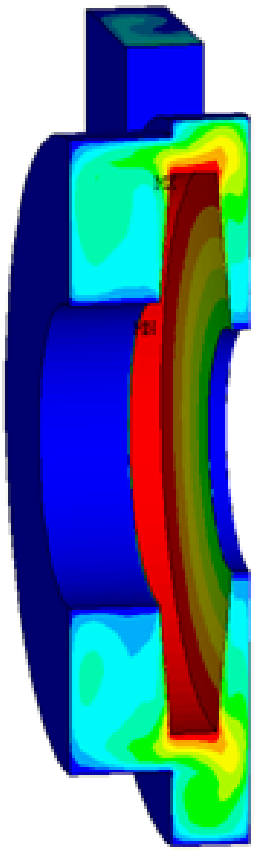
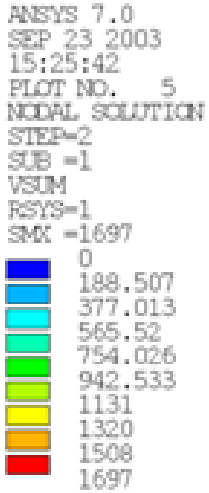
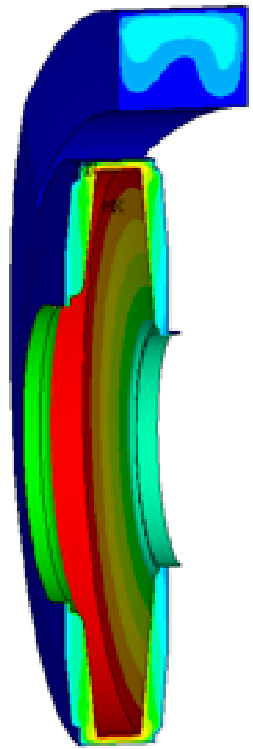
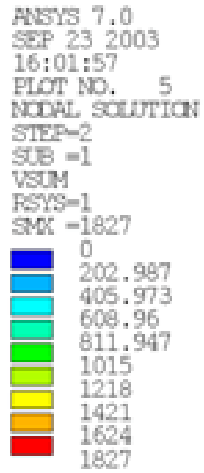
CFD Analysis Results









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

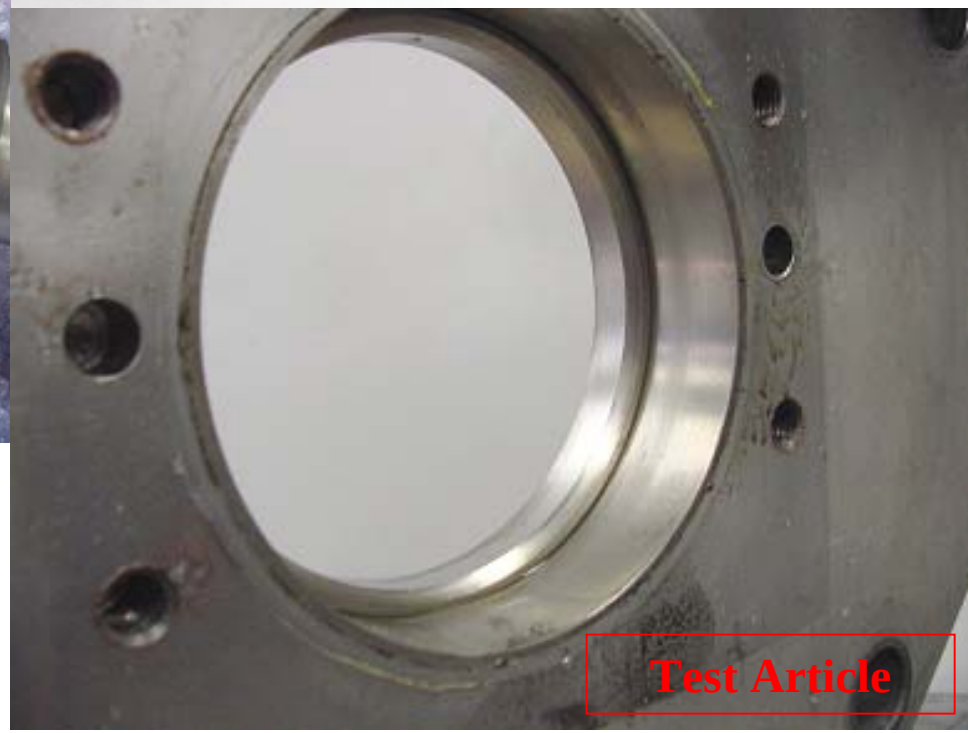
Debris Characterization Analysis

- 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

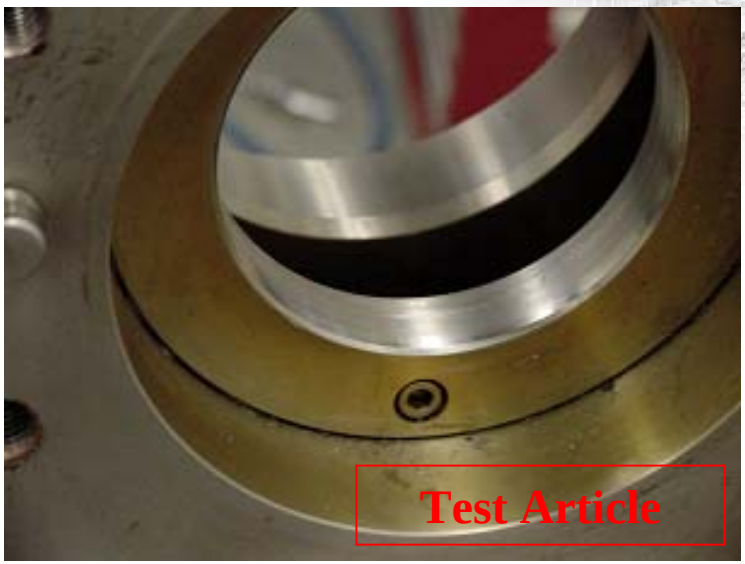
Conservatisms in Analysis

- 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

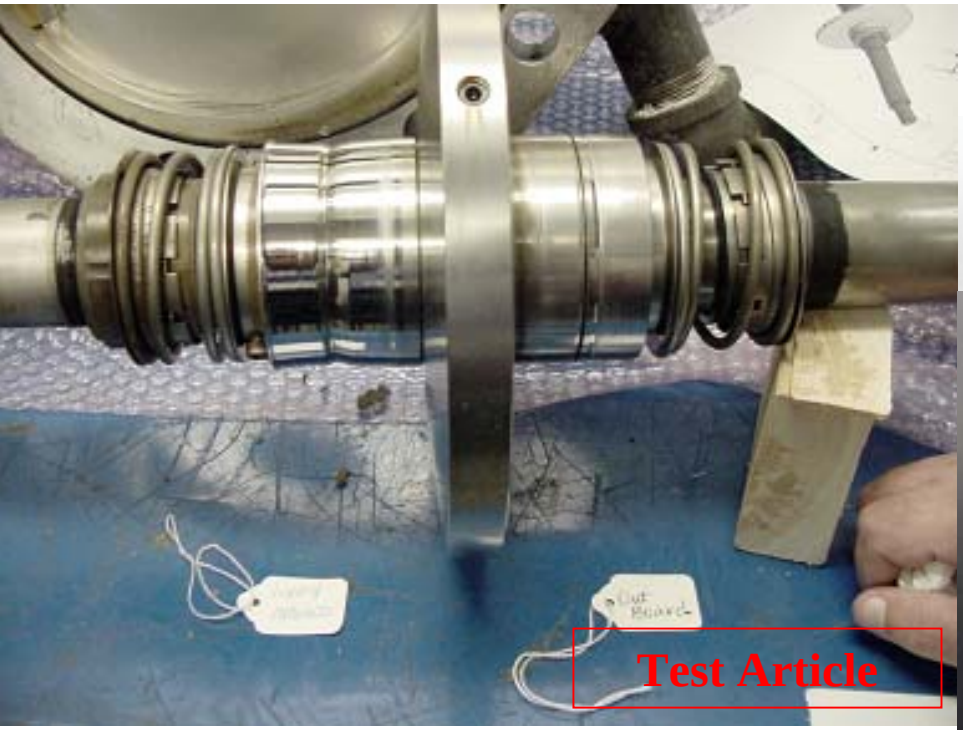
Suction Wear Ring Test Results



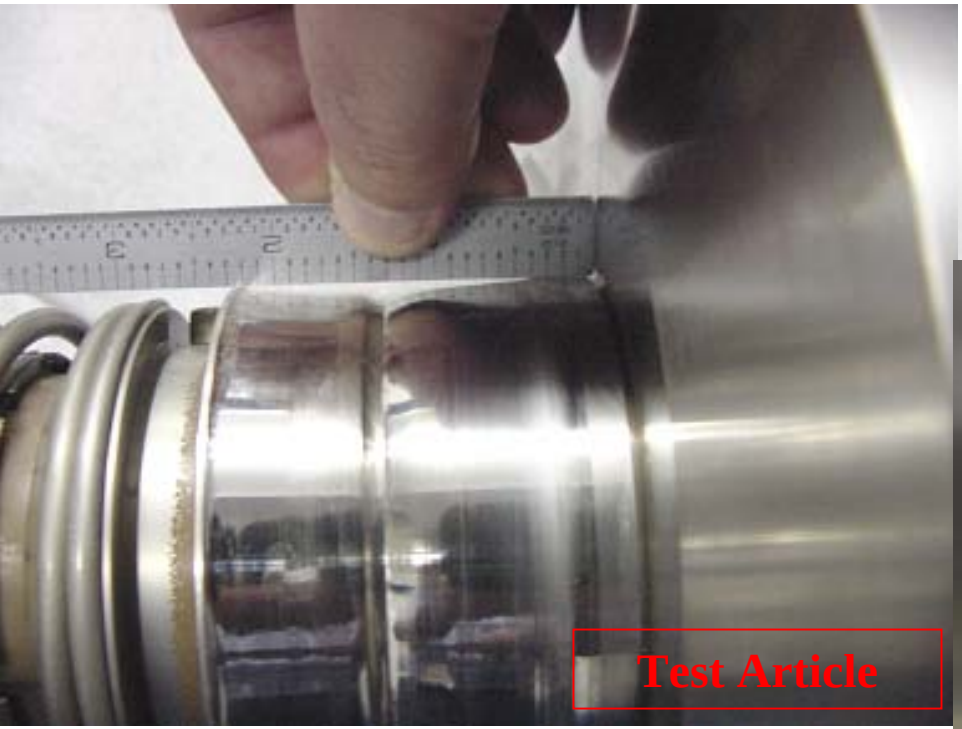
Discharge Wear Ring Test Results

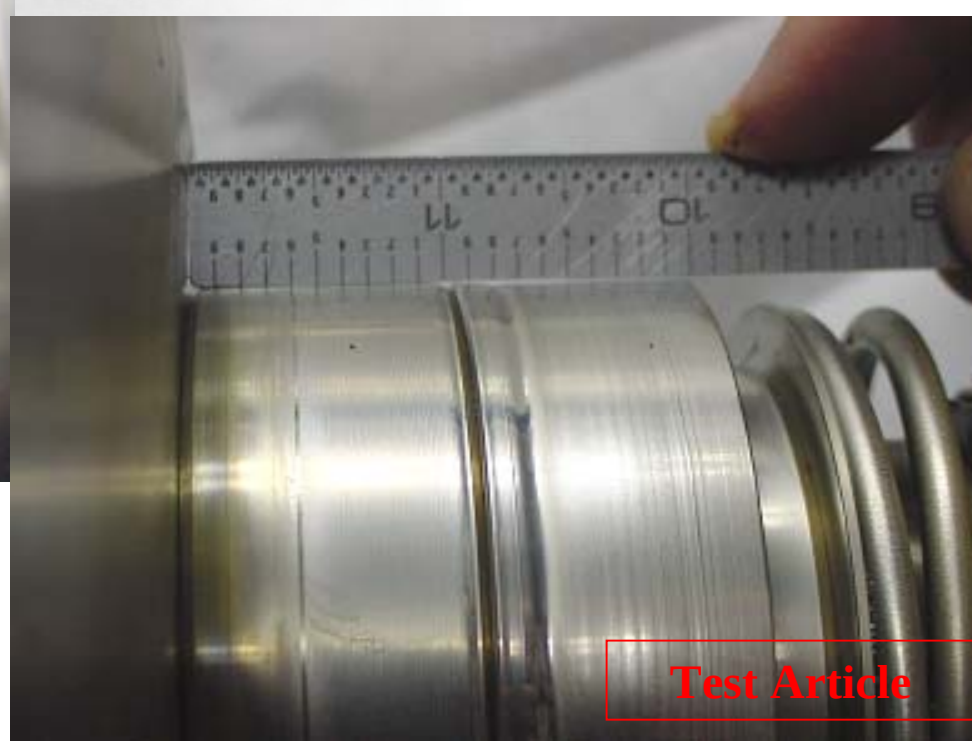


Central Volute Bushing Test Results

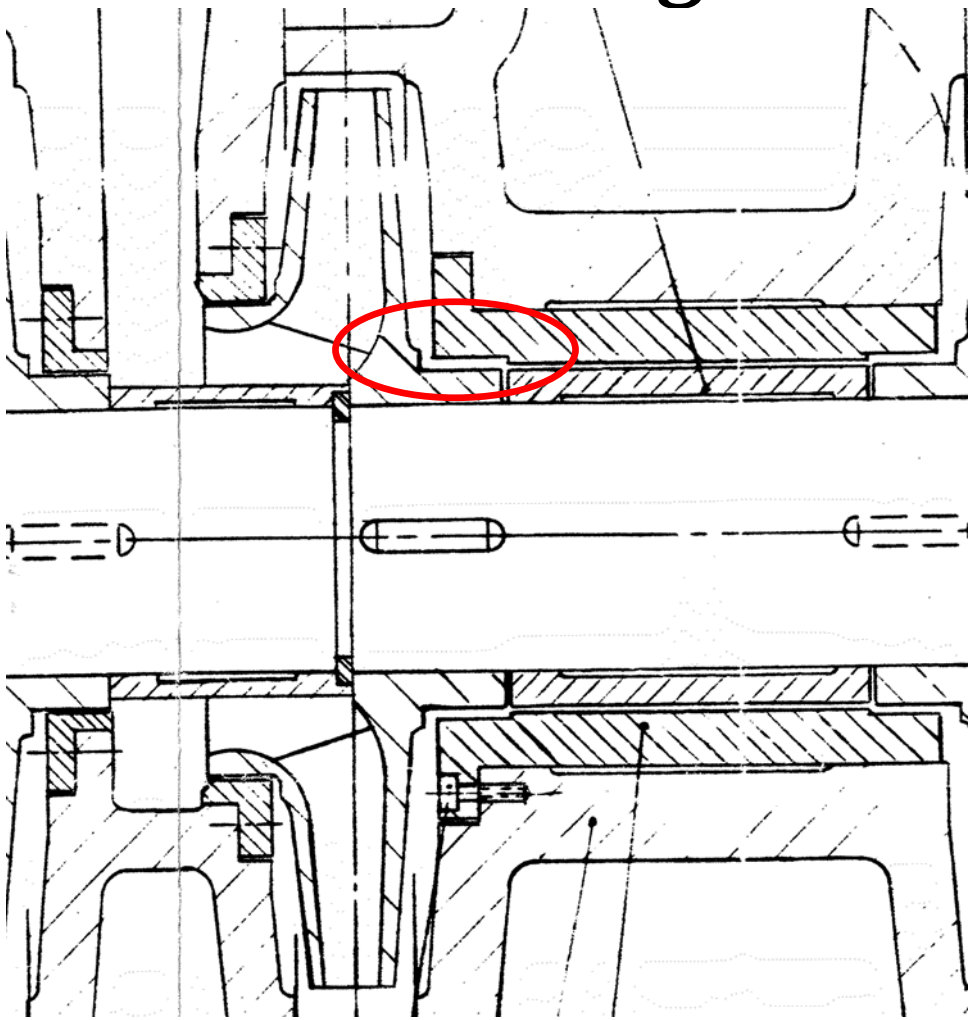


Central Volute Bushing Test Results

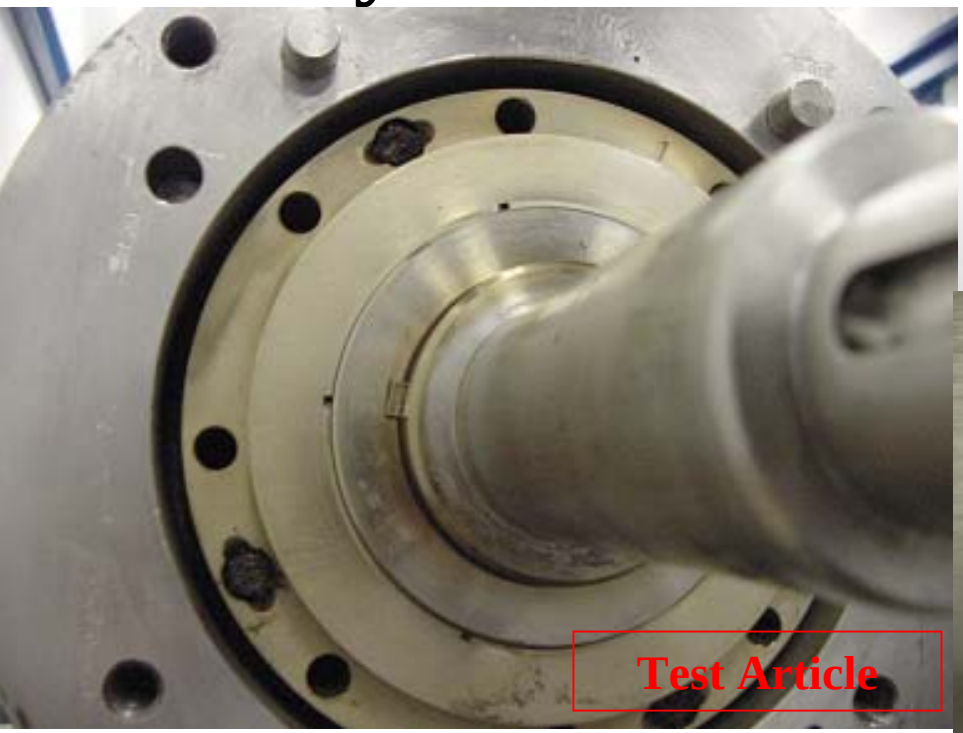




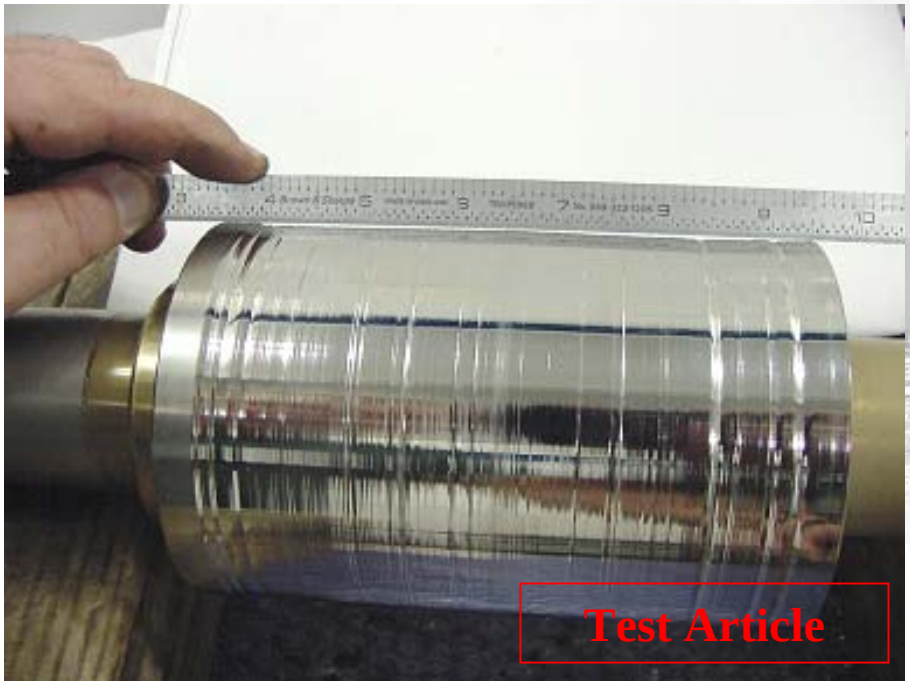
Central Volute Bushing Test Results

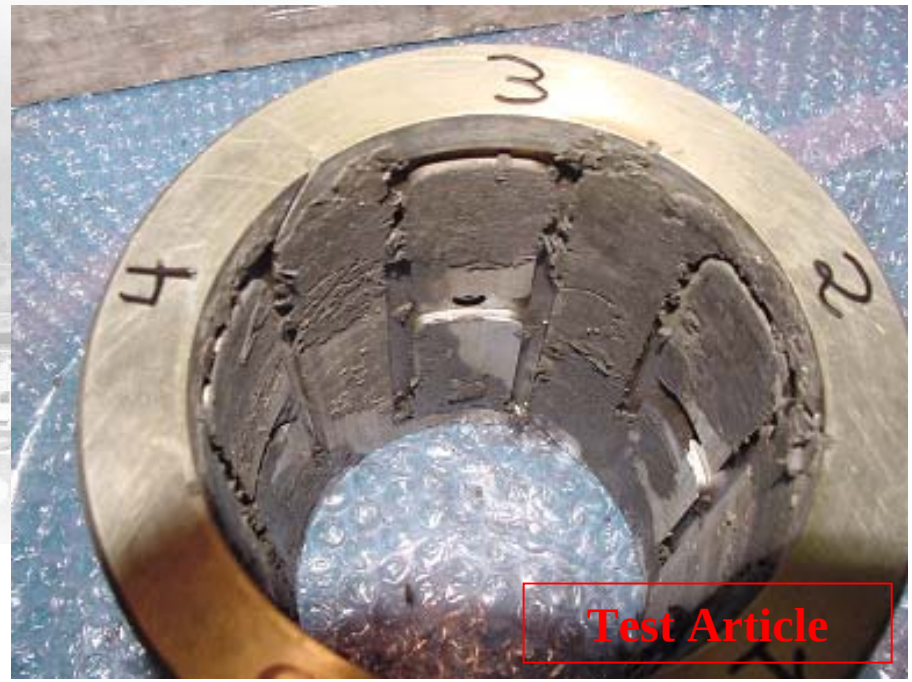


Hydrostatic Bearing Test Results



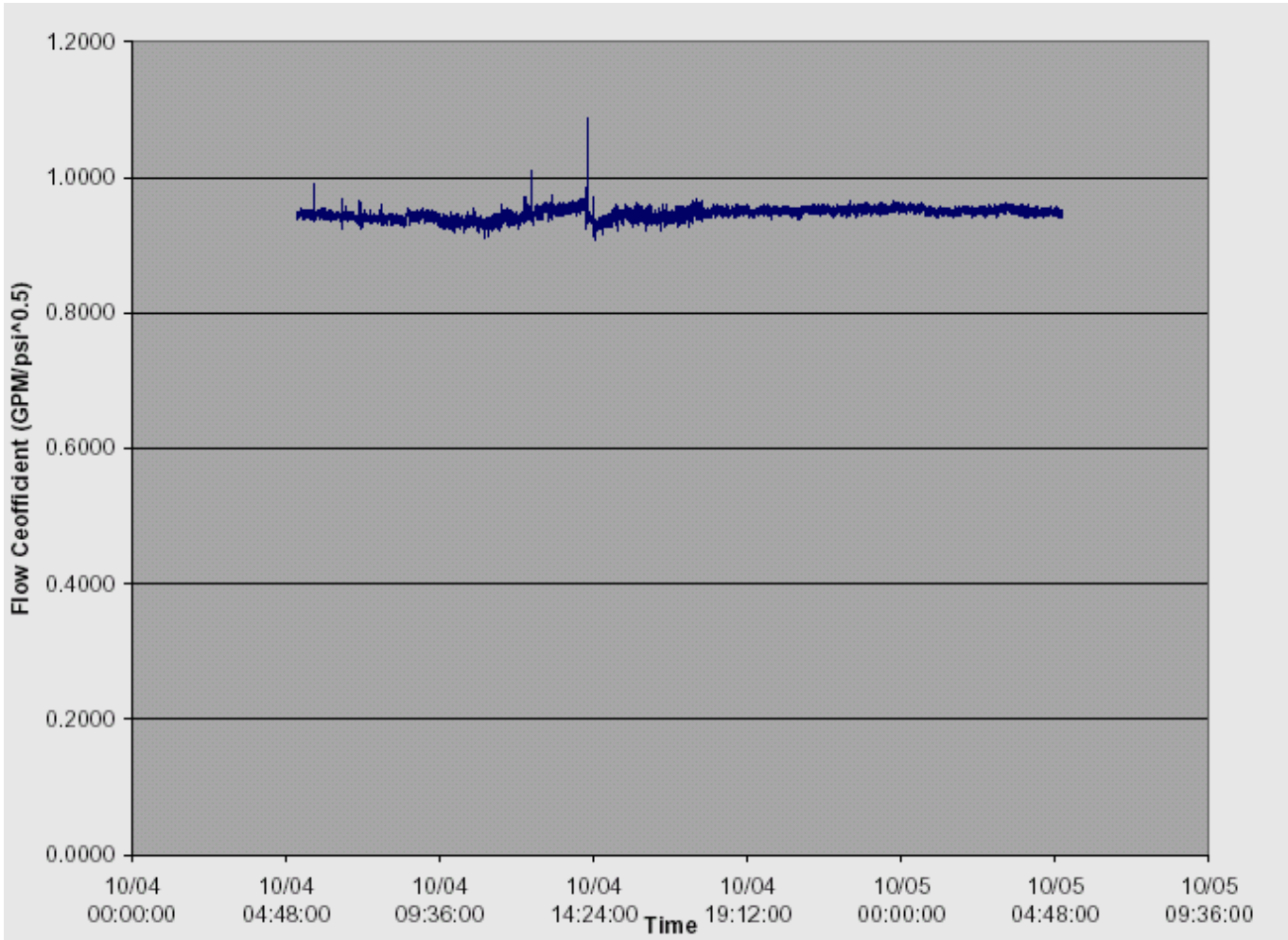
Hydrostatic Bearing Test Results





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

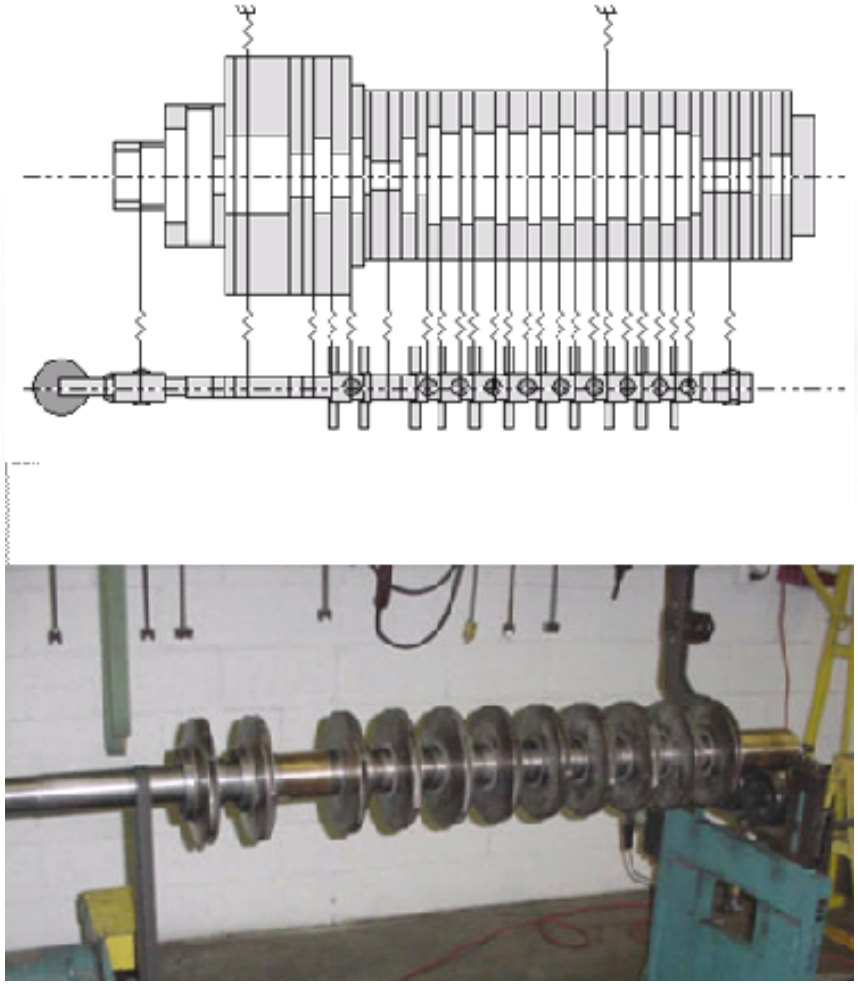
Qualification Testing Results Summary (Continued)

- 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

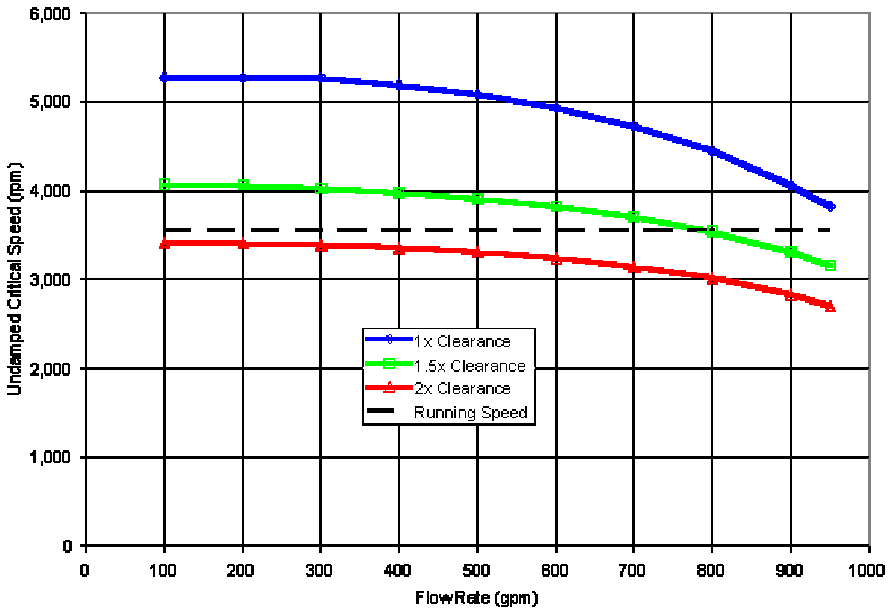
Performance Analyses

- 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

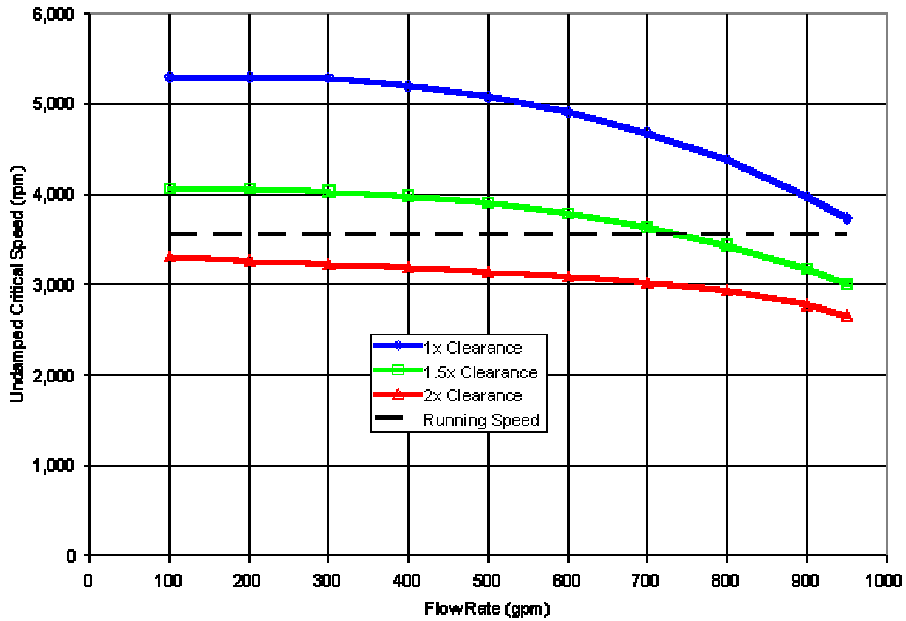
Rotordynamics Analysis Model



Critical Speed Analysis

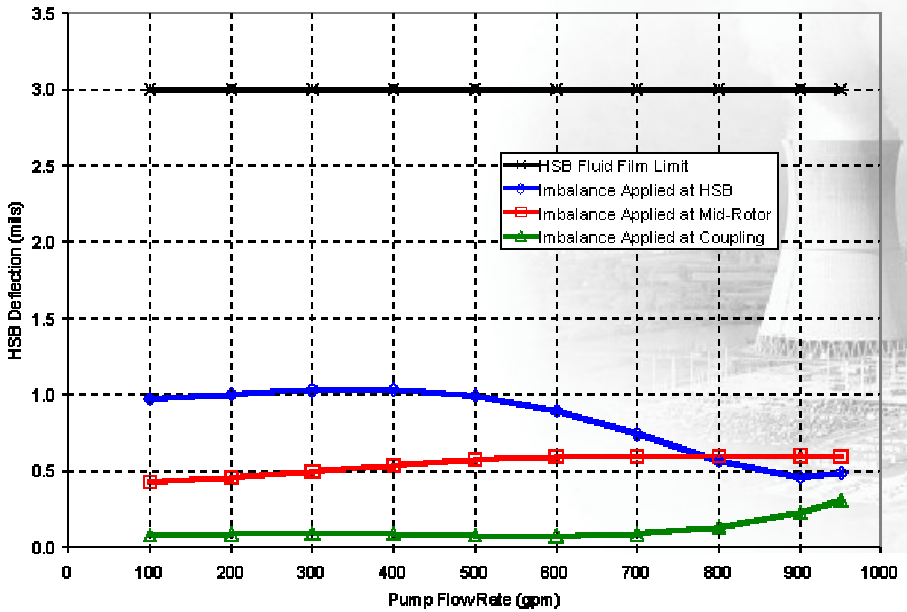


Original Hydrostatic Bearing

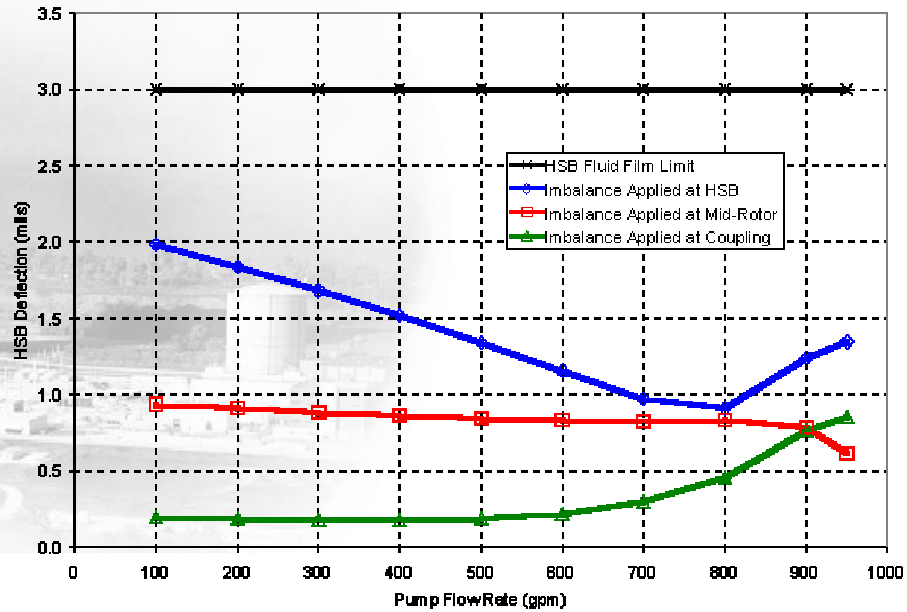


Replacement Hydrostatic Bearing

Forced Response Analysis

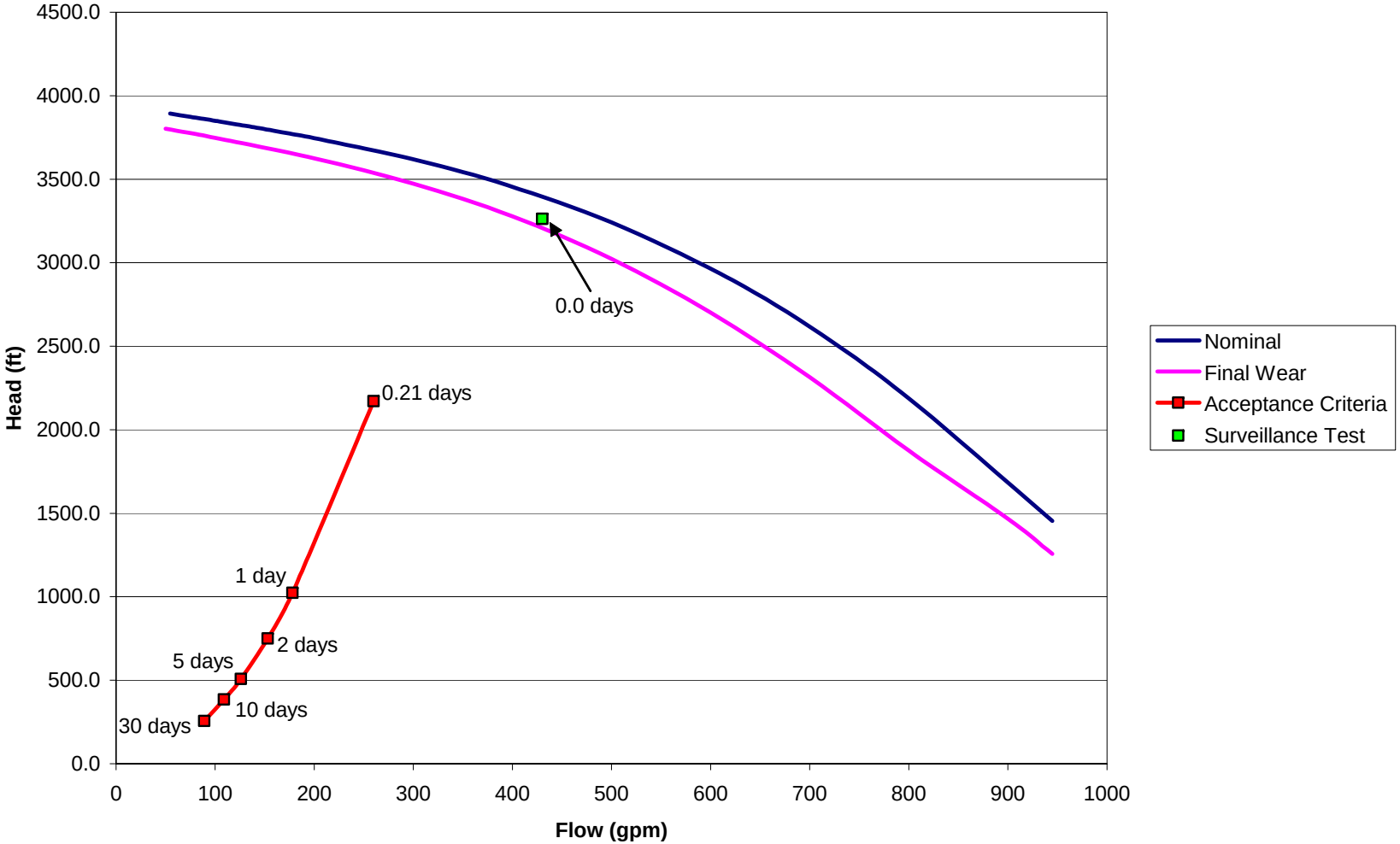


75% Central Volute Bushing Length



50% Central Volute Bushing Length

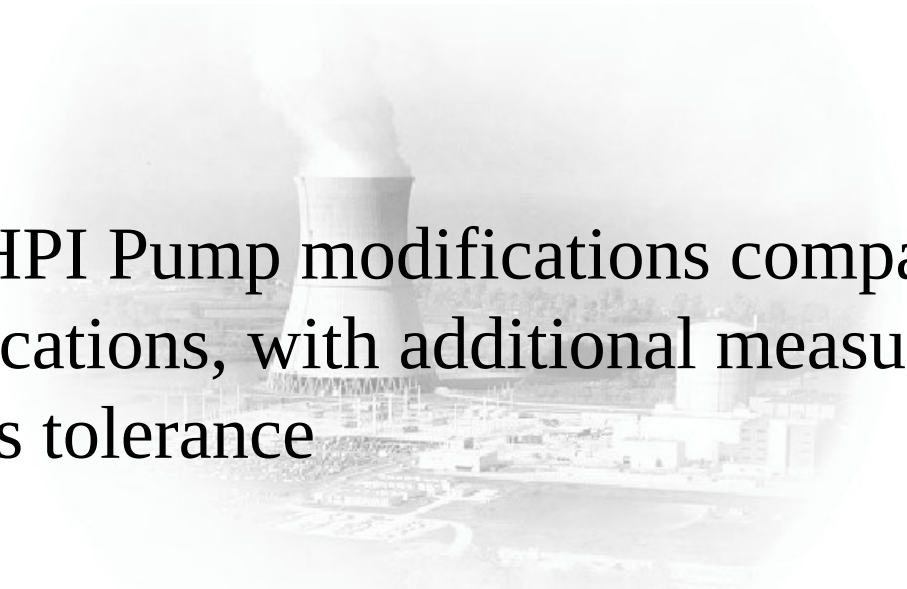
Hydraulic Performance Analysis



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

Concern	Modifications	Testing	Analysis
HSB orifice and pocket plugging	•Installed strainer to filter debris •Moved HSB take-off to low debris location •Included debris escape grooves in HSB pockets	•Mock-up testing of strainer demonstrated adequate flow •Mock-up testing of HSB demonstrated adequate flow	•Completed structural analysis of volute/strainer •Completed HSB hydraulic analysis •FMEA •Completed evaluation of mock-up fixtures
Close clearance wear	•Installed replacement hardfaced parts to minimize wear	•Mock-up testing of new parts determined worn condition •In-plant testing of worn pump demonstrated acceptable performance	•Rotordynamics analysis demonstrated worn condition and new HSB are acceptable •Hydraulic analysis demonstrated worn condition is acceptable

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

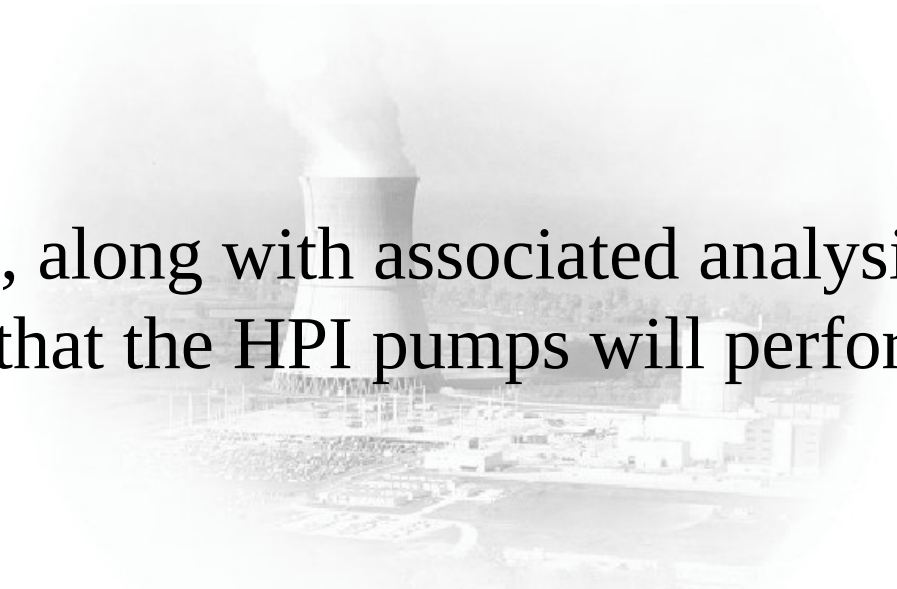
Project Status

- 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

Conclusion



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