Initial Root Cause / Significance Determination Plan

Recirculation flow on pumps AFP-38A & B degraded from 75 gpm to 65 gpm and 68 gpm, respectively. The diminished flow on AFP-38A flow rate was observed after ~11 minutes of run time during a post-maintenance test run. AFP-38B decreased recirculation flow rate was observed immediately after pump start following removal, inspection, and re-installation of the recirculation flow control orifice.

Task

1) Determine the physical cause of the reduced flow
2) Determine whether or not this cause could challenge the design basis functions of the AFW system. This includes:
    a. Whether the cause is/was sufficient to render an AFW pump immediately inoperable
    b. Whether the cause, if uncorrected, would continue to degrade the recirculation flow rate to the point of pump inoperability, and
    c. Whether the cause represents a common mode failure challenge to the system.

Failure Mechanisms Considered

- Plugging of orifice holes by foreign materials
- Scaling induced blockage of orifice holes (system internal debris/corrosion products)
- Check valve plug cocking
- Flow reductions due to other in-line components
- Erroneous flow instrumentation

Approach

1. Identify & evaluate all credible causes of recirculation flow rate degradation and identify supporting or refuting evidence for each.
    a. Plugging with hematite coming from backflow of particulate laden SW through leaking AF4009 concurrent with leaking SW129 or SW130 (cross ties between clean condensate and Service Water for AFW pump suctions).
        i. Chemistry results for samples taken at AFW pump suctions to detect SW inleakage over the last two fuel cycles.
        ii. Chemistry analyses of CST for past two cycles
        iii. Review event details of inadvertent opening of AF4009 and subsequent injection of SW into CST or Steam Generators. (two known historical events)
    b. Plugging with hematitie coming from standing water in bottom of AF pump body flushed into discharge line during post maintenance test.
        i. Maintenance history of this pump in which the system was open to the atmosphere (thereby allowing formation of hematite).

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ii Calculate the maximum possible volume of particulate in the undrained portion of the pump case below the casing drain(s).

c. Plugging with hematite originating from manipulation of the carbon steel vent valves (AF 33A and 33B) located in the pump discharge piping. This may cause dislodging of particulates into the AF pump discharge line which then pass to the recirculation line.
   i. Confirm valve material.
   ii. Frequency of manipulation of these valves.
   iii. Boroscope of the valve area.

d. Mechanical blockage due to cocked piston in check valve AF0015
   i. Radiograph of valve assembly during operation and while not running.
   ii. Contingency: Disassembly of valve and search for chatter marks or scuffing indicating valve has cocked previously.

e. Mechanical blockage due to partial opening (vs full opening) of AOV AF-4007
   i. Review available information to confirm/refute full stroking of valve. Perform additional testing if necessary.

f. Plugging due to foreign particulate matter direct from Water Treatment entering AF suction piping during post maintenance test.
   i. Water Treatment system lineup and operating status (with respect to CST filling operation) during post maintenance test run and previous test runs.

g. Plugging due to scaling of orifice over time
   i. Minimum required recirculation flow necessary to ensure continued AFW pump operability
   ii. Calculation of the amount of blockage in the orifice needed to reduce recirculation flow below minimum requirements
   iii. Calculation (using zeta potential) of time necessary to achieve the level of blockage required to reduce recirculation flow below design bases requirements due to both corrosion product and silt/sediment fouling.
   iv. Review of historic recirculation flow rates, particularly during post maintenance testing.

h. Other possibilities that can cause an increase flow resistance, including formation of hematite (oxygenated atmosphere)
   To be determined RESIN BEADS FROM CST?

2. Contingencies for those causes that are not eliminated: analytically determine the bounding conditions that would result in AFW inoperability and compare those conditions with the actual conditions found in the system.
   a. For increased flow resistance due to particulates in the orifice determine the shearing forces in comparison to structural characteristics of possible particulate matter
      i. Calculation of shearing force as a function of orifice geometry (press & temp) and recirculation flow rate.
      ii. Structural analysis of particulates recovered from the system.

b. For increased flow resistance due to fouling determine the zeta potential of the particulates and the maximum layer thickness. From this, determine the corresponding impact on recirculation flow degradation.
    i. Analyze sample of particulate from orifice for zeta potential, or determine zeta potential from structural analysis of particulate sample.
    ii. Calculation of the amount of blockage in the orifice needed to reduce recirculation flow below design bases requirements.
c. Using the design basis assumptions for a seismic event, determine the particulate matter density distribution in the CST and its impact on recirculation flow rates as a function of the blockage of the orifice.
    i. Design basis assumptions for relevant seismic event.
    ii. Calculation of particulate dispersion during design basis seismic event.
d. Using as-found dimensions on check valve AF0015 calculate potential for "cocking" of the piston, and determine the bounding conditions for the worst-case cocking of the piston.
    i. Determine as found dimensions of check valve AF00015 internals.
    ii. Perform flow rate calculations with a cocked check valve – one for as-found condition and the other for bounding calculation

Schedule

Lab Analyses, model building, data gathering	2 weeks *	Nov 5-19
Running model with data	1 week	Nov 20-27
Writing report	1week	Dec 2-6

* This is an estimate. Due to the lack of ample sample material the laboratory tests will have to be performed in sequence. Therefore, the duration of all laboratory tests may be extended due to scheduling issues.