Historical

- 1902 First Plant Built - Now houses Facilities Mechanical and Electrical trades on the lower level and Faculty Art Studios upstairs.
- The Current Heating Plant was built in 1934.
- 1953 new Boiler installed for efficiency and redundancy.
- 1970 new #6 Oil Fired Boiler installed along with 420,000 Gallon Storage Tank and retainage bunker.

Historical Con't

- 1987 500 kW Steam Turbine Generator installed Generated up to 1,700 MWhs/year
- 2001-3 Installation of a new boiler to replace the 1953 boiler, and a 3,000KW generator. COGEN generates up to 4,000 to 5,000 MWhs/Yr.
- 2014 , a new contract with Berkshire Gas that allows us to have uninterruptable gas.
- 2014 two new above ground #2 Fuel Oil tanks installed to replace the #6 oil.
- #6 oil tank drained, striped and demolished.

Buildings Connected to Central Steam

- 70 Buildings are connected to the Central Campus
- Approximately 1.9 Million Sq. Ft.

Major Equipment

- Boiler #1,(160 psi sat. steam. Cap/66,000#/hr.)
- Boiler #3 (450 psi. 650°F SH. Cap/70,000#/hr)
- A 7 Stage, 3000 Kwh, Back Pressure Steam Turbine Generator (COGEN)
- Auxiliary Equipment such as; Fuel pumps, Feed water pumps, Water Treatment system, and Electrical Switchgear

Care and Maintenance of the Steam Turbine Generator

- After installation of the COGEN in 2003, the STG has been operated from November until April every Heating Season.
- When shut down for the season, the COGEN skid is wiped down of oil and debris, the Stainless Steel air filters for the Generator are water washed, dried, then replaced.
- No Other Maintenance is done on the Unit.
- The Turbine would be restarted again in November and run until April.

Reasons for Lack of Maintenance

- The old Plant Manager did not believe there was a need to do anything to the turbine as he believed it hardly had any hours on the unit.
- The old Plant Manager sent out oil samples annually but did not fully understand what the test results were telling him, and the lab he sent them to did not Flag anything, or make recommendations.
- The old Plant Manager did not request in his operational budget money for filters, valve maintenance, borescoping, or any other PM type of maintenance that would of given him a heads up that the machine was degrading.
- Upper Management was content that everything was being operated correctly and never questioned why there wasn’t any budget for turbine maintenance.

Reasons for Permission to Open and Inspect Steam Turbine

- In October of 2014, the new Plant Manager convinced Facility Management that a preliminary internal borescoping was warranted to try and see what the internal side of the steam turbine looked like.
- The borescoping revealed several issues; the hand valves in the HP section of the turbine could not be removed. The LP section was accessible only through the relief valve in the exhaust trunk, the generator windings were very dirty and had oil and dust covering them. (see Pictures)
- Based on this borescope inspection, the new Plant Manager was finally able to convince upper management to open, clean and inspect the steam turbine during the summer shutdown.
- Upper Management was confident that everything would be fine as the machine had hardly any operating hours.

LP Blade Shroud Deposits

Borescoping of turbine in October of 2014. This borescoping helped convince facility management that a through internal inspection was warranted.

LP Rotating Blade Deposits

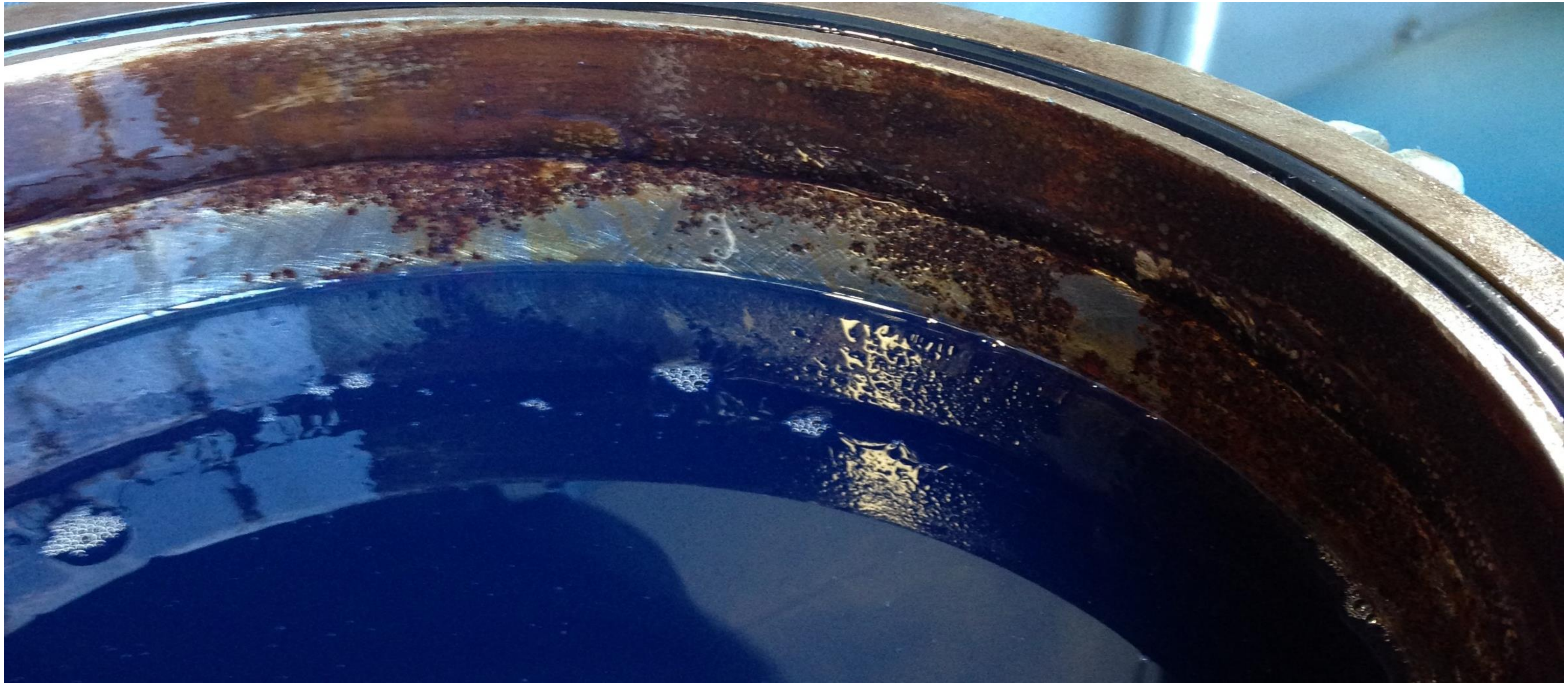
Borescope Pictures

Generator

Interior of the generator. This is the floor showing oil and debris.

Results from Lack of Maintenance

- In November of 2014, the new Plant Manager had the oil pumps started and began circulating the lube oil in the sump. The next morning both filters in the duplex filter were pegged at 20 PSID. The Plant Manager had the filters changed. This was the first time the oil filters were changed in 12 years. (see filter picture)
- The first season the new Plant Manager ran the turbine, the OEM chart showed that we were off the curve by about 400 Kwh. There was one day when the ambient temperature was at -5°F and the #3 boiler was at 69,000#/hr steam flow, but the turbine could only produce about 2,600 Kwh.
- Occasionally, usually in the early morning hours or on the weekends, an electrical fault alarm would come in, but usually cleared. There wasn't any indication that it was coming from the generator and the unit did not trip. It appeared to be an anomaly.



Inside of Duplex Strainer

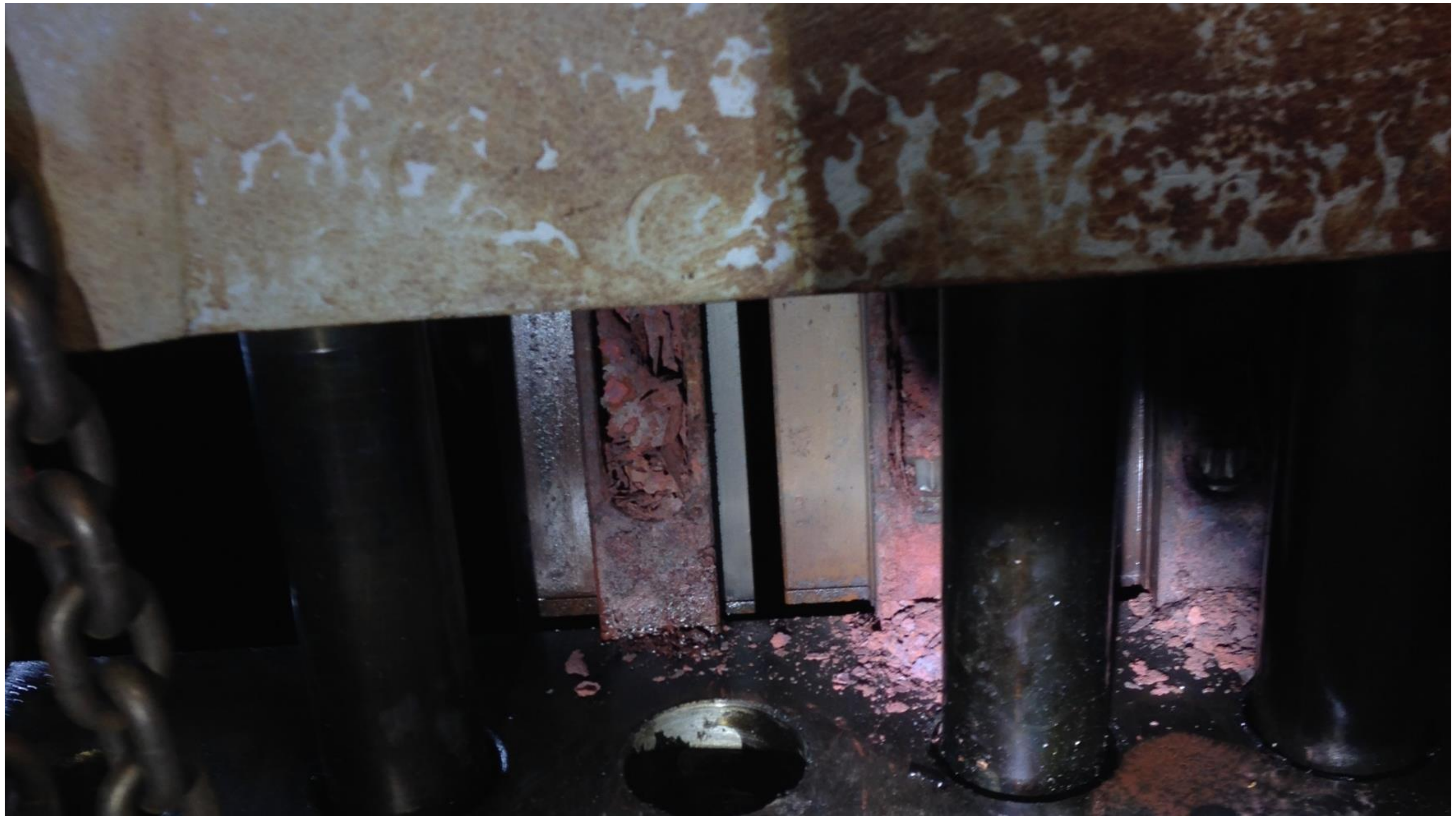
Lube oil was never conditioned or changed. Filters were never replaced and turbine was never properly laid up from April until November. Moisture in the lube oil from steam seals plated out on filter walls and pitted cylinder walls.

Observations from First Overhaul Since Installed

- It took 3 days to lift the top half of the turbine casing. The top half was almost rust welded. (see Pictures)

- The diaphragms took over 2 weeks to remove on the bottom half of the turbine, while the top half had to be sent to the repair shop to be removed. (see Pictures)

- There are 4 hand valves, one on the top casing and three on the bottom casing. The top valve was removed at the shop, and the threads were destroyed. A decision was made to rebuild the hand valves on the bottom half on site without actually removing them from the casing to prevent the destruction of the threads.



Top Half of Casing Lifted

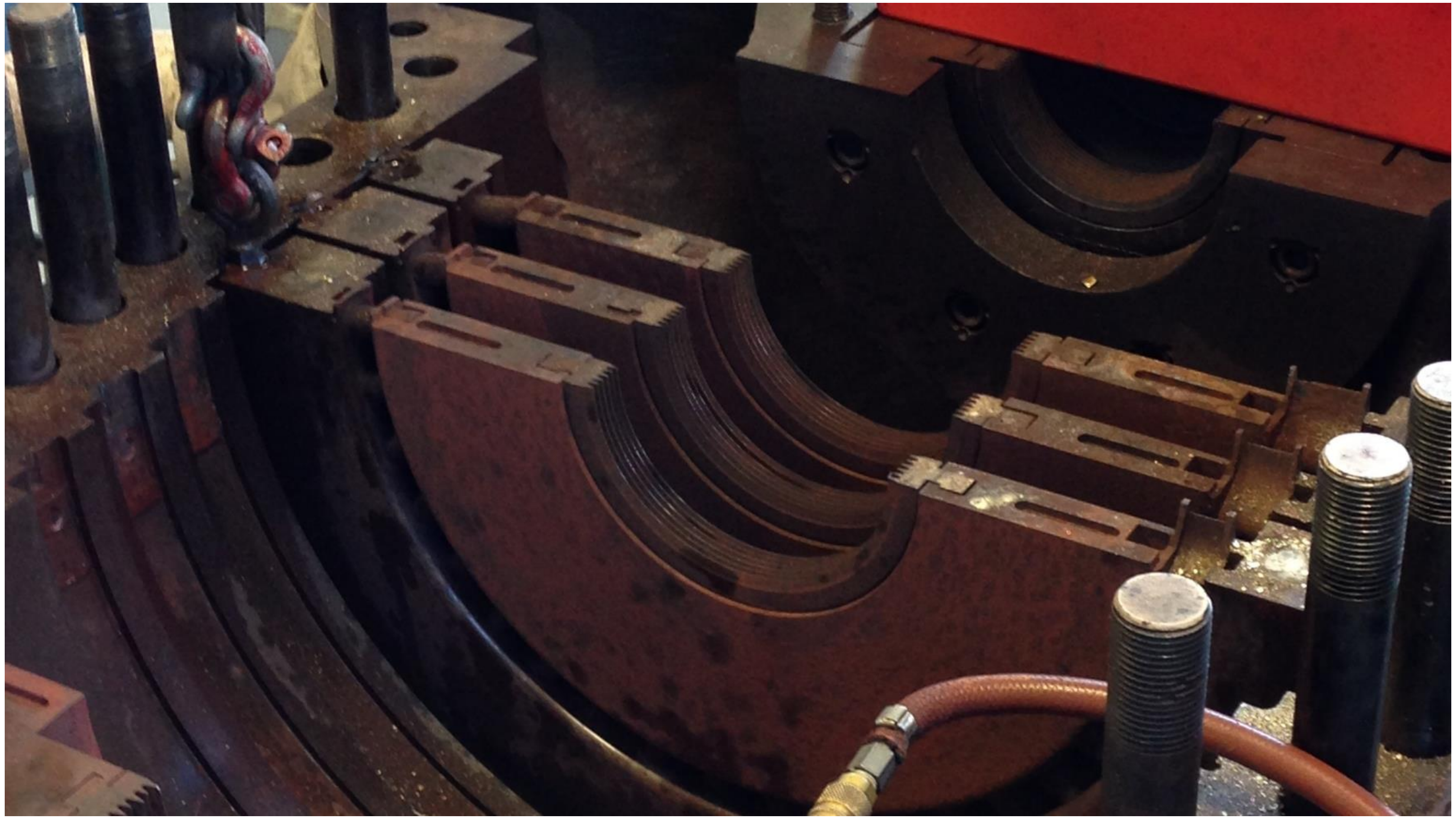
It took three days to lift the top half of the turbine casing. When it was lifted rust flowed out like sand in an hour glass.

Top Half of Turbine Separated

This is what the blades and diaphragms looked like after the rust was cleaned up.

Diaphragms

This is the 4th, 5th and 6th Diaphragms on the bottom half of the turbine. All set screws were corroded and unable to be turned out, they had to be drilled out. Then the diaphragms had to be rocked back and forth using chain falls to loosen and break free.



Diaphragms

Turbine company used porta-power to try and dislodge diaphragms and had over 40K/# of pressure, still did not move.

Diaphragm

Every diaphragm had radial cracks that had to be ground out and built up with welds, then ground flush.

Results from Improper Operation

- OEM manual and operational curve specifies that the turbine should not be run below 600 Kwh. The old Plant Manager would routinely operate the turbine at less than 100 Kwh for days. Below 300 Kwh and the turbine counter stops working, so even though it operated for 24 hours, only a fraction of those hours would be counted.
- The throttle valve would be opened less than 1% admitting less than 8K#/hr of steam. This was barely enough steam to keep the turbine online and cool.
- The throttle valve seat became worn and the turbine would ramp up to 1100 RPM on start up instead of stopping at 500 RPM hold point.
- By the time the steam traveled through to the 7th stage, it was condensed and turned the last stages into a water wheel. (see Pictures)

Throttle Valve Seat

The throttle valve seat, stem, and cage were all worn and had to be replaced with OEM parts. Even after replacing all the parts, the valve did not pass a hydro due to steam cuts in the valve body that had to be ground, built up with weld and ground down again.

Throttle Valve Seat

More Pictures showing corrosion.

High Pressure Blade – Inlet Side

Evidence of steam and moisture erosion

HP Blade – Outlet Side

High Pressure blade showing the outlet side

6th Stage of Turbine - Inlet

The 6th stage of the turbine showing the inlet side

6th Stage Outlet Side

The 6th stage of the turbine showing the outlet side

Generator Inspection

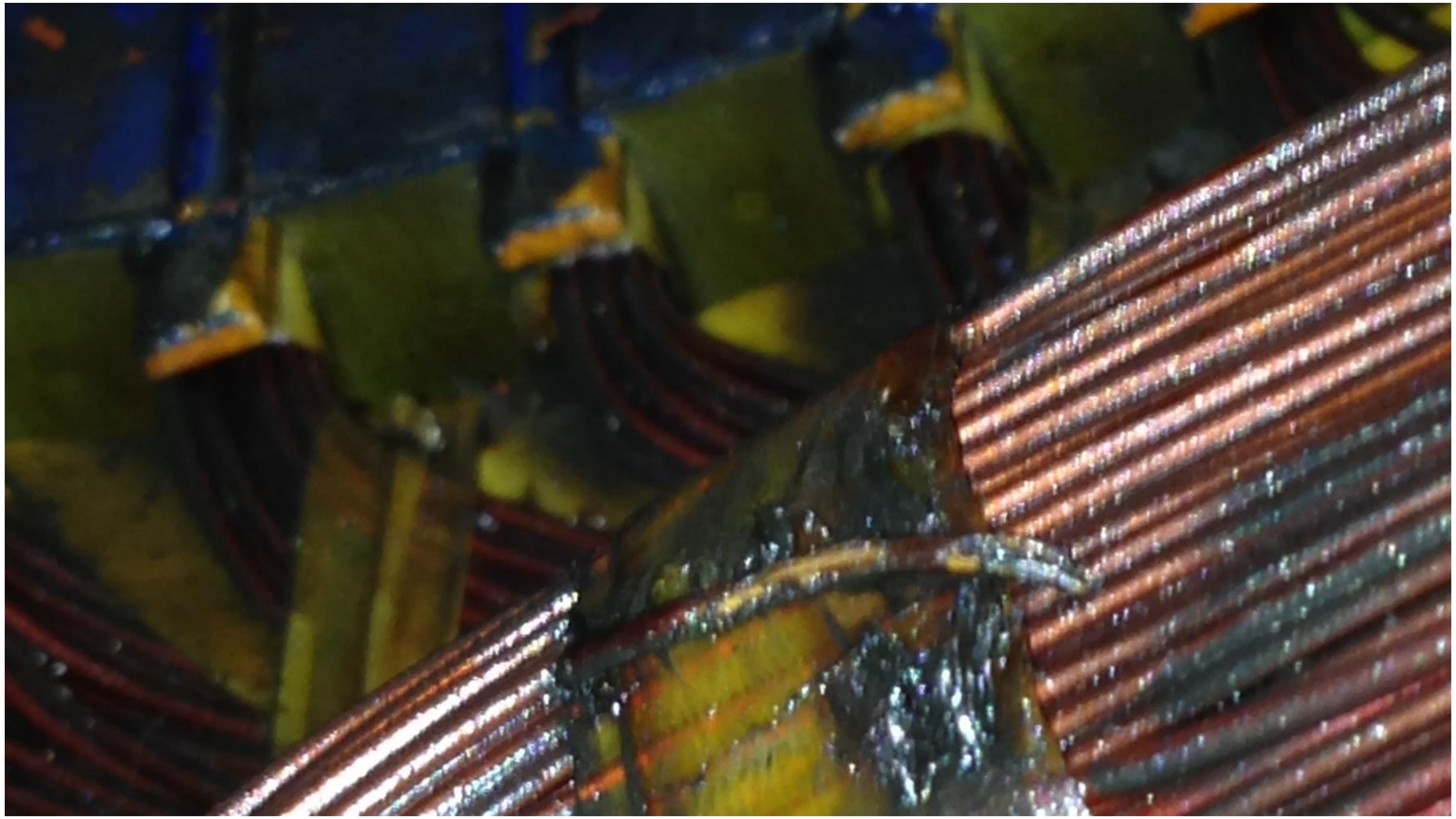
- Generator was pulled and sent to a repair facility to be inspected, cleaned and baked.
- The preliminary inspection showed the windings to be covered in oil and debris. (see pictures)
- The exciter showed the shaft to have rust build up, evidence of rotor to stator contact, and a broken wire in the exciter which could of explained the occasional electrical fault alarms. (see picture)

Generator Internal Inspection

Windings covered in oil and caked with dirt and debris.

Exciter Shaft

The shaft on the exciter end was covered in rust deposits.



Broken Exciter Wire

This wire on the exciter was found to be broken and the entire exciter had to be rewound. According to the electrical shop, we would never have been able to generate full load with this broken wire.

Rotor to Stator Contact

This picture shows where at one time the rotor and stator had made contact.

Conclusion

- Generator was cleaned and baked.
- The exciter was rewound.
- All six of the diodes were replaced.
- Turbine rotor and blades were blasted and polished. Stages 5 & 6 were replaced as the accelerated corrosion made them impossible to save.
- Rotor was dynamically balanced.
- All labyrinth packing, and bearings were replaced.

Conclusion

(Continued)

- All diaphragms were cleaned and NDT inspected.
- The cracks on the diaphragms were ground out, built up with welding, then ground flush again.
- The Trip and Throttle Valve was completely overhauled and rebuilt.
- All instruments and gauges were calibrated and replaced if found to be bad.
- Oil was drained, sump swabbed out and all gaskets replaced on access doors.

Moving Forward

- The internal inspection of the turbine found that there was accelerated corrosion throughout the turbine.
- Most of this corrosion could be directly attributed to lack proper lay up procedures during months of down time.
- Going Forward, plans are being developed for lay up procedures that will minimize or eliminate this type of corrosion due to moisture within the turbine.
- There are plans to add a dehumidifier that will push dry air into the HP section and pull the air out of the exhaust end. This closed loop dehumidification will incorporate a humidistat that will circulate up 500 SCF of dry air continuously during shutdown months.

Moving Forward

(Continued)

- The oil sump will have a side stream filter that will be installed to circulate the oil through two filters, one for particulates, and the other for moisture.

- The oil sump breather vents have a ‘button’ type filter and will be replaced with a Rebuildable desiccant breather to eliminate moisture from entering when unit is down.

- Oil sump was designed for an oil heater, but none was installed when the unit was purchased. A new immersion heater will be purchased and installed to keep the oil warm, and to help eliminate lengthy roll times to heat the oil on start ups.

Q U E S T I O N S

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