
Unit #5 and Unit #6
Head Cover Erosion
Repair Project



PUGET
SOUND
ENERGY

About Puget Sound Energy

- Washington State's oldest local energy company.
- PSE is a combined electric and gas utility serving customers in 10 counties.
- 1.1 million electricity customers.
- 760,000 natural gas customers.

About Puget Sound Energy



- Combined electric and natural gas service
- Electric service
- Natural gas service





Snoqualmie Hydroelectric Project

- Powerhouse #1 originally constructed in 1898 with four Pelton units, then it was expanded in 1904 to add a 5th unit.
- Powerhouse #2 first constructed in 1910 with the installation of Unit #6, a horizontal Francis unit, then was expanded in 1956 to include Unit #7, a vertical Francis unit.
- Total generating capacity of 44.4 MW.



Snoqualmie Redevelopment Project

- Extensive 5 year project to upgrade all major project features including both Powerhouses, the Diversion Dam and the Gatehouse.
- Creation of a new “historic district” including both a Museum and Depot where antique parts from the original Powerhouses are on display.
- Complete removal and replacement of Units #5 and #6.
- Total generating capacity increased to 54.4 MW.

The New Unit #5 and Unit #6

- Unit #5 – 6.75 MW
- Unit #6 – 14.4 MW



Unit #6 Head Cover Erosion

- February 2013 – the new Unit #6 was commissioned.
- March 2014 - An unexplained RTD failure for the upper stationary seal ring. Water was encountered when attempting to replace the RTD which was installed in a thermowell.
- The wear pattern on both the RTD and the thermowell suggested physical contact with the crown of the runner.



Unit #6 Head Cover Erosion

- April 2014 – Initial borescope inspection through the RTD hole in the head cover with inconclusive results, couldn't locate physical damage on the runner crown.
- October 2014 – Cavitation warranty inspection of Unit #6, the extent of the erosion damage to the head cover and upper stationary seal ring is fully realized.

Unit #6 Head Cover Erosion



Unit #6 Head Cover Erosion

- 7,130 total operating hours prior to cavitation warranty inspection.
- Stationary upper seal ring - Nickel Aluminum Bronze (B271, C95500).
- Rotating upper seal ring – Stainless Steel (A182, grade F6NM).
- Unit #6 immediately removed from service and negotiations were initiated with the turbine supplier.

Unit #5 Head Cover Erosion

- Commissioned in October 2013.
- October 2014 – Initial inspection of Unit #5 head cover due to the erosion conditions discovered on Unit #6. Total accumulated operating time was 5,545 hours, the upper seal ring clearances were found to be within specification and some erosion was noted on the plugs for the upper seal ring inspection ports.
- January 2015 – A hole appears through the Unit #5 head cover, total accumulated operating time was 7,397 hours.
- The head cover is fabricated from 1” thick A-36 carbon steel.

Unit #5 Head Cover Erosion



Unit #5 Head Cover Erosion

- Severe erosion around the entire circumference of the head cover immediately adjacent to the upper stationary seal ring.



Head Cover Erosion – Historical Lesson

- The original Unit #5 was built by Platt Iron Works and it was a very early Francis turbine design with virtually no replaceable wear surfaces within the water passage.



Head Cover Erosion – Historical Lesson

- By 1939, replaceable wear surfaces had been retrofitted to many parts of the original turbine, including:
 - Wicket gate facing plates.
 - Upper and lower stationary seal rings.
 - A cover plate that was attached to the underside of the head cover.

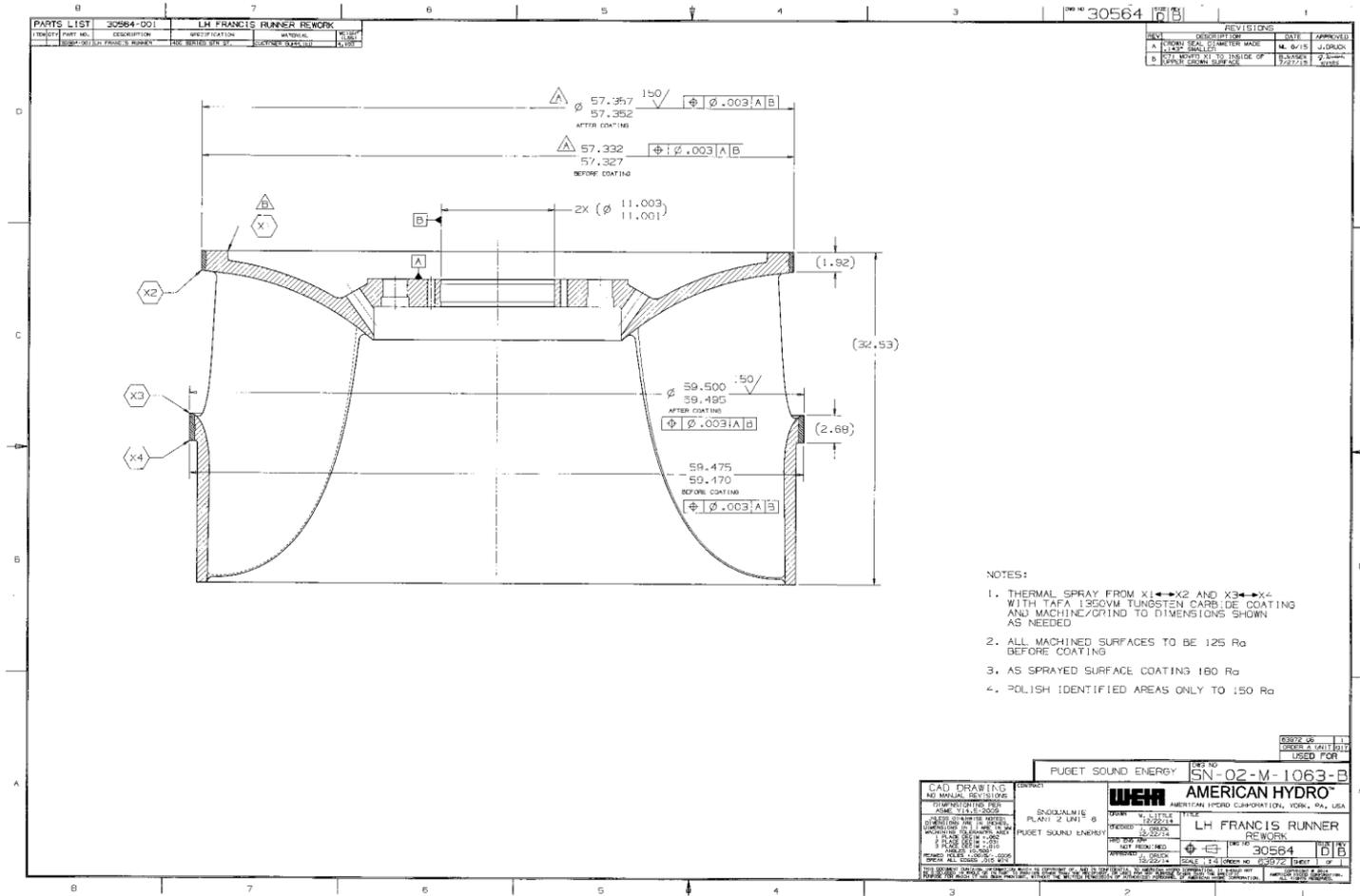
Head Cover Damage Assessment

- The extent of the erosion damage to both head covers was measured and a thorough finite element analysis was performed to ensure that each head cover was still structurally sound.
- The finite element analysis considered three cases:
 - Normal operation
 - Load rejection
 - Runaway
- The results indicate that the maximum stress in the remaining head cover material in each of the three operating scenarios remains below the maximum allowable design stress for the head covers ; $< 1/3$ yield strength at normal operating conditions and $< 2/3$ of yield strength at emergency operating conditions.

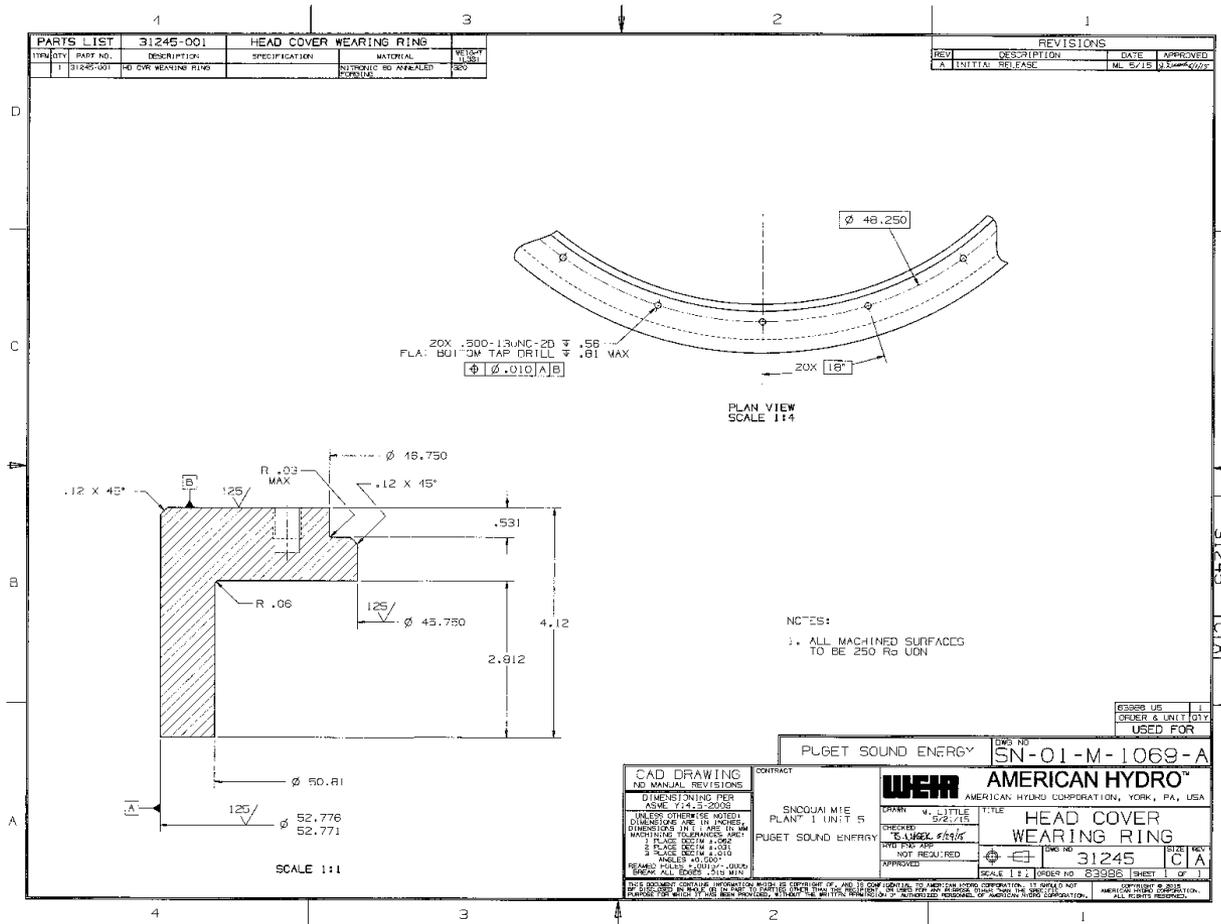
Erosion Modifications to the New Units

- The cover plate concept was shared with the turbine manufacturer along with an idea for an “L” shaped upper stationary seal ring which would ensure that the area that was subject to erosion would be renewed each time the upper stationary seal ring was replaced.
- A tungsten carbide flame spray coating was also applied to the following areas:
 - The upper and lower rotating seal ring surfaces on the runner.
 - The upper and lower stationary seal rings.
 - The underside of the head cover, over the new cover plate.
 - Both of the wicket gate facing plates.
- Devcon ceramic repair putty was used to fill in the eroded areas due to concerns about warping the head covers during a conventional weld repair process.

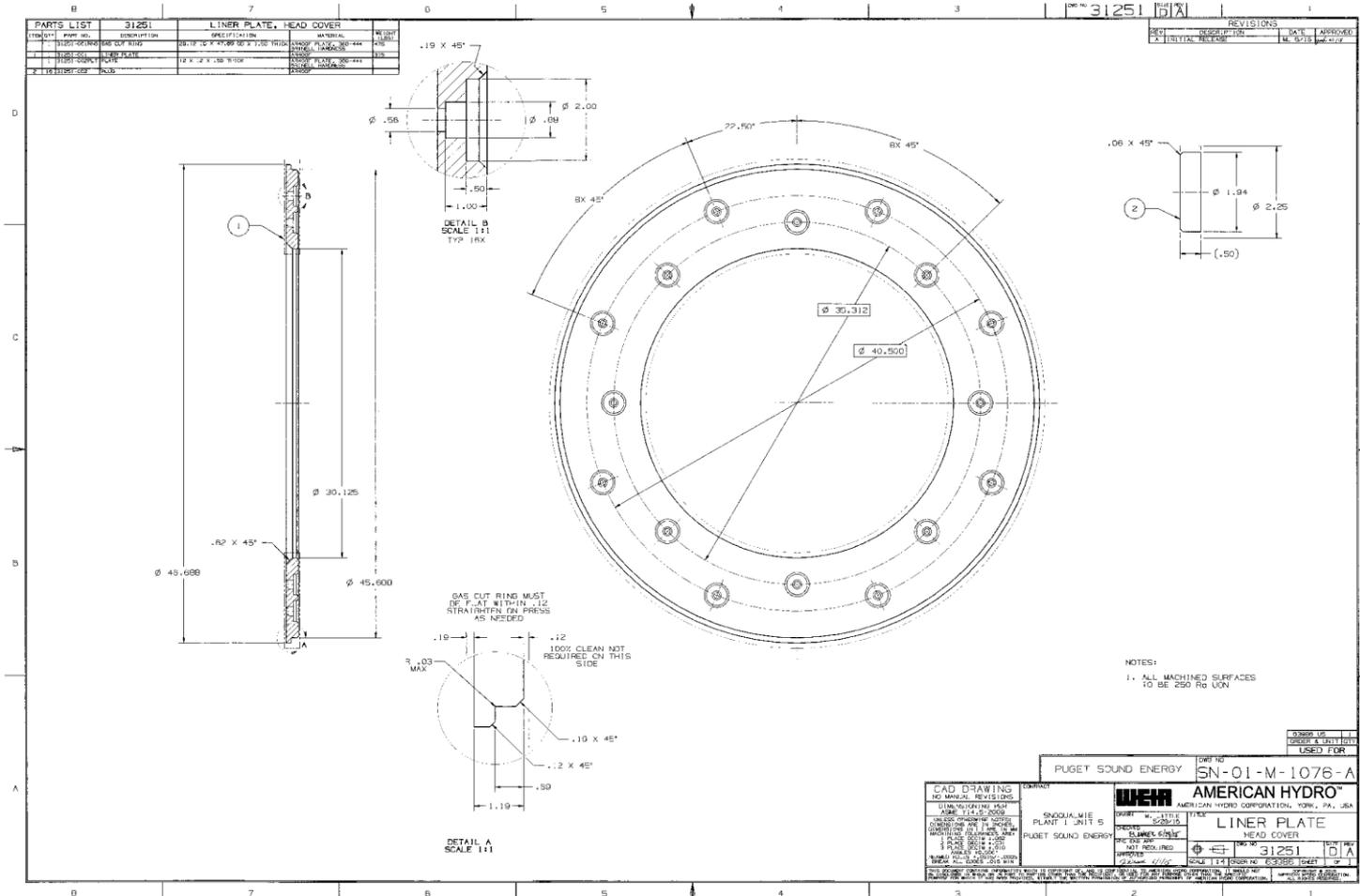
Runner modifications



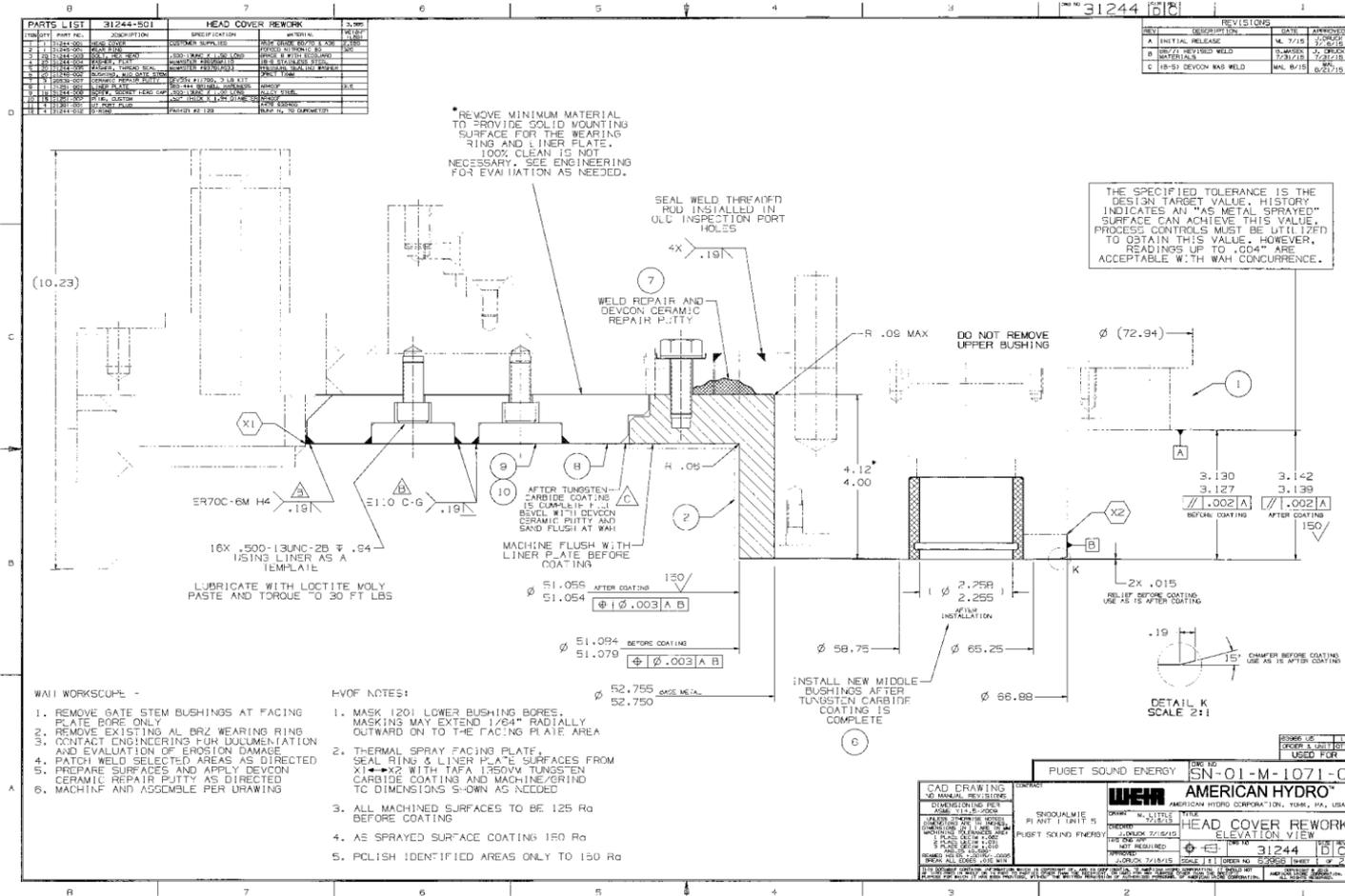
L Shaped Upper Stationary Seal Ring



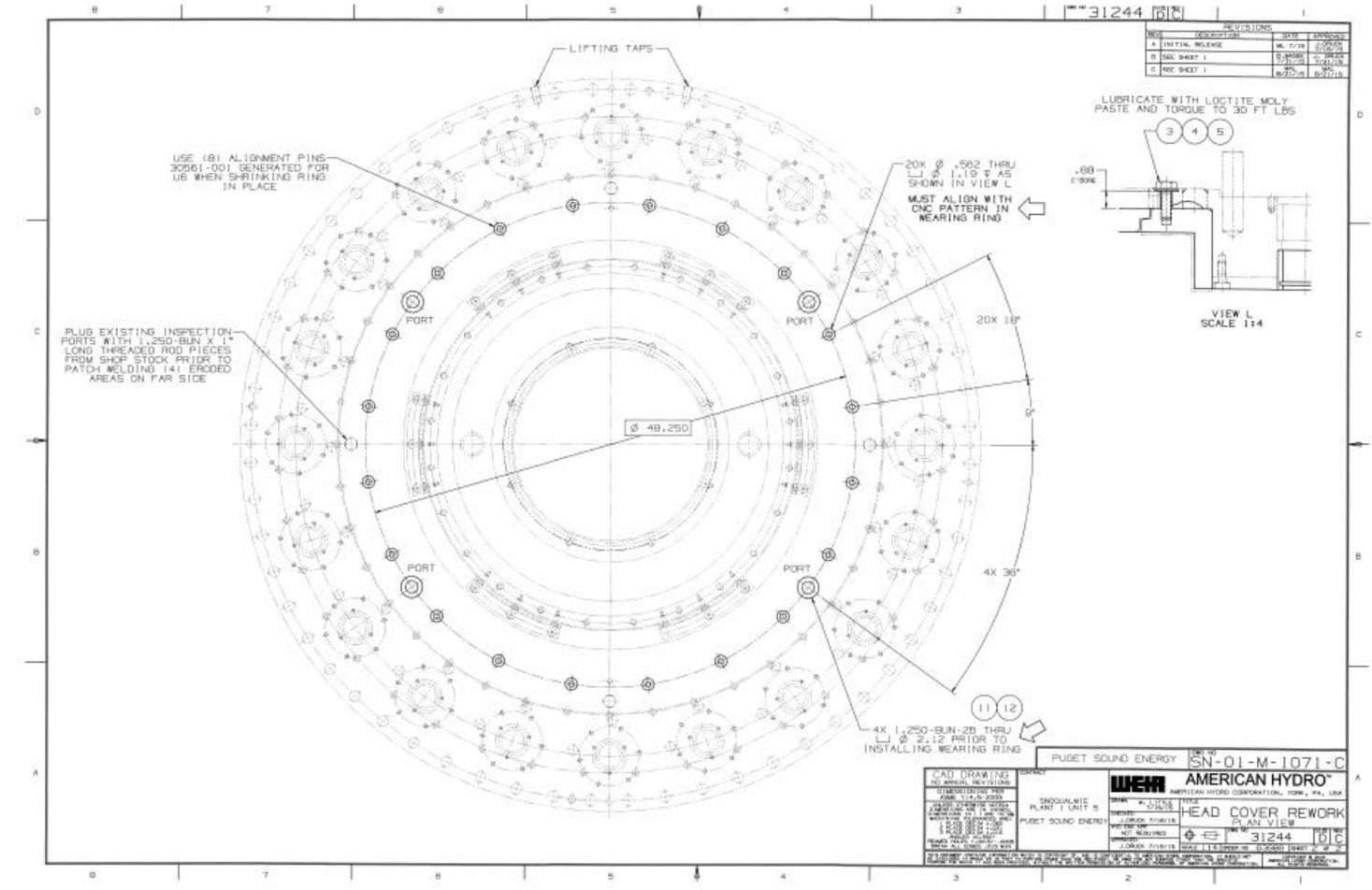
Head Cover Liner Plate



Head Cover Assembly



Future Erosion Monitoring



Conclusion

- Unit #6 was returned to service in January.
- Unit #5 was returned to service in February.
- Questions?