer/fall of 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
  - Assessed the alternatives to address the issue

- Today
  - Present resolution plan

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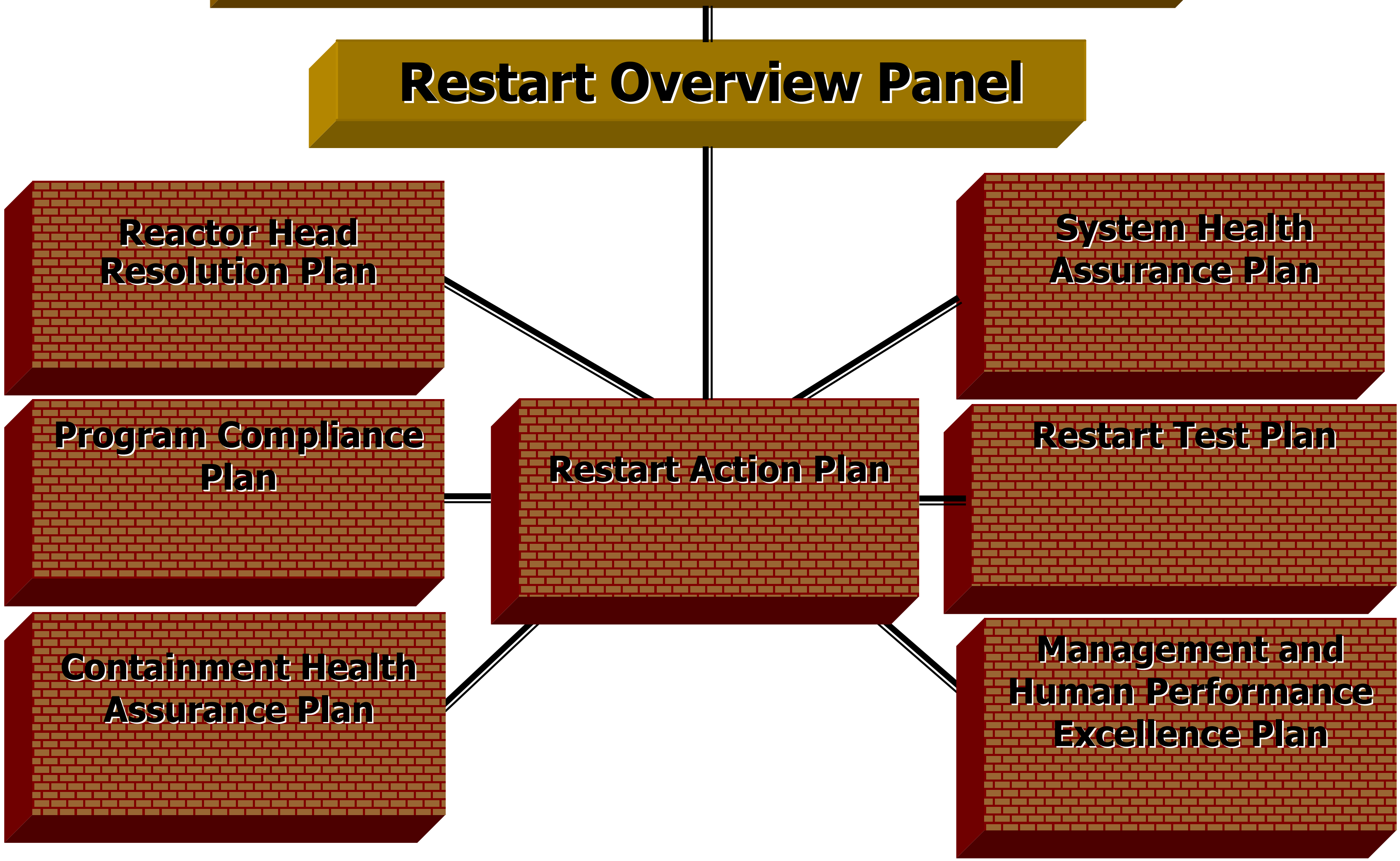
Return to Service Plan



Desired Outcome

- An understanding by the NRC of the proposed High Pressure Injection Pumps modification and testing, and assurance that the pumps will perform their required safety functions

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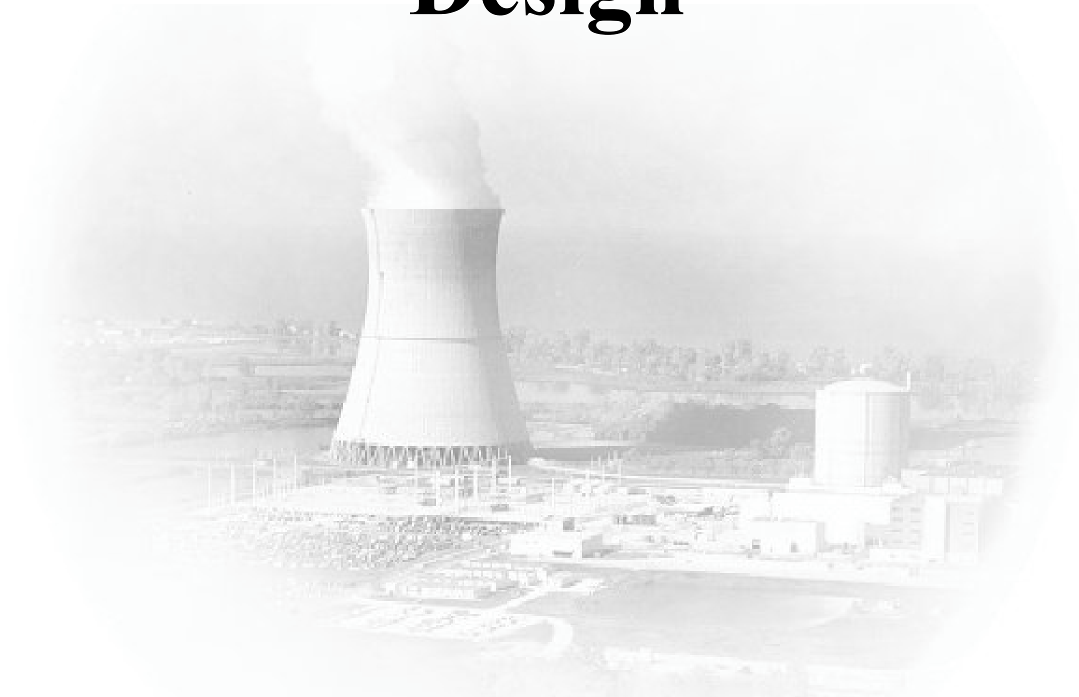
High Pressure Injection (HPI) Pump Design



Jim Powers

Director - Davis-Besse Engineering

High Pressure Injection System
Design Functions

- HPI System provides emergency functions as part of the Emergency Core Cooling System
  - Two redundant trains provide emergency core cooling for small break LOCA
  - Operates in conjunction with Low Pressure Injection System and Core Flood Tanks to limit core damage in accordance with the requirements of 10CFR50, Appendix K for a range of small break LOCAs
  - Provides borated water to decrease Reactor Coolant System (RCS) reactivity
  - Provides makeup for reactor coolant contraction due to cooling of RCS

High Pressure Injection System
Safety Functions

- Large-Break (LBLOCA)
  - Borated Water Storage Tank (BWST) injection mode operation
  - LBLOCA safety analyses do not credit HPI
- Small-Break (SBLOCA)
  - BWST injection mode and Containment Emergency Sump recirculation mode operation
  - Flow requirements from safety analyses
- Boron precipitation control
  - Containment Emergency Sump recirculation mode operation
  - 250 gpm required through Auxiliary Pressurizer Spray line Boron precipitation control

High Pressure Injection Pumps

- Manufacturer
  - Babcock and Wilcox
- Type
  - Horizontal, eleven stage centrifugal pumps
  - 600 HP electric motors
  - Hydrostatic bearing
- Design Pressure/Temperature
  - 2000 psig/ 300^{0}F
- Design/Manufacture Code
  - ASME Pump & Valve Code, Class II, November 1968
- Surveillance Test/Inservice Testing
  - ASME Section XI
- Believed to be unique to Davis-Besse in domestic nuclear industry

HPI Pump Design Issues

- Post-LOCA Operation Issues
  - In post-LOCA recirculation mode operation, HPI pump suction is from Containment Emergency Sump
  - Sump is likely to contain debris from LOCA blowdown and containment spray actuation
  - HPI Pumps must be capable of operating with debris in the pump flow

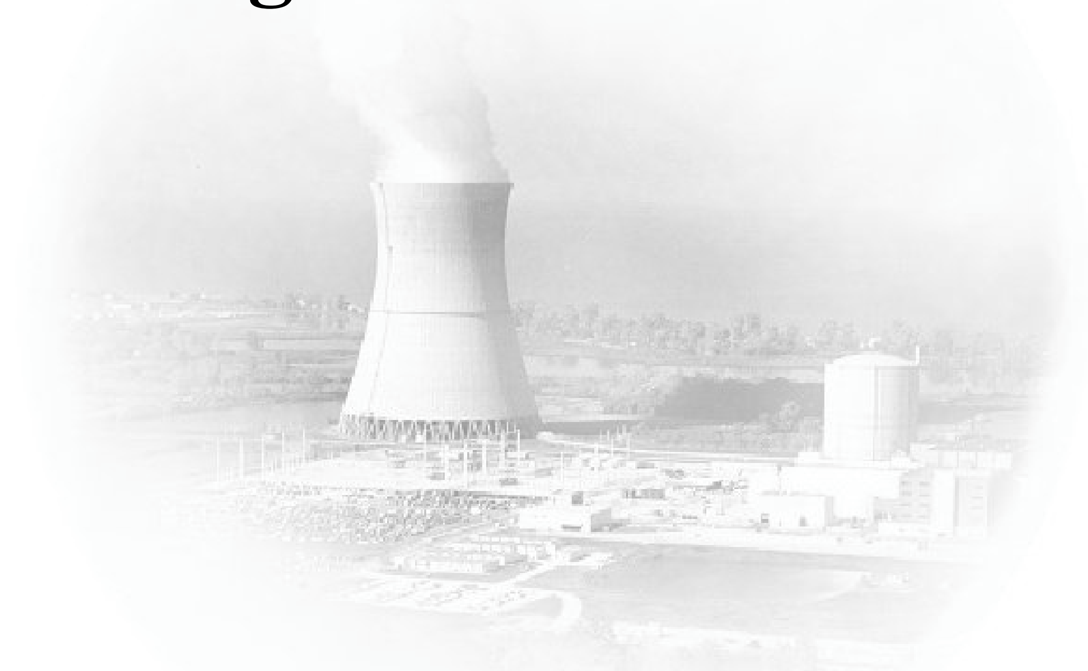
HPI Pump Design Issues

- System Health Assurance identified three design issues
  - Hydrostatic bearing plugging
    - Bearing orifices are smaller than emergency sump strainer and could become plugged
    - Bearing pad clearances are smaller than sump strainer
  - Fine 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

HPI Pump Modification
Objective

- Implement a resolution plan to resolve HPI pump debris issue that
  - Modifies only the HPI pump
  - Makes no substantive change to existing licensing basis, procedures, USAR, or design basis documents
  - Makes no changes to Technical Specifications

High Pressure Injection (HPI) Pumps Design Issue Resolution



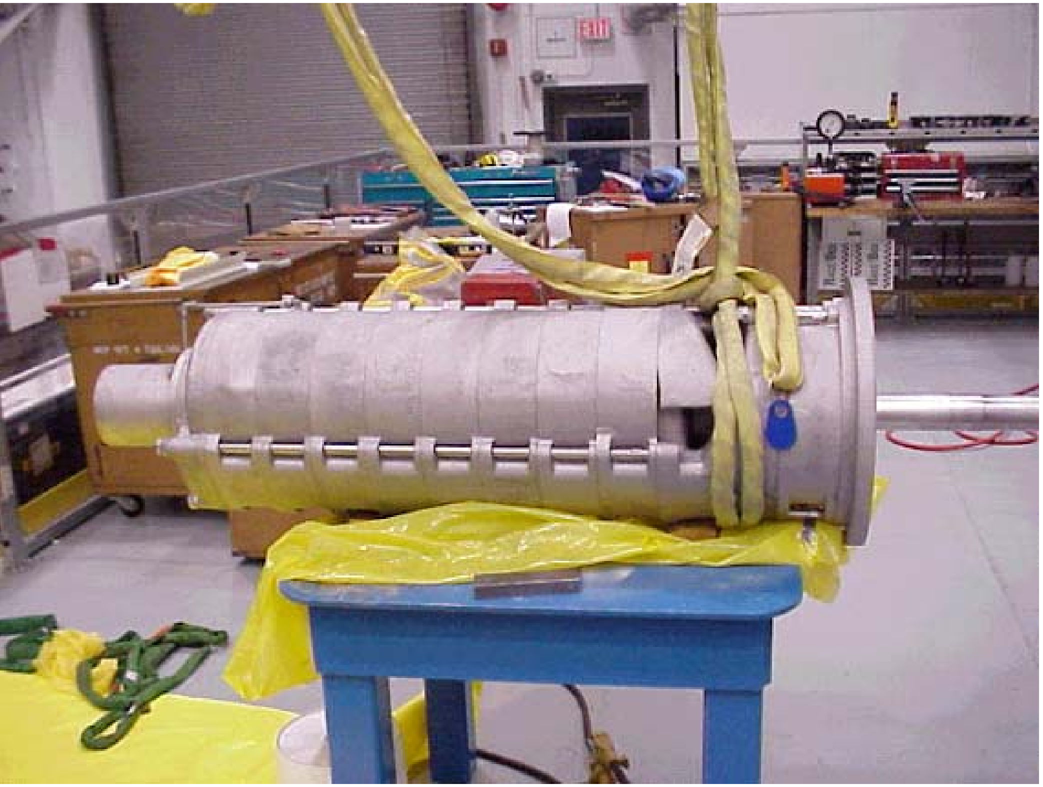
Bob Coward

MPR

Project Overview

- Issue
  - Debris in containment emergency sump post-LOCA may degrade HPI pump performance
    - Plugging of hydrostatic bearing orifice
    - Plugging of hydrostatic bearing pads
    - Wear of fine clearances

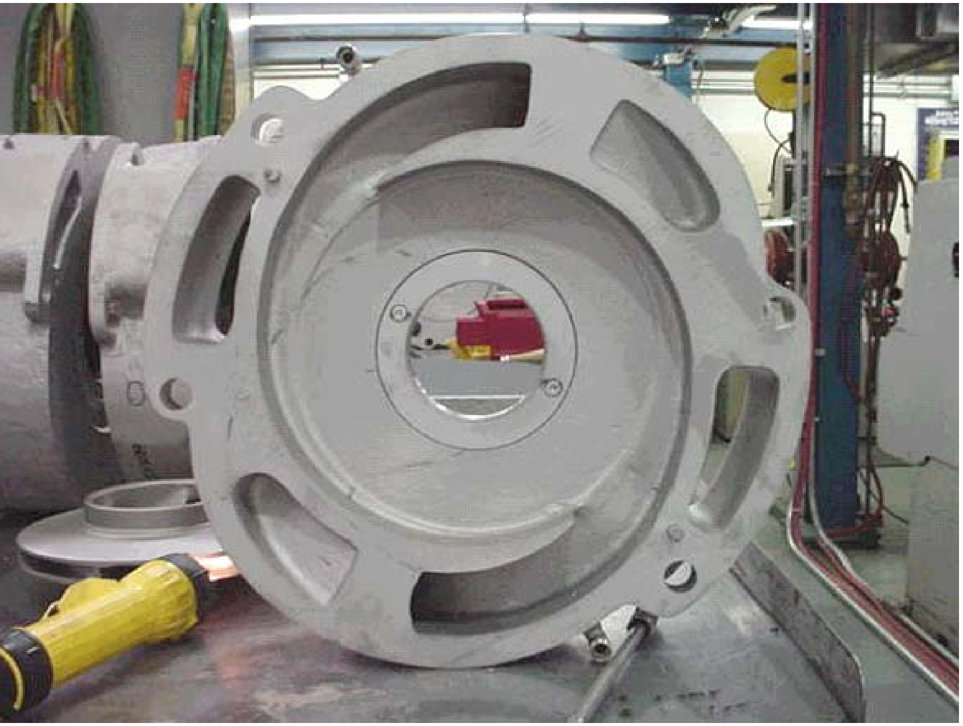
HPI Pump Internal Assembly



Eleven stage internal assembly

Assembly Process

4th Stage Volute



4th Stage Volute

4th Stage Volute with Impeller

Back Side of Volute with Impeller

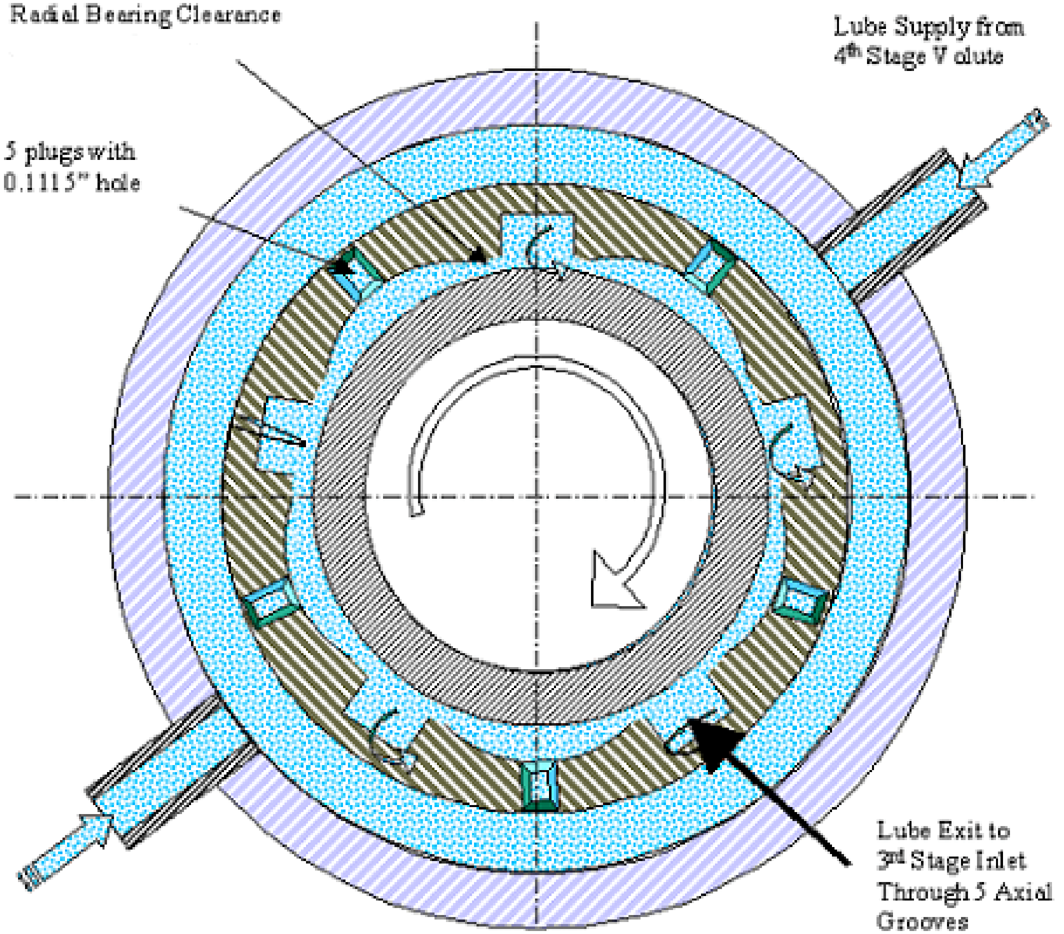
Hydrostatic Bearing Orifice Plugging

- Design issue
  - Orifices in supply to hydrostatic bearing pads are 0.111 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
- Resolution
  - Add a self-flushing strainer plate at entrance to bearing supply tube

Hydrostatic Bearing Pad Debris

- Design issue
  - Bearing design includes tight clearances (0.012 inch to 0.015 inch diametral) at edges of hydrostatic bearing pads
  - Debris in water flowing to bearing pads may be larger and accumulate in the bearing pad, impacting bearing performance
  - Degradation of bearing performance may impact pump operation
- Resolution
  - Demonstrate existing clearances are acceptable based on test of actual bearing with conservative debris loading

Hydrostatic Bearing Configuration



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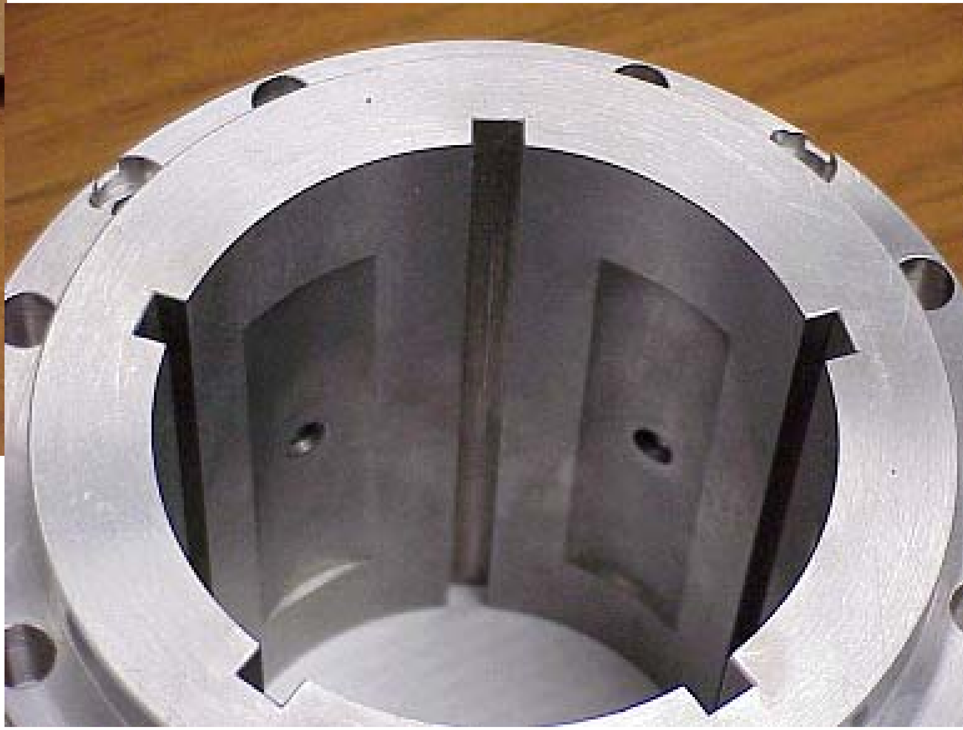
Hydrostatic Bearing Design



Fine Clearances Wear

- Design issue
  - Pump design includes tight clearances
    - Central volute bushing (0.011 inch to 0.014 inch diametral)
    - Hydrostatic bearing (0.012 inch to 0.015 inch diametral)
    - Wear rings (0.019 inch to 0.021 inch diametral)
  - 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
- Resolution
  - Use analysis, mock-up, and in-plant testing to demonstrate reliable pump operation with expected increased clearances

Cyclone Separator Supply Line Plugging

- Postulated design issue
  - New containment sump strainer has 0.188 inch diameter openings
  - Supply line to the cyclone separator was considered to be as small as ~ 0.125 inch diameter
  - Supply line may plug with debris that passed through sump strainer, starving flow to the cyclone separator and seal
- Resolution
  - Updated information shows supply line is ~ 0.35 inch diameter, but cyclone separator inlet port is 0.180 inch diameter
  - Potential need for cyclone separator modification or replacement under consideration (pump modifications not necessary)

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Resolution Approach

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

- Analysis
  - Rotordynamic analysis to demonstrate satisfactory pump operation with increased fine clearances
  - Hydraulic analysis to demonstrate satisfactory pump performance with increased fine clearances

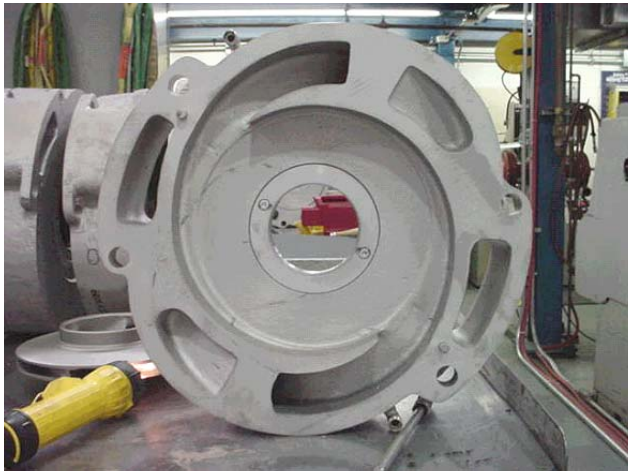
Resolution Approach
(Continued)

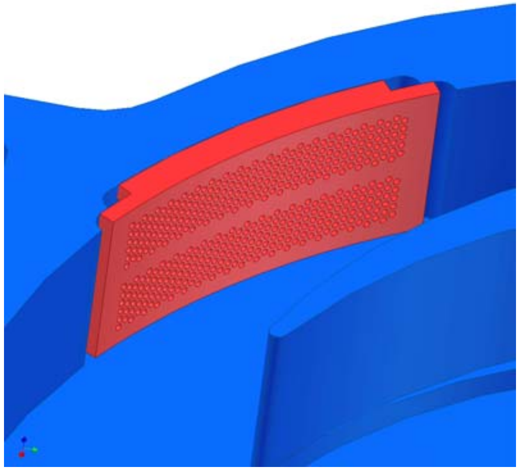
- Perform mock-up testing of
  - Strainer installation to confirm self-flushing nature and debris dispersal effect
  - Hydrostatic bearing under debris loading to confirm satisfactory operation
  - Fine clearances to determine wear rates
- Perform in-plant testing to
  - Validate rotordynamics model
  - Validate hydraulic performance model
  - Demonstrate satisfactory pump operation with increased clearances
- Perform post-modification testing to confirm pump operation

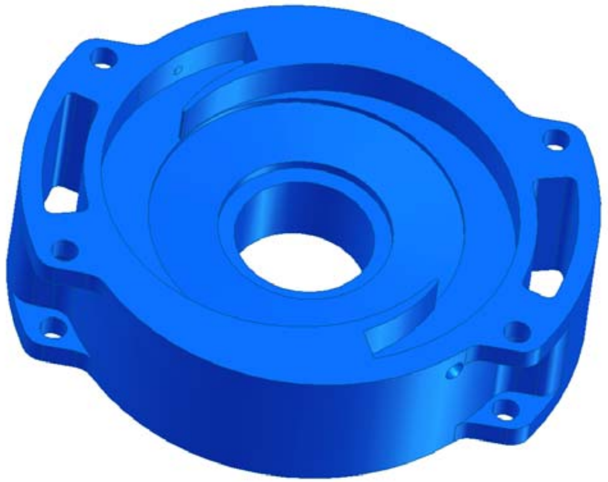
Pump Modification

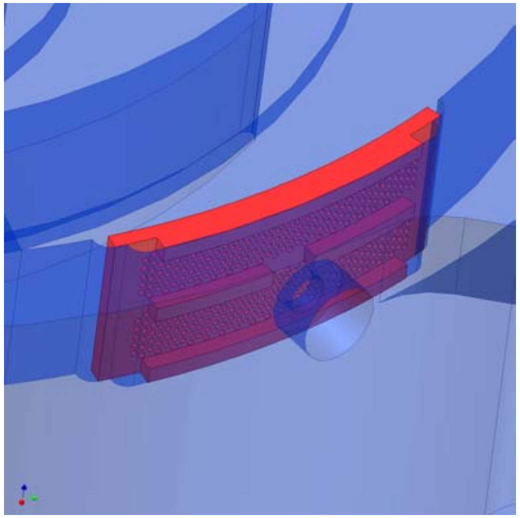
- Modification
  - Install strainers over the hydrostatic bearing supply ports in volute
  - Relocate hydrostatic bearing supply ports to increase flow velocity over strainer and reduce debris entering hydrostatic bearing
  - Perform all design and modification activities as safety related
- Design analyses
  - Perform stress analysis of modified volute and strainer
  - Perform hydraulic analysis of hydrostatic bearing flow path
  - Perform Computational Fluid Dynamics (CFD) analyses to support moving take-off port

Original Strainer Concept

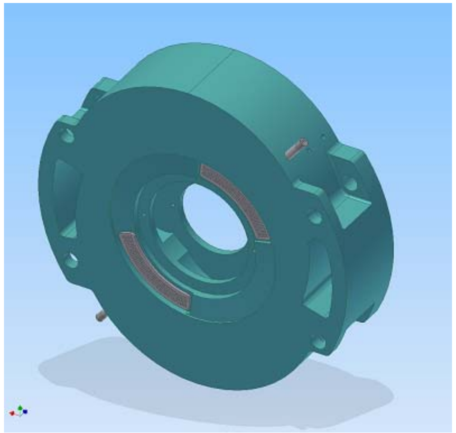


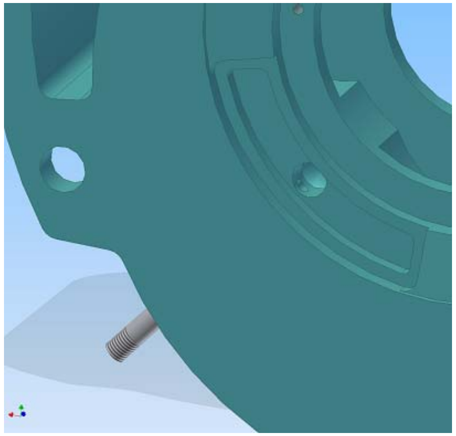






Final Strainer Design





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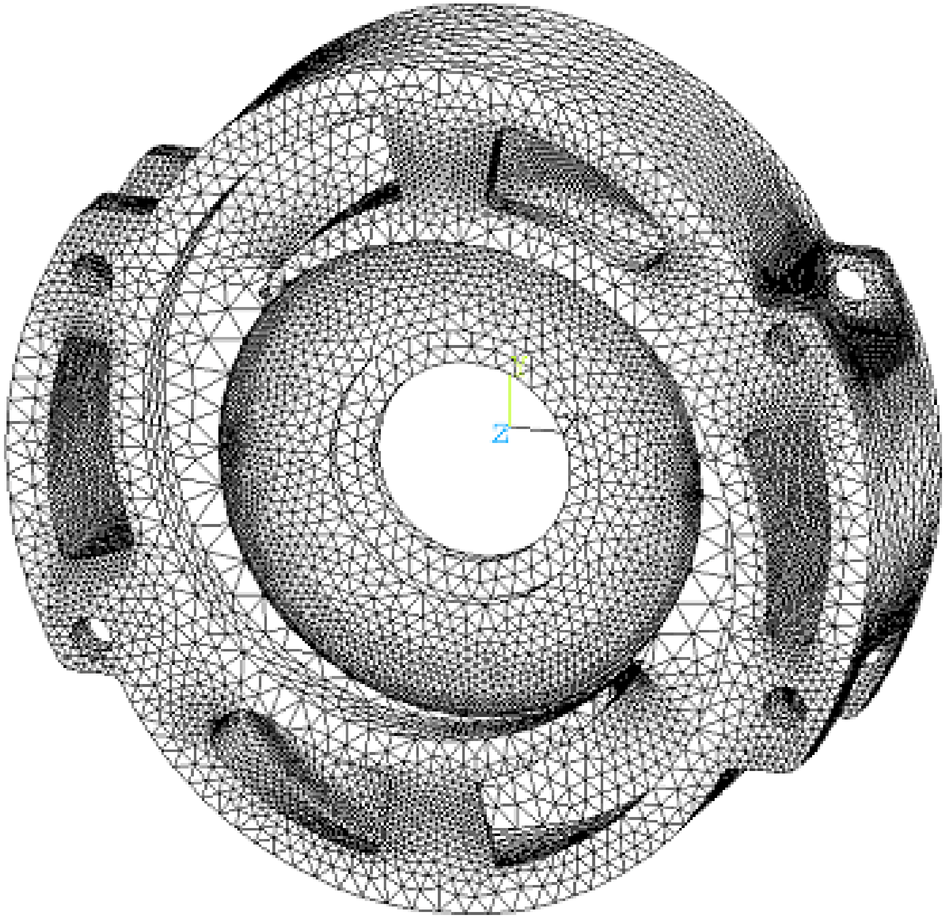
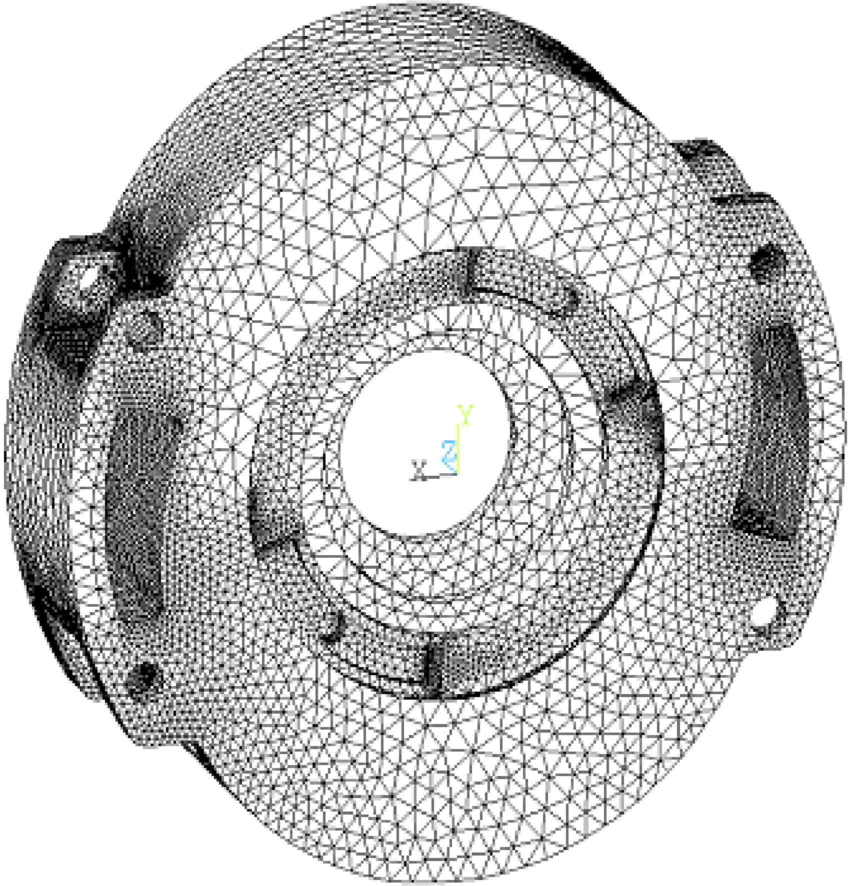
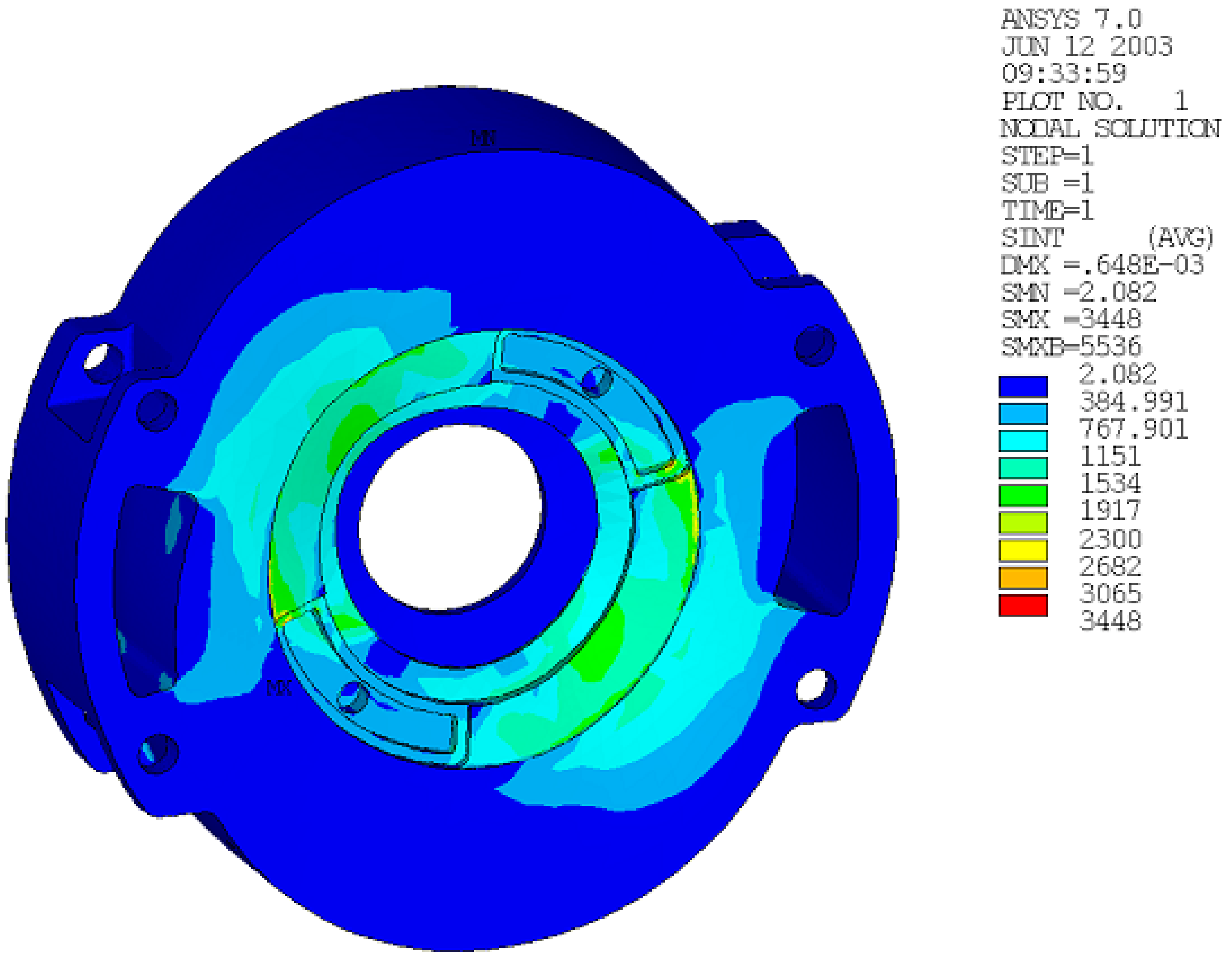
Volute Finite Element Model

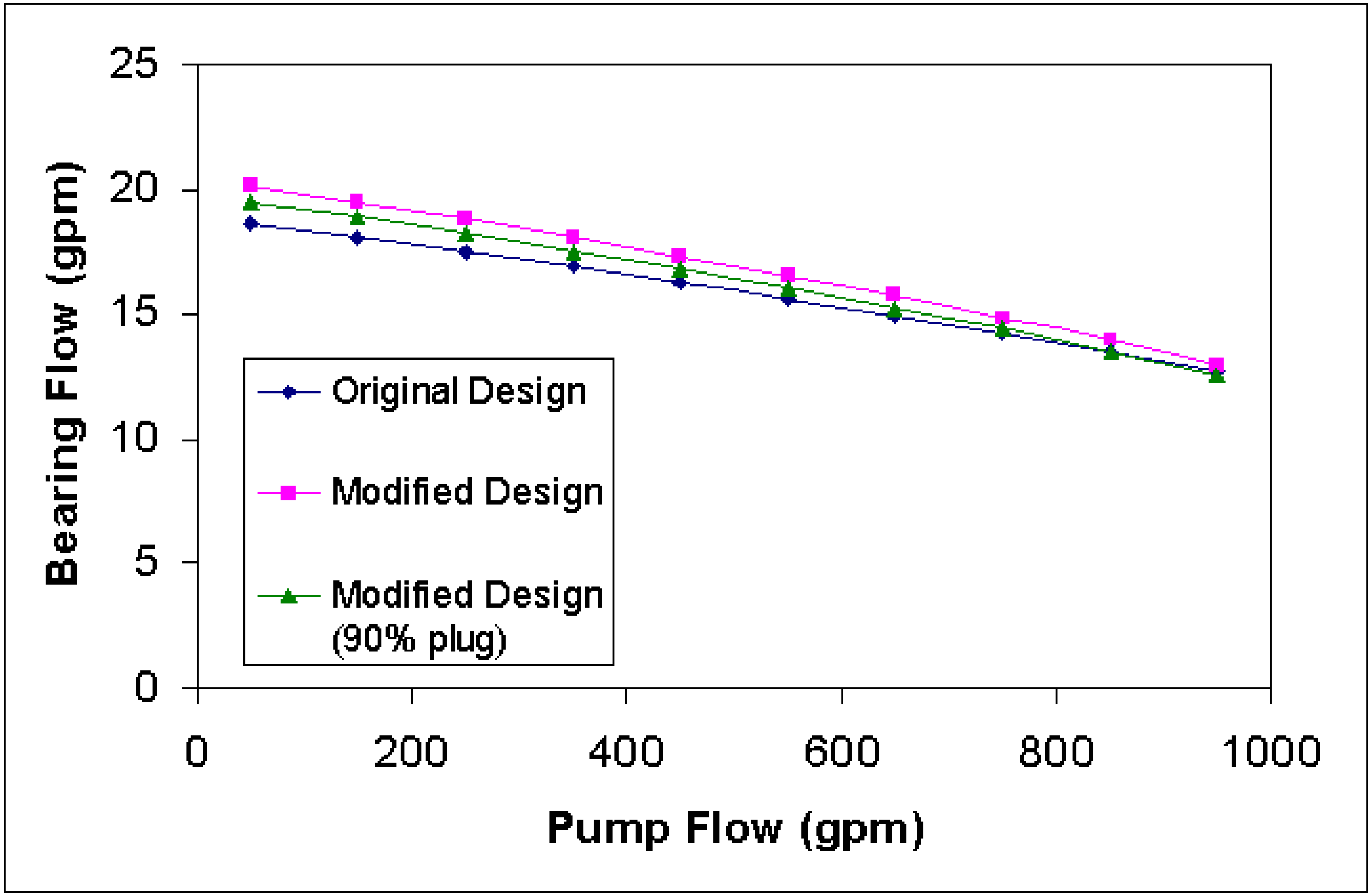




Finite Element Analysis Results



Hydrostatic Bearing Flow



Pump Guinard Testing

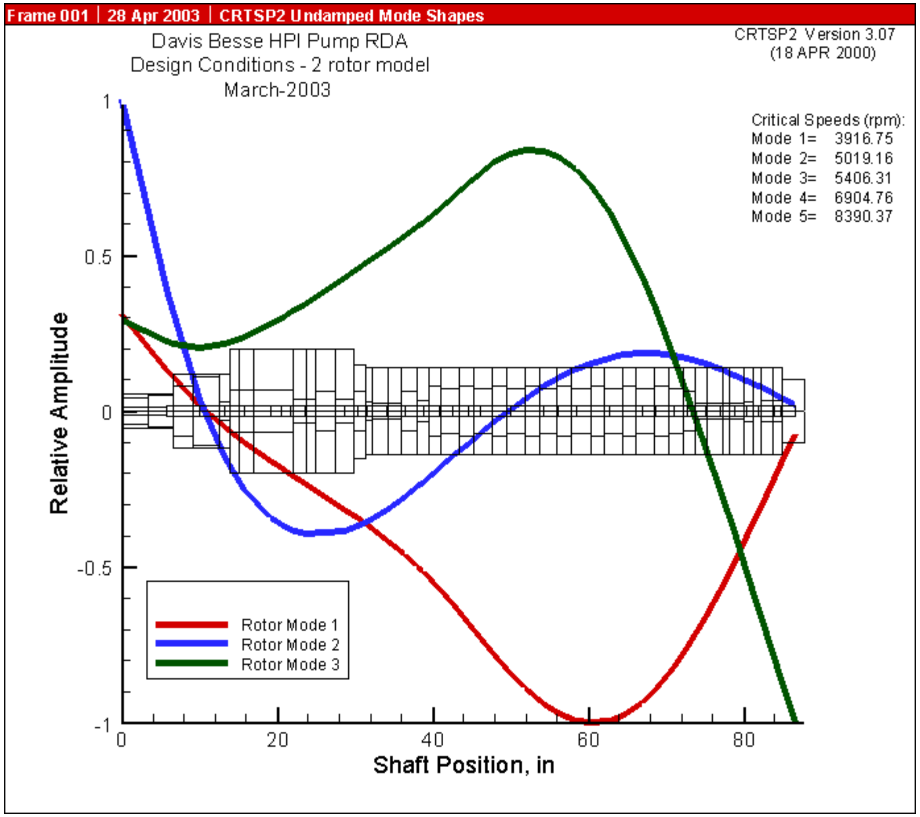
- French PWRs use similar class pump for makeup/HPI
  - Normal service instead of standby
  - 12 stages instead of 11 stages
  - 4500 rpm instead of 3600 rpm
  - Central hydrostatic bearing instead of bushing
- Nuclear Safety Authority requested validation pumps would operate satisfactorily in emergency conditions
  - Testing performed in 1980-1981
- Pump operated satisfactorily after hydrostatic bearing supply port was moved to side of volute near impeller

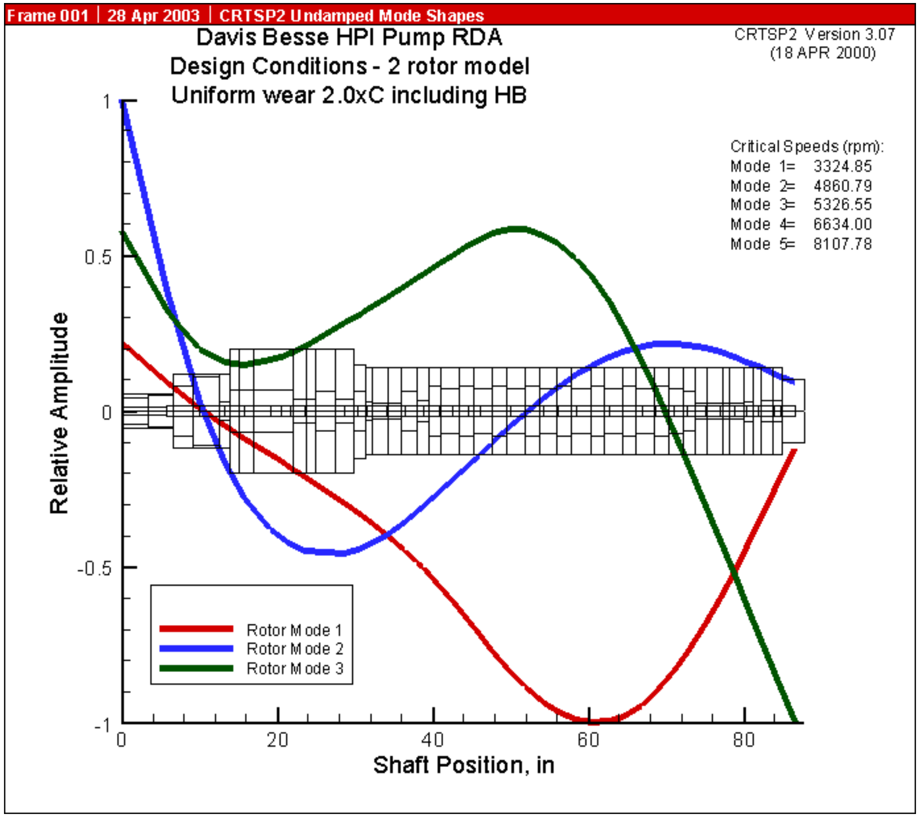
Analyses

- Rotordynamics Analysis
  - Model tuned using vibration data from 1X in-plant test
  - Preliminary model predictions show vibration levels for increased fine clearances (up to 2X) are acceptable and not significantly greater than 1X levels

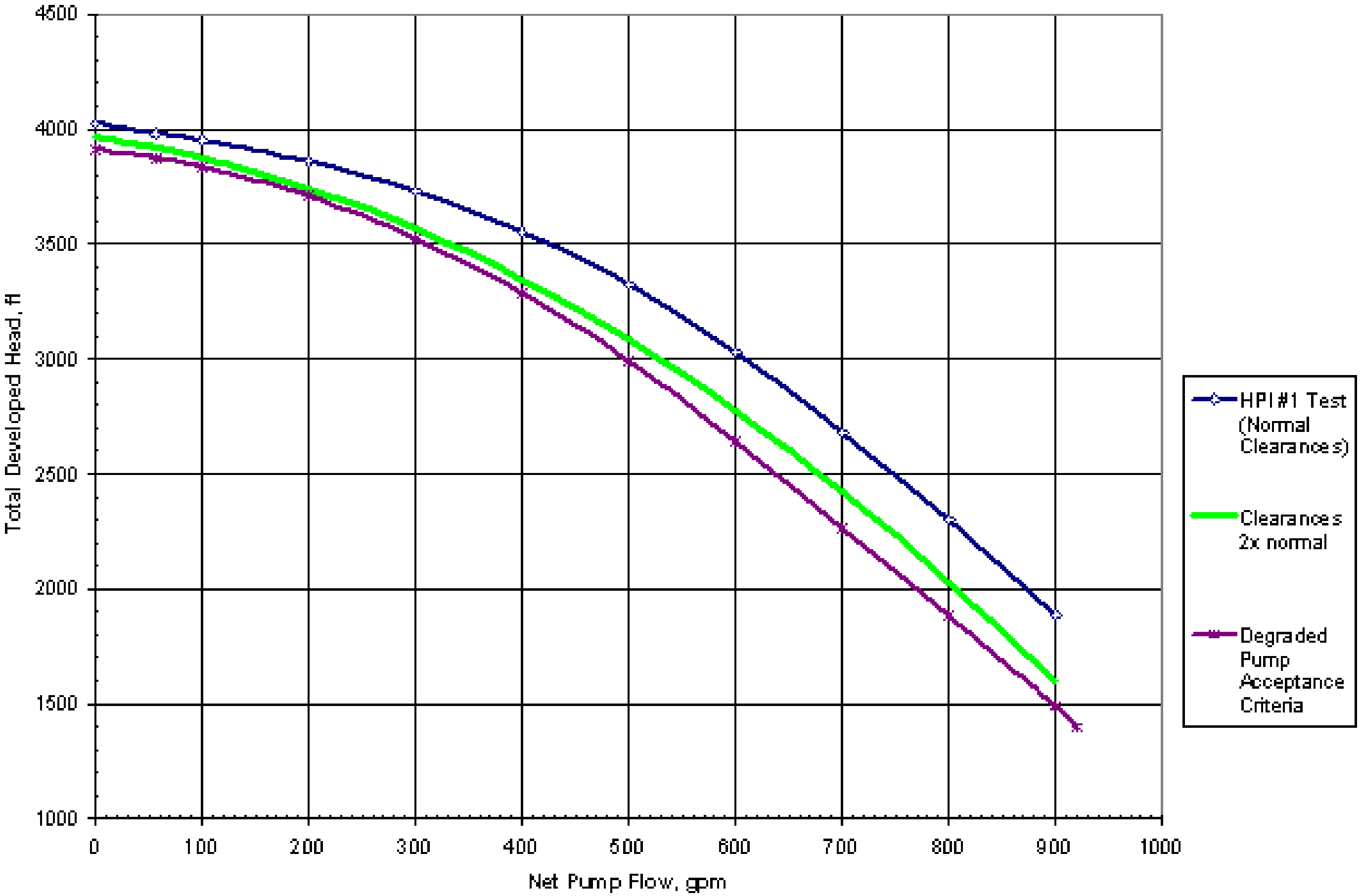
- Hydraulic Analysis
  - Model considers leakage between stages across wear rings
  - Calculations performed for 2X fine clearance condition
  - Predicted performance for 2X meets surveillance test requirements

Rotordynamics Analysis





Hydraulic Performance Analysis



Mock-Up Testing

- Test objectives
  - –Confirm strainer self-flushing behavior
  - –Confirm hydrostatic bearing operation
  - –Measure wear ring clearance increases
  - –Measure central volute bushing clearance increases
  - –Measure hydrostatic bearing clearance increases
  - –Measure debris "separating" effect by pump impellers

Mock-Up Testing

- All tests
  - Fixture design matches critical characteristics of HPI pump
  - Performed in accordance with QA Program requirements
  - Debris characterization based on Davis-Besse containment design
  - Full scale components
  - Capability to adjust clearances
  - Capability to pause/re-start test for interim results

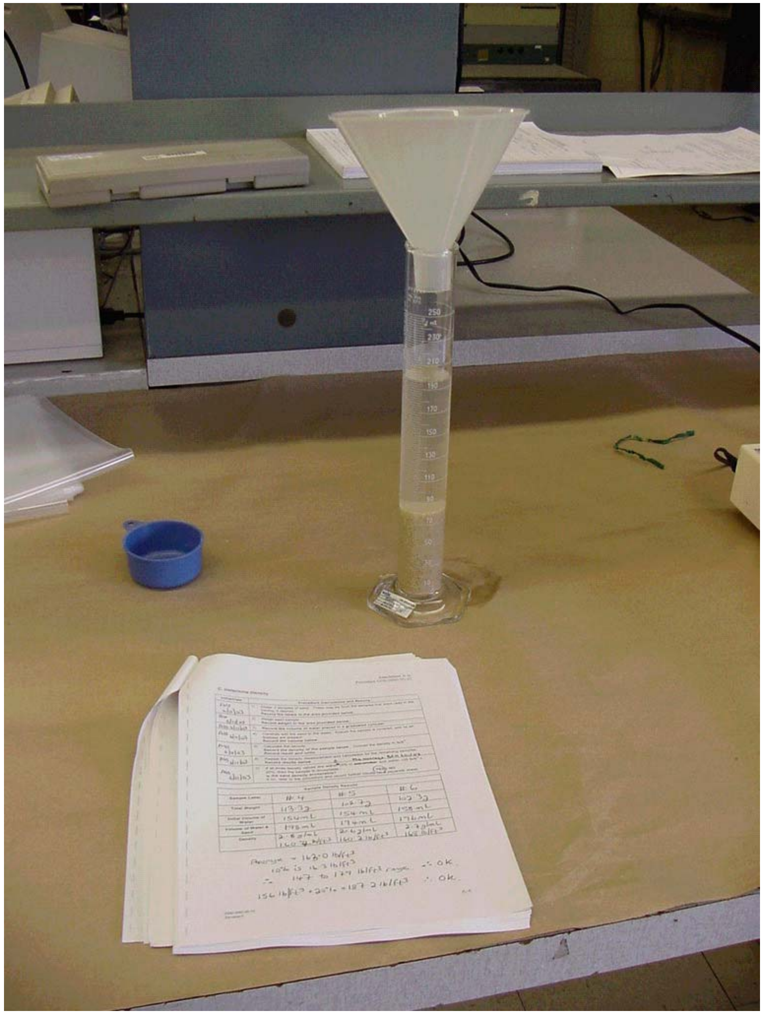
Debris Characterization

- HPI pump debris loading based on
  - –LBLOCA scenario
  - –Sump strainer size
  - –Mass and density of particles
  - –Flow velocities in containment
- Debris solution includes
  - –Fibrous insulation
  - –Rust particles
  - –Qualified and unqualified coatings
  - –Dirt and dust
  - –Concrete particles

Debris Characterization
(Continued)

- Approach
  - Analyses based on debris generation and debris transport analyses for Davis-Besse containment sump, 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
  - Commercial dedication performed to qualify COTS materials
  - Debris handling procedure addresses initial loading, sampling, and re-loading

Debris Acceptance/Inspection



Debris Acceptance/Inspection
(Continued)

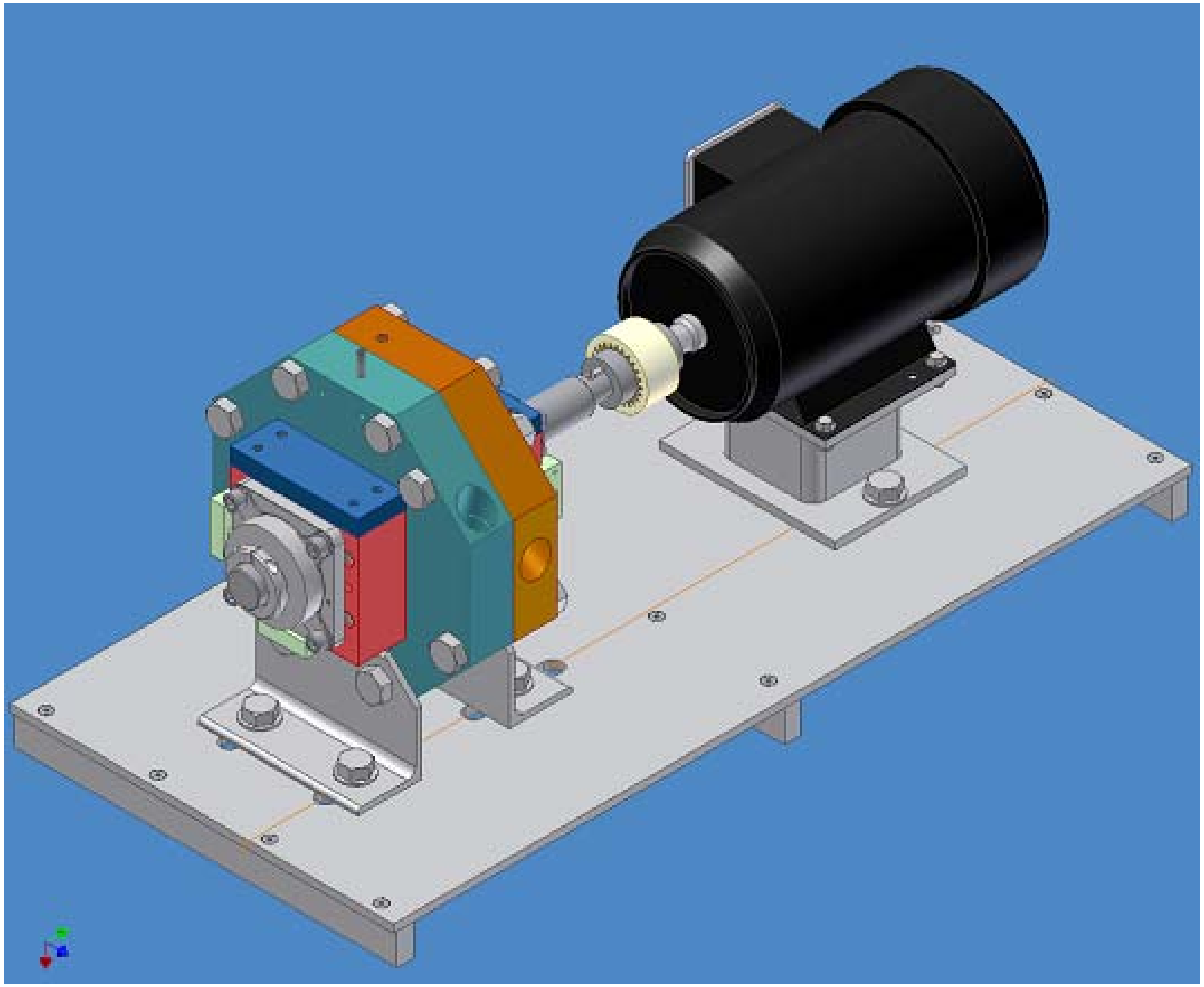
Debris Characterization
(Continued)

- Conservatisms
  - –75% of generated debris transports to HPI pump
  - –No credit for filtering of small debris on sump strainer surfaces
  - –Particle/fiber sizes biased toward increasing potential for pump degradation
  - –All hard concrete debris is considered transportable and in size range with potential to wear critical pump surfaces

Mock-Up Testing

- 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

Suction Wear Ring Fixture



Suction Wear Ring Fixture
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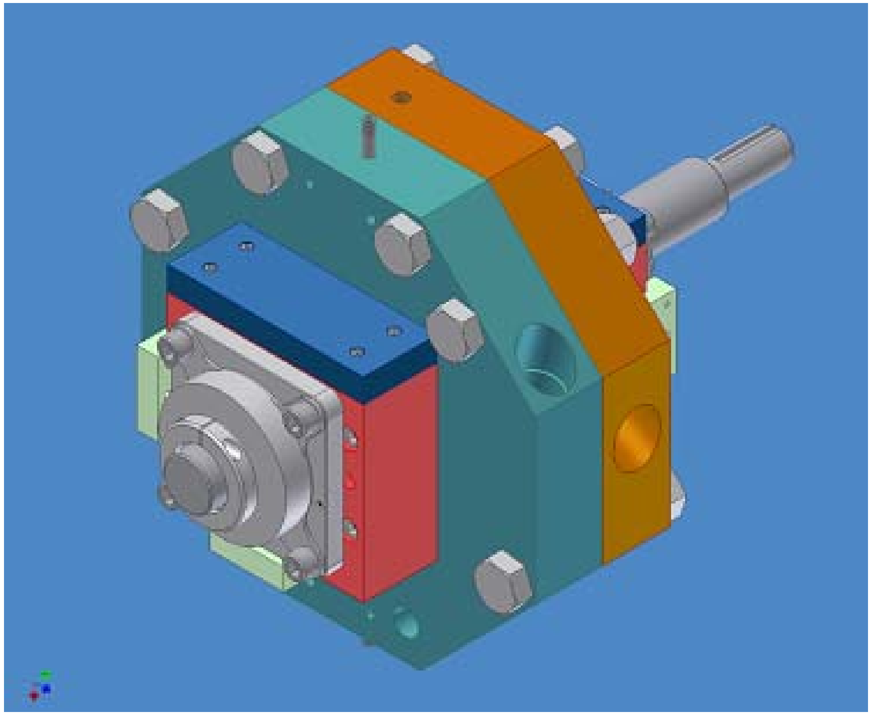

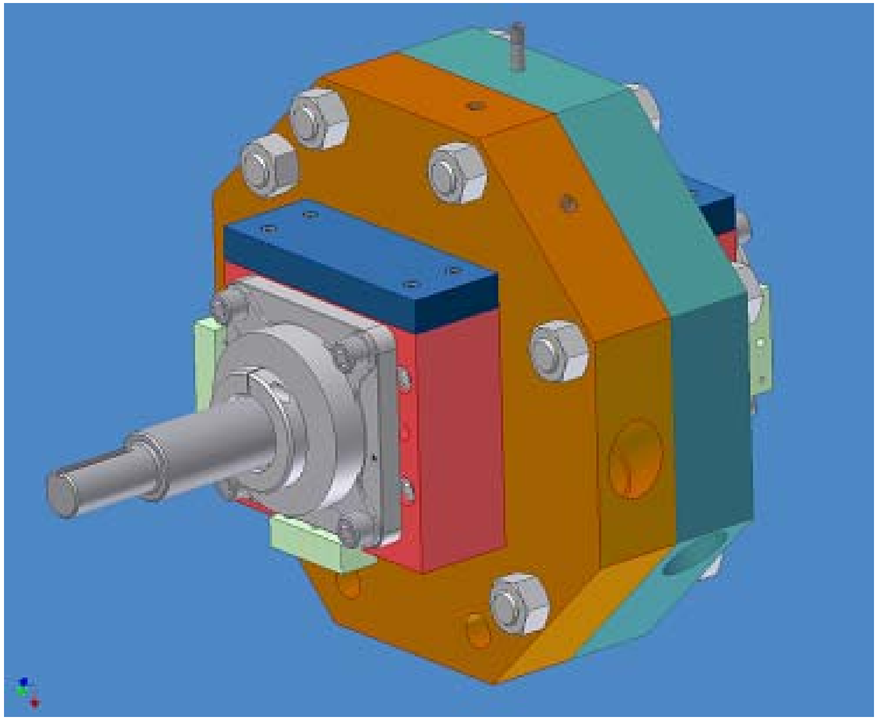

Suction Wear Ring Fixture
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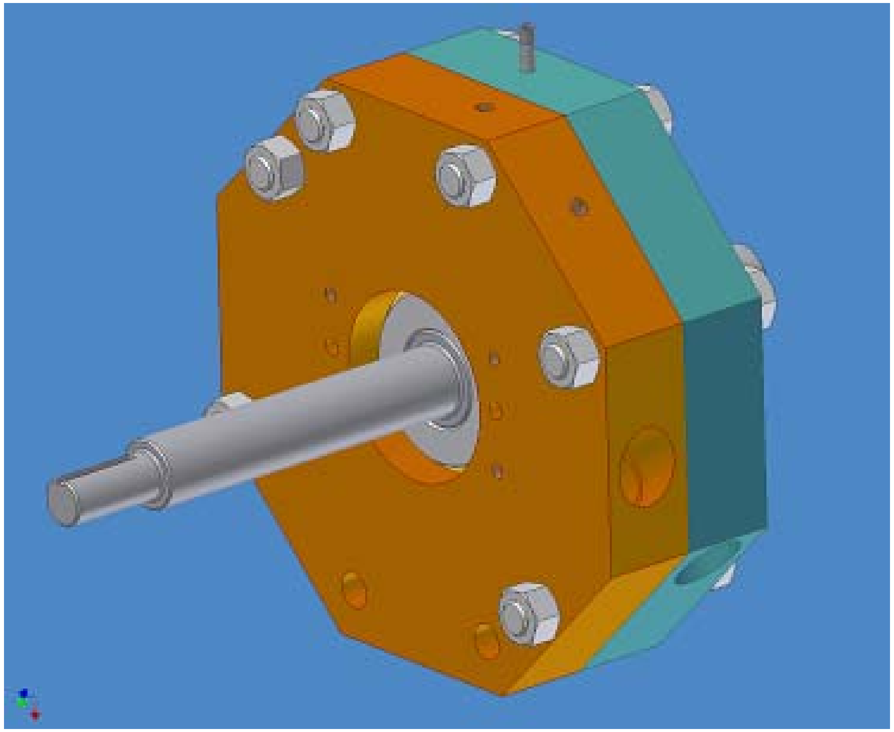

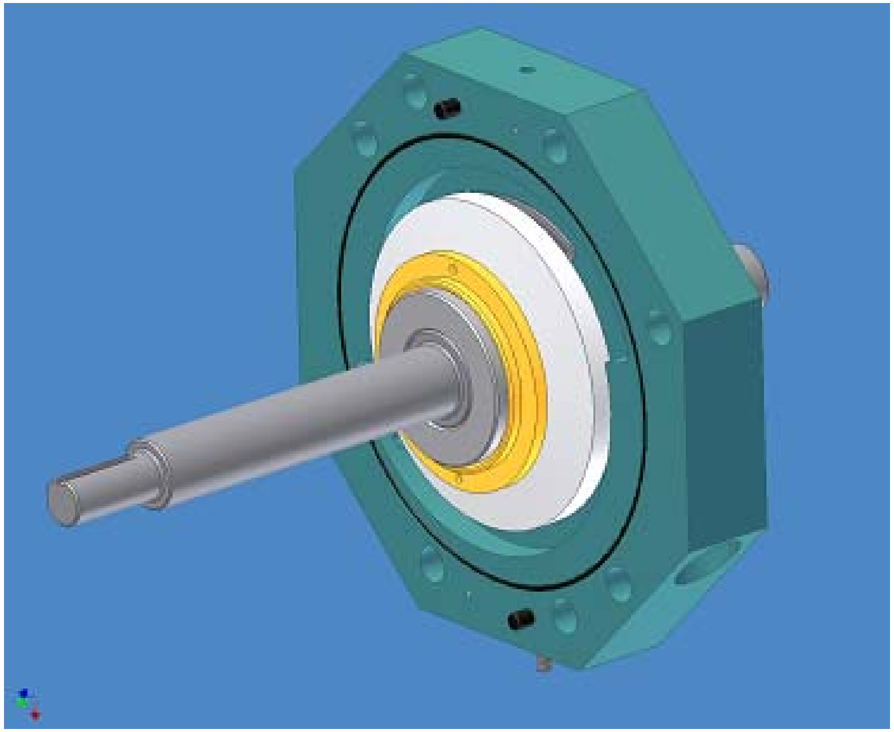

Suction Wear Ring Fixture
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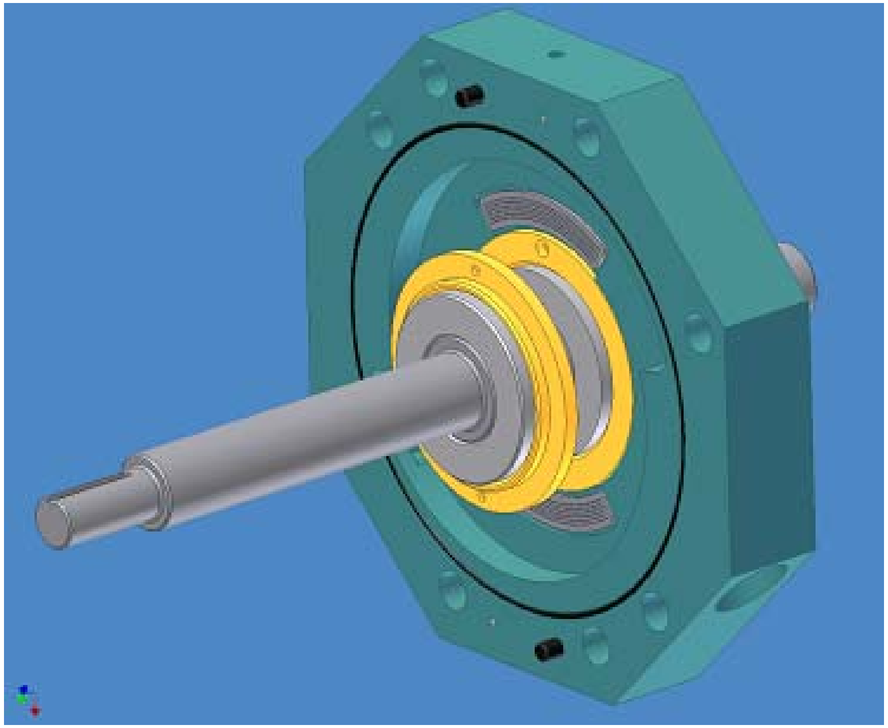

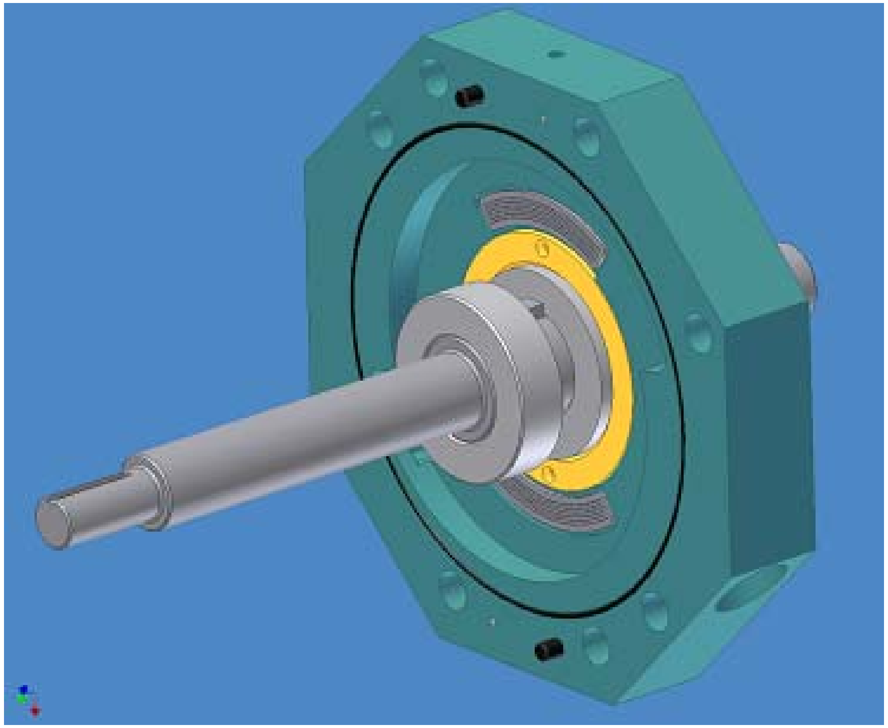

Discharge Wear Ring Fixture

Mock-Up Testing

Mock-Up Testing
(Continued)

In-Plant Testing

- Baseline pump test ("1X")
  - Conducted during surveillance test
  - Increased data acquisition capability
  - Results used to validate rotordynamics model
    - Increased response at 942 gpm
    - Low vibratory response throughout flow range

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In-Plant Testing
(Continued)

- Worn pump test ("2X")
  - Spare pump assembled with 2X fine clearances
  - Increased data acquisition capability
  - Results used to validate rotordynamics model, validate hydraulic model, and demonstrate pump operation is acceptable
    - Preliminary results show low vibratory response over full range of operating conditions
    - Preliminary results show hydraulic performance acceptable
    - Most importantly – pump ran well with clearances opened to twice normal
- Post-modification testing will be performed to demonstrate satisfactory operation of modified pumps

Failure Mode and Effects Analysis

- Failure Mode and Effects Analysis in progress as design activity
- Strainer design includes full penetration groove welds on three sides, fillet weld on fourth side
- Expected result is no increase in probability of failure

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Status

- Modification design
  - Design complete and in review
  - 10CFR 50.59 evaluation in progress
  - Long lead parts/material on order
- Mock-up testing
  - Debris characterization complete
  - Fixture design and fabrication complete
  - All test loops operating earlier this week
  - Complete confirmatory tests this week
  - Complete wear tests in July

Status
(Continued)

- Rotordynamic analysis
  - Preliminary model completed
  - Benchmarking in progress using results of in-plant tests
- Hydraulic analysis
  - Preliminary model/calculation completed
  - Final calculation in preparation based on in-plant test results
- In-plant activities
  - Baseline and worn pump tests completed
  - Both pumps removed and at fabricator for modification
  - Pump re-installation planned for mid-July

Summary

- Modifications and associated analysis and testing are expected to fully resolve debris issue
- Current schedule shows completion to support normal operating pressure test in July

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Closing Comments

Gary Leidich
Executive Vice President - FENOC