



PILGRIM NUCLEAR POWER STATION REGULATORY CONFERENCE

EDG A Cooling Fan Right Angle Drive Gearbox

July 13, 2017

Entergy Representatives

Brian Sullivan	Site VP
Jack Davis	VP, Regulatory Assurance (Fleet)
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OPENING REMARKS

Brian Sullivan

Site Vice President

Pilgrim Nuclear Power Station

Agenda

Opening Remarks	Brian Sullivan
Overview	Dave Noyes
Endurance Test and Vibration Analysis	Tom White
Root Cause Evaluation	Dave Noyes
Corrective Actions	Grant Flynn
Risk Significance	Tom White
Closing Remarks	Brian Sullivan



OVERVIEW

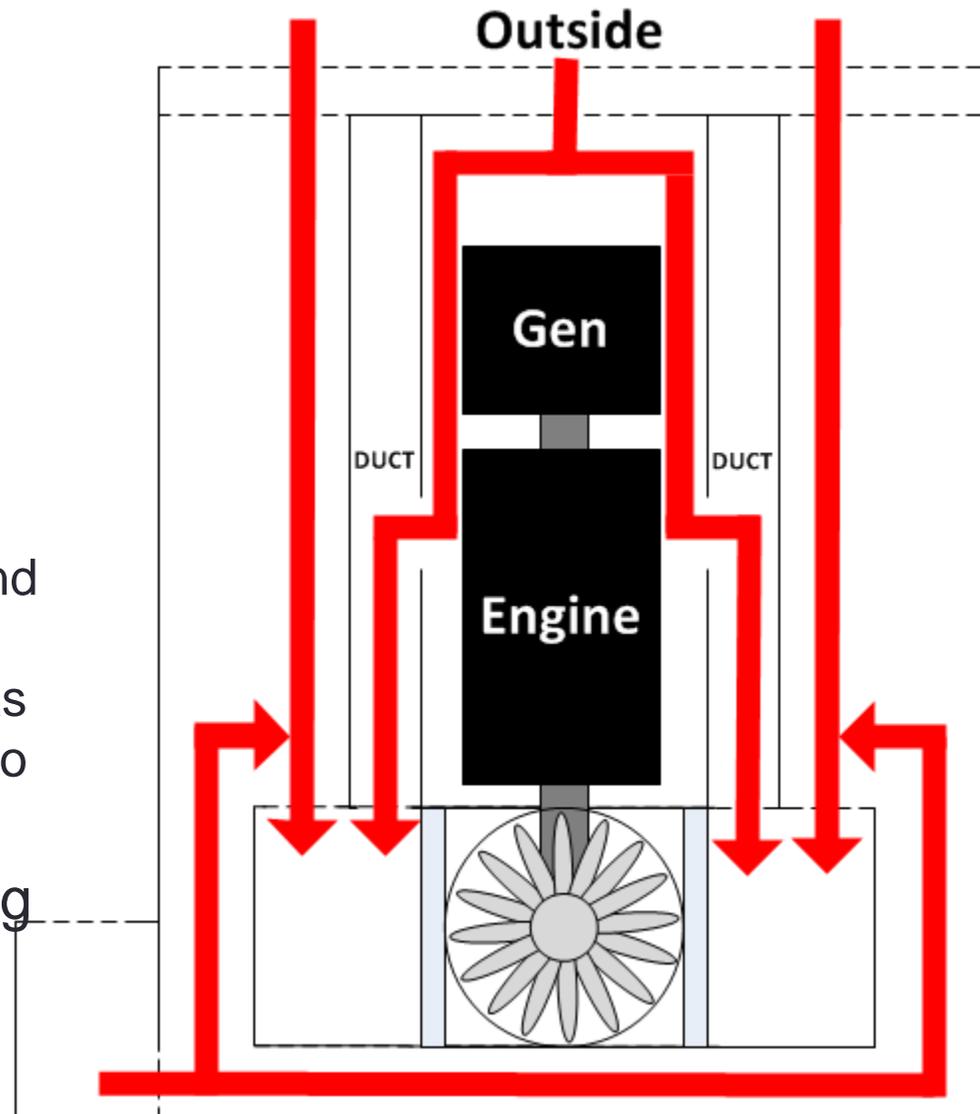
Dave Noyes

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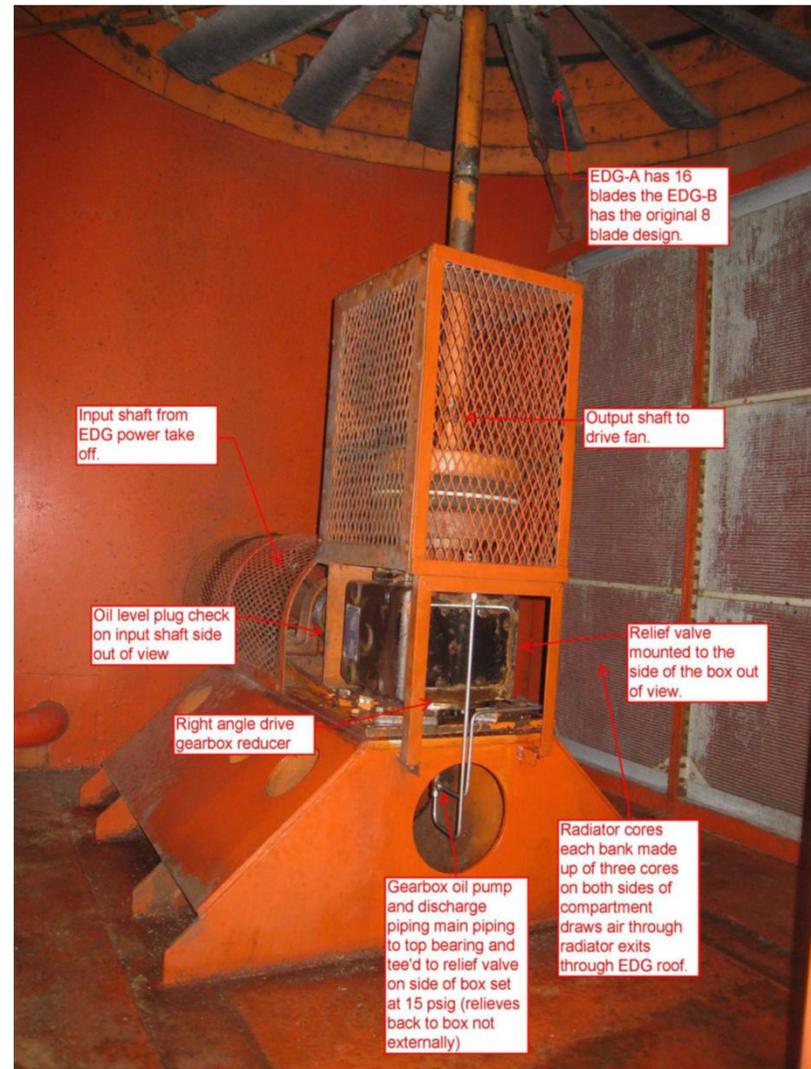
Introduction

- PNPS agrees with the “Design Control” Violation
 - The deficient performance was in 2000 and current design process would have driven a complete review.
 - Recently Endurance Test and Engineering Analysis demonstrate that EDG A was functional at any time prior to September 2016.
- Familiarization with Cooling Fan and Gearbox design.

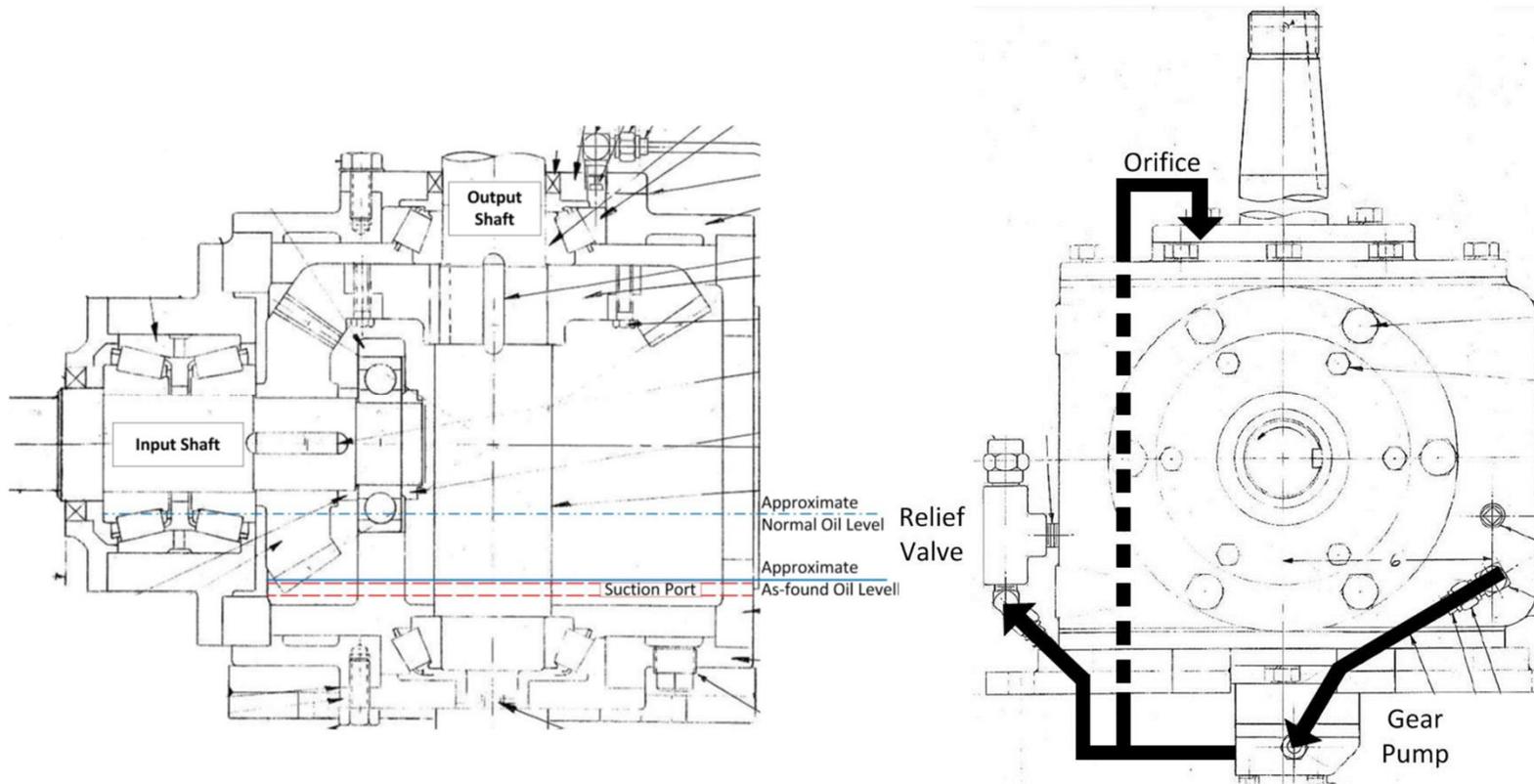


Introduction

- As-found Condition
- Actual picture of EDG-A cooling fan gear box room

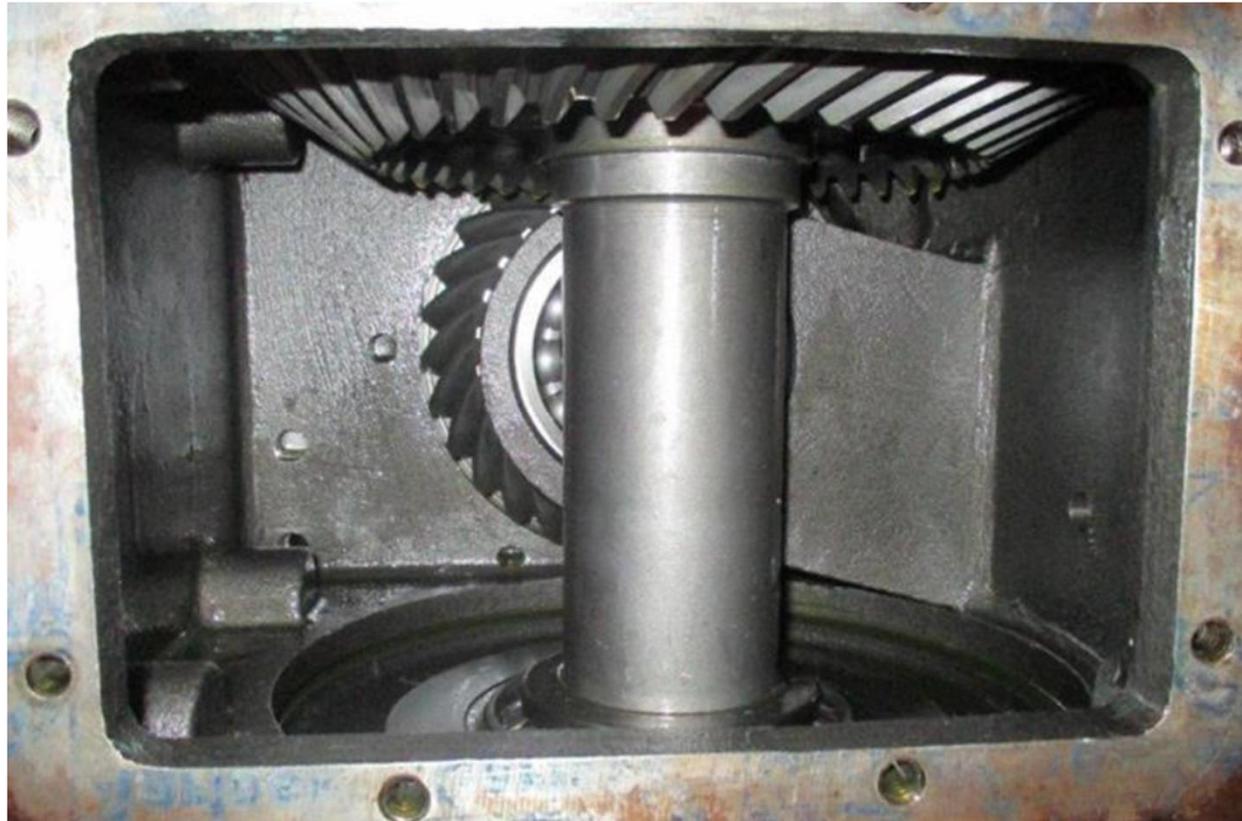


EDG A Cooling Fan Gearbox



Gearbox Internals

Robust design with machined gears



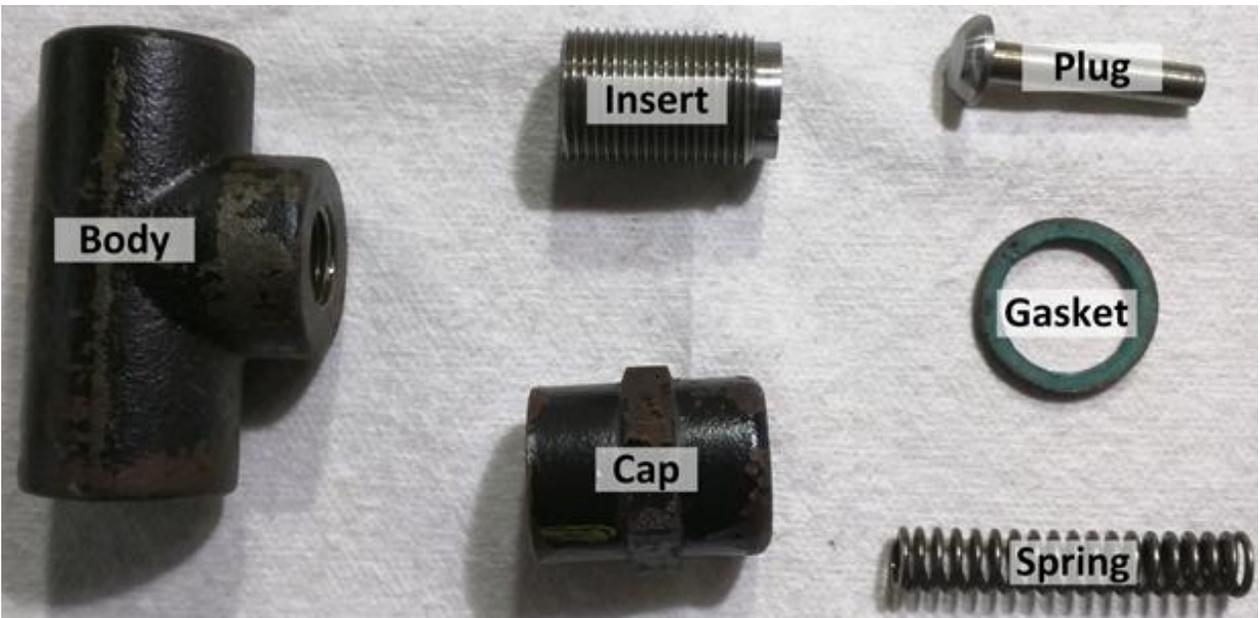
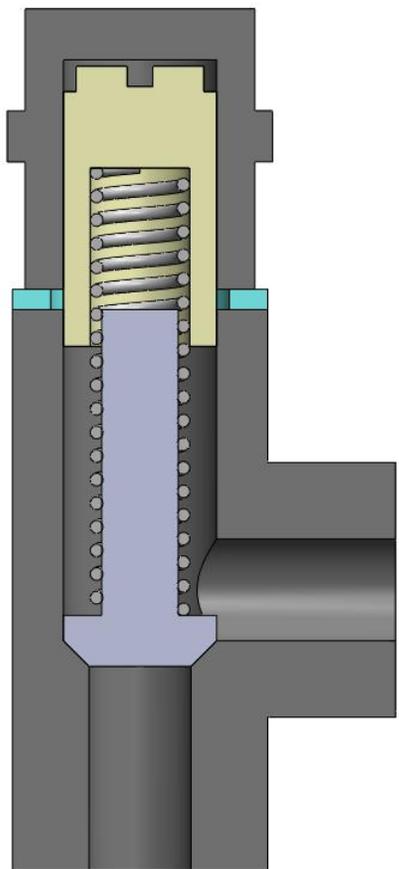
Gearbox Oil Level – Post-Endurance Test

Gear on horizontal shaft always in contact with oil



Relief Valve

Vibration incapable of loosening a properly set RV



As-Found Condition of Relief Valve

Oil lost only during gear pump operation





ENDURANCE TEST DESIGN AND RESULTS

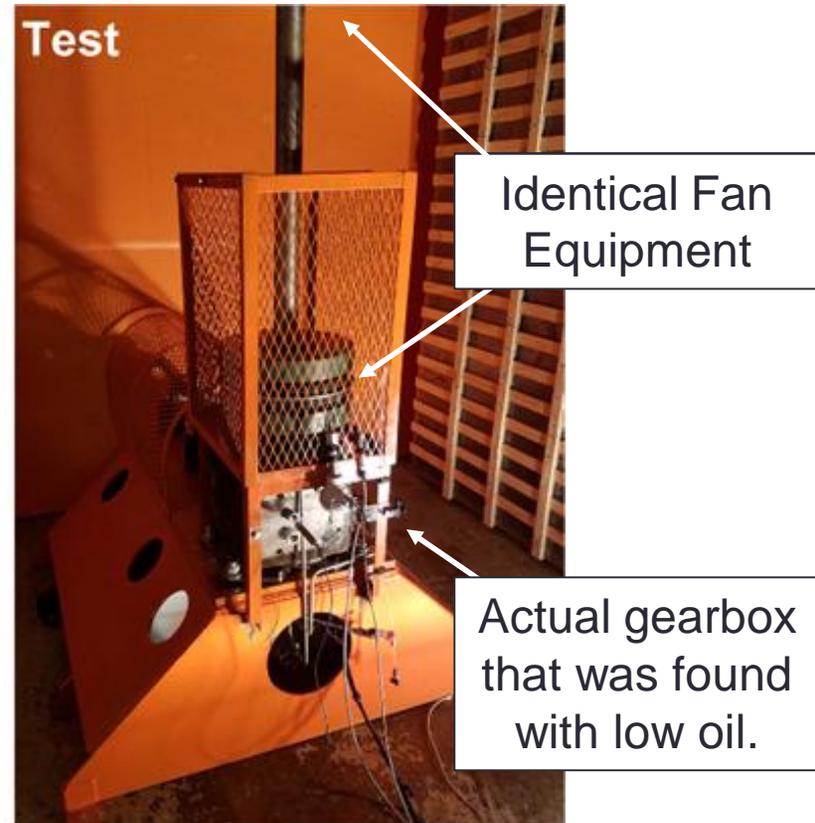
Thomas White

Manager, Design and Programs Engineering

Test Setup

Test setup well represented
actual installation

- Equipment Representative of Air Side EDG-A Radiator System



Test Conditions

Test Conditions well represented actual installation

- System produces conservative air flow conditions:
 - Similar gearbox loading; and
 - Lower convective cooling of the gearbox.
- Gearbox was instrumented to monitor potential signs of degradation:
 - Vibration; and
 - Temperatures near bearings.
- Baseline runs showed similar vibration levels to those measured in the plant.

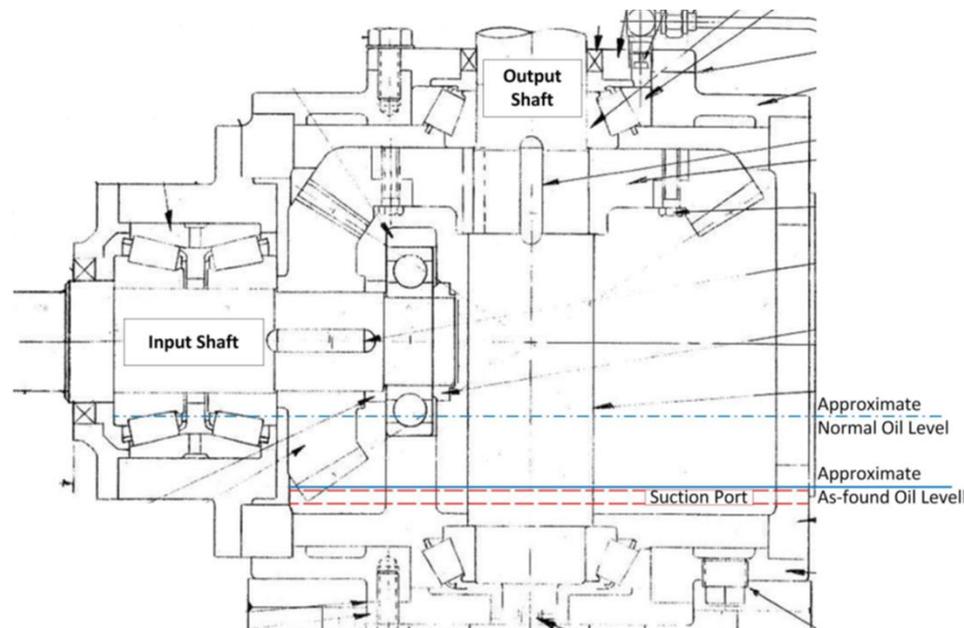
Endurance Test Conditions

- Air temperature bounded possible plant conditions. The temperature was determined for:
 - Highest ambient temperatures recorded on site between August 31 to September 28, 2016
 - Highest accident scenario (LOCA) engine loading
- Relief valve was offset in the as-reported as-found condition, and restrained to bound any condition that could occur.



Endurance Test Conditions

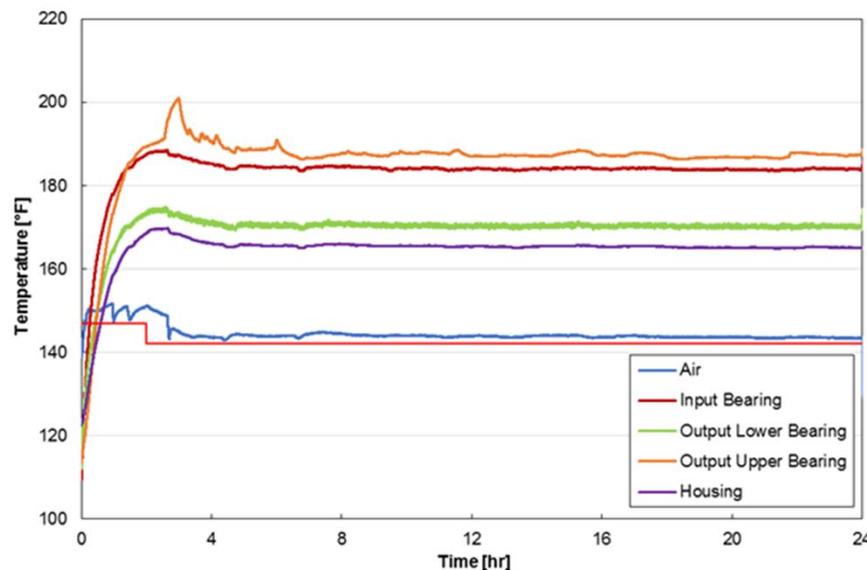
- The initial oil level was at the as-found level observed by the maintenance technicians.
 - Allowed the oil to drain undisturbed for 48 hours prior to testing.
 - Level was well below input shaft bearings.



Endurance Test Temperature Results

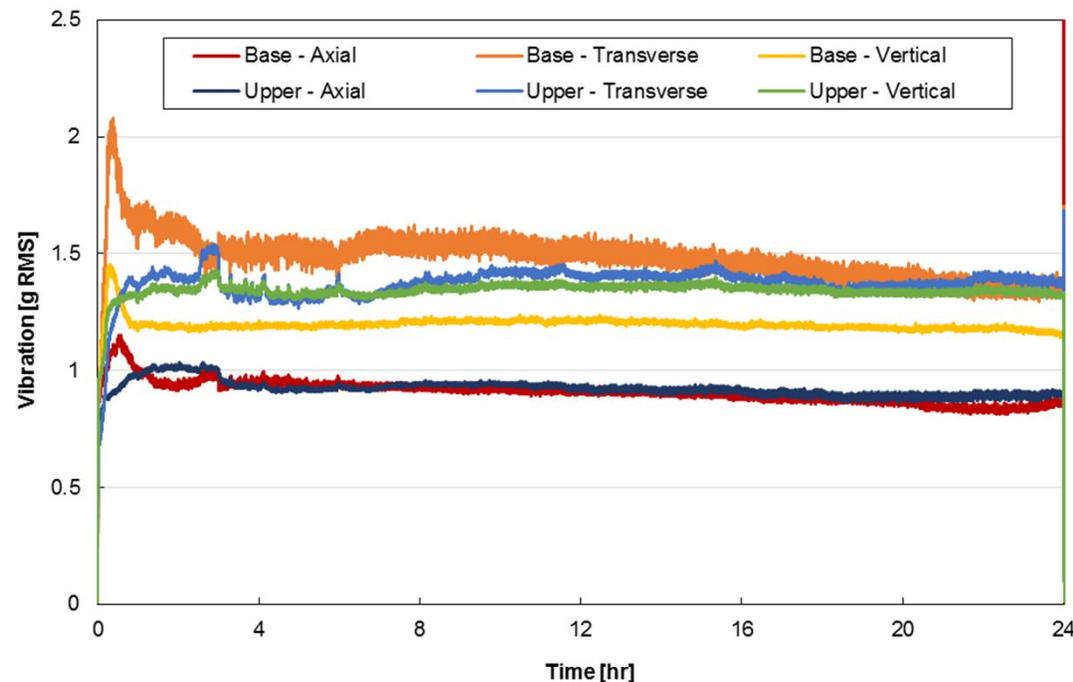
Temperatures remained well below the 300 F limit

- The gearbox successfully performed its function of transmitting power to the fan for 24 hours with low oil.
- Gearbox temperatures reached steady-state values well below manufacturer's damage threshold limits.



Endurance Test Vibration Results

- The gearbox vendor stated that no increase in vibration indicates no equipment degradation
- Gearbox vibrations reached steady state values during testing in acceptable range



Endurance Test Results

- Demonstrated sustainable operation
- Post-test internal inspections showed no visible damage to gear teeth or the roller bearings.
- Gearbox backlash measurements essentially the same before and after testing
- Oil analysis found indicators of small wear particles
 - Less than 5 mils
 - Symptomatic of misalignment
 - The observed wear would not have impacted long term operation.



Endurance Test Conclusions

- Test demonstrates gearbox would have fulfilled its safety function for 24 hours starting at as-found oil level.
- It is concluded that gearbox would have continued to operate with low oil for an extended period of time well beyond 24 hours based on:
 - Stable Test Parameters: Temperatures and vibrations reached steady state values within 6 hours. Temperatures are within manufacturer's design limits. No signs of gearbox degradation could be identified from monitored parameters.
 - Stable Oil Level: Oil leaked from relief valve during first 20 minutes, but no leakage occurred thereafter. All measured temperatures were well below the oil vaporization temperature, and therefore level would not be further reduced by vaporization.

Endurance Test Conclusions (cont'd)

- Post-Test Gearbox Condition: Post-test inspection found no visible damage, and gearbox backlash was not degraded. Analysis of oil after testing found very small (< 5 mils) metallic wear particles. Wear particles identified would not have any detrimental effects on near-term continuous operation.
- Margin in Gearbox Design – Gearbox is designed to transmit ~3x more power than required to drive radiator fan at design conditions.
- Cooling Capacity – High air flow near gearbox results in significant convective cooling which can remove additional heat generated due to low oil operation without significant increase in temperature.
- Oil Chemistry – Lubrication oil used has extra pressure (E.P.) additives that create a permanent oil film on component surfaces, and temperatures did not exceed manufacturer's limit where additives start to break down.

Endurance Test Conclusions (cont'd)

The test demonstrated long-term sustainable performance as evidenced by:

- Stable component temperatures
- Stable oil level
- Consistent low vibration
- Lack of post-test equipment degradation

- It's the opinion of our industry experts who ran the test, based on sound engineering principles and judgement, the gear box could have functioned for much longer than the 24 hour test – 30 days.



ROOT CAUSE EVALUATIONS

Dave Noyes

Director, Recovery

Pilgrim Nuclear Power Station

RCEs 2016-07443 and 2016-09706

- RCE 2016-07443, Rev 1 – Low Gearbox Oil Condition
 - Assess the EDG ventilation gearbox relief valve disassembly and the impact on EDG A functionality/operability
- RCE 2016-09706 , Rev 0 – Programmatic Deficiencies
 - Failure to effectively monitor the gearbox oil level based on a consideration of loss of inventory during testing
 - Introduction of the new failure mode (external relief valve) without appropriate design control considerations
 - Failure to identify, evaluate, and report the presumed loss of safety function associated with the equipment failure analysis

RCE 2016-07443

Root Cause: (Most Probable) An inadequate procedure for directing the gearbox oil pre-start check was the Root Cause.

Contributing Causes:

- Less than adequate training for non-licensed operators on method of verification (manual action) of the oil level in the fan gearbox.
- Inadequate program design of surveillance test for post-cool down inspection of EDG radiator fan room.

RCE 2016-07443 – Extent of Cause/Condition

- The Condition was extended to other safety related equipment with gear boxes with oil levels which could be subject to a low or no oil condition included:
 - High Pressure Coolant Injection (HPCI) Turbine
 - Standby Liquid Controls (SLC) Pumps
 - Control Rod Drive (CRD) Pumps
 - Reactor Core Isolation Cooling (RCIC) Turbine
 - Recirculation Motor Generator Set Fluid Drive Pumps
- The Cause was extended to procedures that provide instructions for fluid verification of safety related mechanical equipment.
- No Similar Issue Identified.

Relief Valve Vibration Analysis

- Analytic Approach
 - A calculation evaluated conservative vibration loading to thread pre-load.
 - Determined with the relief valve at normal set pressure, the insert will not back out due to in-plant vibrations.
- Testing Approach
 - A test monitored the movement of the valve insert and cap under vibrations.
 - Determined with the relief valve at normal set pressure, the insert will not back out due to in-plant vibrations.
 - Determined that the as-found relief valve insert and cap position did not result from in-plant vibrations.

RCE 2016-9706

Root Cause: Effective monitoring of equipment inside the EDG radiator fan room to ensure operability of the EDG was not established due to restricted access to the room for personnel safety concerns with EDG in emergency standby. This caused the condition by preventing identification of the loss of oil from the EDG radiator fan gearbox prior to performing the surveillance test for EDG B, resulting in a loss of safety function for onsite emergency AC power.

Contributing Causes:

- Inadequate work practices during implementation of the design change process in 2002.
- Inadequate implementation of the corrective action program in the proper classification and prioritization of the condition report.

RCE 2016-9706

Extent of Cause/Condition

- The Condition was extended to other Tech Spec auxiliary electrical equipment that may be inoperable for reasons other than low oil level.
- The Cause was extended to effective monitoring of other safety-related systems whose failure could result in the loss of a safety function.



CORRECTIVE ACTIONS

Grant Flynn

Senior Manager, Operations

RCE 2016-07443 – Corrective Actions

- On September 28, 2016, after identifying the low oil condition:
 - Drained oil and internally inspected gearbox visually; with no damage identified.
 - Reassembled, bench tested and set the relief valve at 15 psig and refilled the gearbox with new oil. The monthly Surveillance Test was then successfully completed.
- Pre-start check procedure changed to provide additional guidance on how to validate the gearbox oil level.
- Non-licensed operator trained on gearbox oil level validation method.

RCE 2016-9706, Corrective Actions

- Establish an effective method to monitor equipment inside the EDG radiator fan rooms to ensure reasonable assurance of equipment operability when the EDGs are in emergency standby or in operation. Revise procedures to incorporate the established method to monitor equipment inside the EDG radiator fan rooms
- Perform an 50.59 Process Applicability Determination for the addition of the EDG fan gearbox relief valve to determine whether a full 50.59 evaluation is needed.
- Perform an assessment of completed minor modifications intended to accommodate component replacement with an engineering evaluated equivalent component to determine if any new failure mode was introduced but not properly recognized or evaluated.



RISK SIGNIFICANCE

Thomas White

Manager, Design and Programs Engineering

Key Risk Assessment Differences

Preliminary

- In the as-found condition the EDG was not functional and would have failed to run for its 24 hour PRA mission time.
- The disassembly of the relief valve was due to normal engine vibrations, and as such the exposure period extended to March 2016.
- Risk Significance dominated by Lower Switchgear Room fires which were assumed to cause a non-recoverable LOOP with reliance on the A5 bus, which would lead to core damage if the EDG A failed.
- Did not credit FLEX Action to Charge Batteries following an ELAP

Current

- The Endurance Test provided compelling evidence that the EDG A would have operated for at least the 24 Hour mission time prior to September 28, 2016.
- Engineering Vibration evaluation showed that if the relief valve was at its setpoint with the cap installed vibration could not cause the disassembly.
- Best Estimate is that this condition is of very low safety significance, with the only increase in CDF being due to the time EDG A was out-of-service to evaluate and correct the low oil level.

SAFETY SIGNIFICANCE SUMMARY

- Best estimate result is very low safety significance, limited to the increase associated with EDG A unavailability for evaluating and correcting the low oil level condition
- Sensitivity analysis using PNPS PRA model determined very low safety significance, using an EDG A failure rate 10 times normal and a one month exposure period.



CLOSING COMMENTS

Brian Sullivan

Site Vice President

Pilgrim Nuclear Power Station

Summary

- We agree with the violation.
- EDG A was always functional (24-hour PRA mission and likely full 30-day mission time)
- This condition is of very low safety significance, with the only increase in CDF being due to the time EDG A was out-of-service to evaluate and correct the low oil level