

### What happened?

In February 2021, loss of voltage during maintenance on the governor system increased hydraulic pressure in the accumulator to 4344 kPa (overpressure).

During investigation, an unrelated design flaw was discovered in the governor.

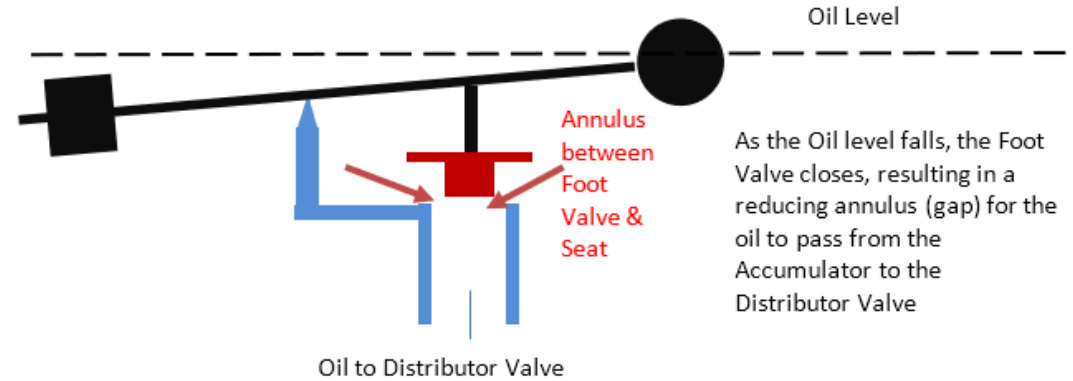
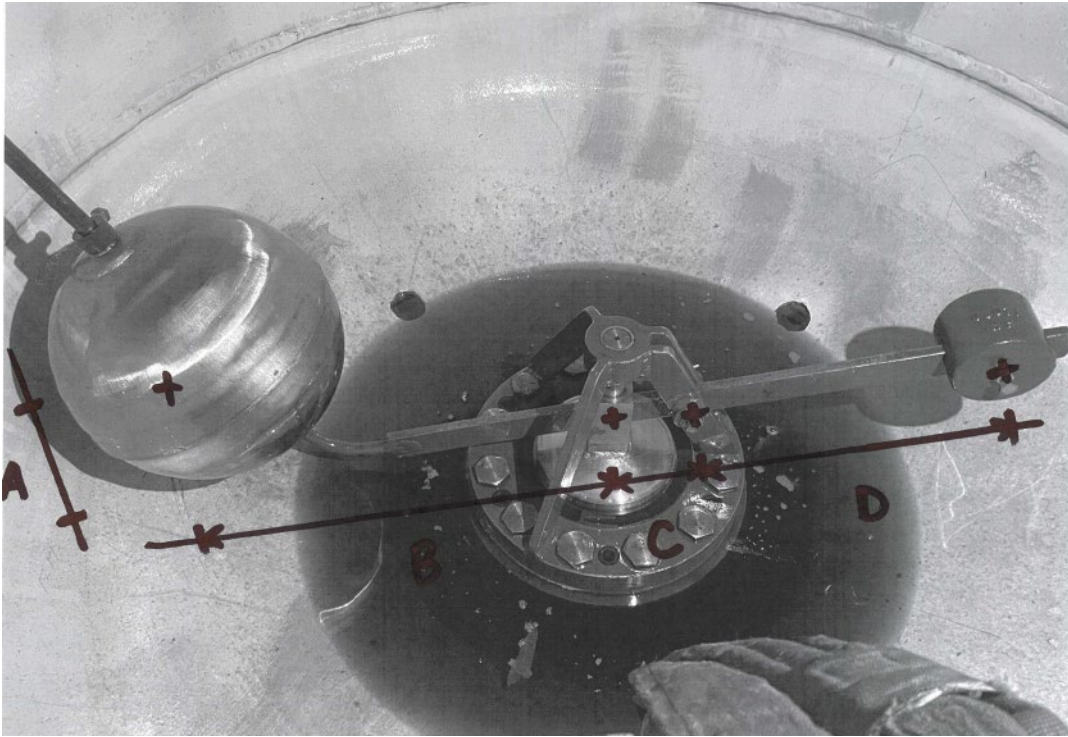
If the unit tripped due to low oil level or low oil pressure in the accumulator, the accumulator foot valve would close prior to wicket gate closure. Therefore, wicket gates would not close as intended during the trip.

This system vulnerability was introduced during upgrades in 1999–2000 and was undetected in our system until now.

### What did we learn?

- The original governor system was upgraded to a digital governor system in 1999–2000, with a few changes in functionality. Initially, some oil for closure of the wicket gates was supplied from the bypass valve servo as the bypass valve opened (this no longer occurs).
- When oil level in the accumulator is low, we discovered there is a discrepancy of 70mm between the actual and theoretical levels for when the foot valve closes, due to dynamic oil flow effects.
- We also discovered the available oil did not meet IEEE 125:2007 requirements to have at least 150% of the closing oil volume available when low level trip initiated.
- In addition, there was significant delay (about 95s) in the indication of oil levels in the accumulator, both in level transducers and in the OEM installed gauge glass.
- In the event of a low oil level/pressure trip, the governor system would be ineffective and only headgate closure would prevent Loss of Control or an overspeed event.
- Our engineers have proposed a set of changes to rectify these issues.
- It is unknown whether the full implications were considered or understood by the project team in 1999–2000. This has highlighted the importance of fully documenting plant changes and system vulnerabilities for the sake of posterity.

## Explanation for early valve closure



As the Oil level falls, the Foot Valve closes, resulting in a reducing annulus (gap) for the oil to pass from the Accumulator to the Distributor Valve

The most credible explanation:

- Oil exits the hydraulic accumulator through a foot valve with a float that controls opening and closing of the valve.
- As the oil level falls sufficiently so that the float begins to drop, the annulus (gap) through which the oil exits is reduced in size.
- The wicket gates close at constant speed, therefore a constant flow of oil is now travelling through a decreasing area. Oil velocity increases, which in turn lowers the pressure under the closing valve. Eventually, the pressure difference under the valve overcomes the buoyancy of the float and the foot valve closes early.
- Oil flow is cut off, and pressure within the accumulator keeps the valve closed.
- There is 70mm discrepancy between actual & theoretical levels for valve closure.