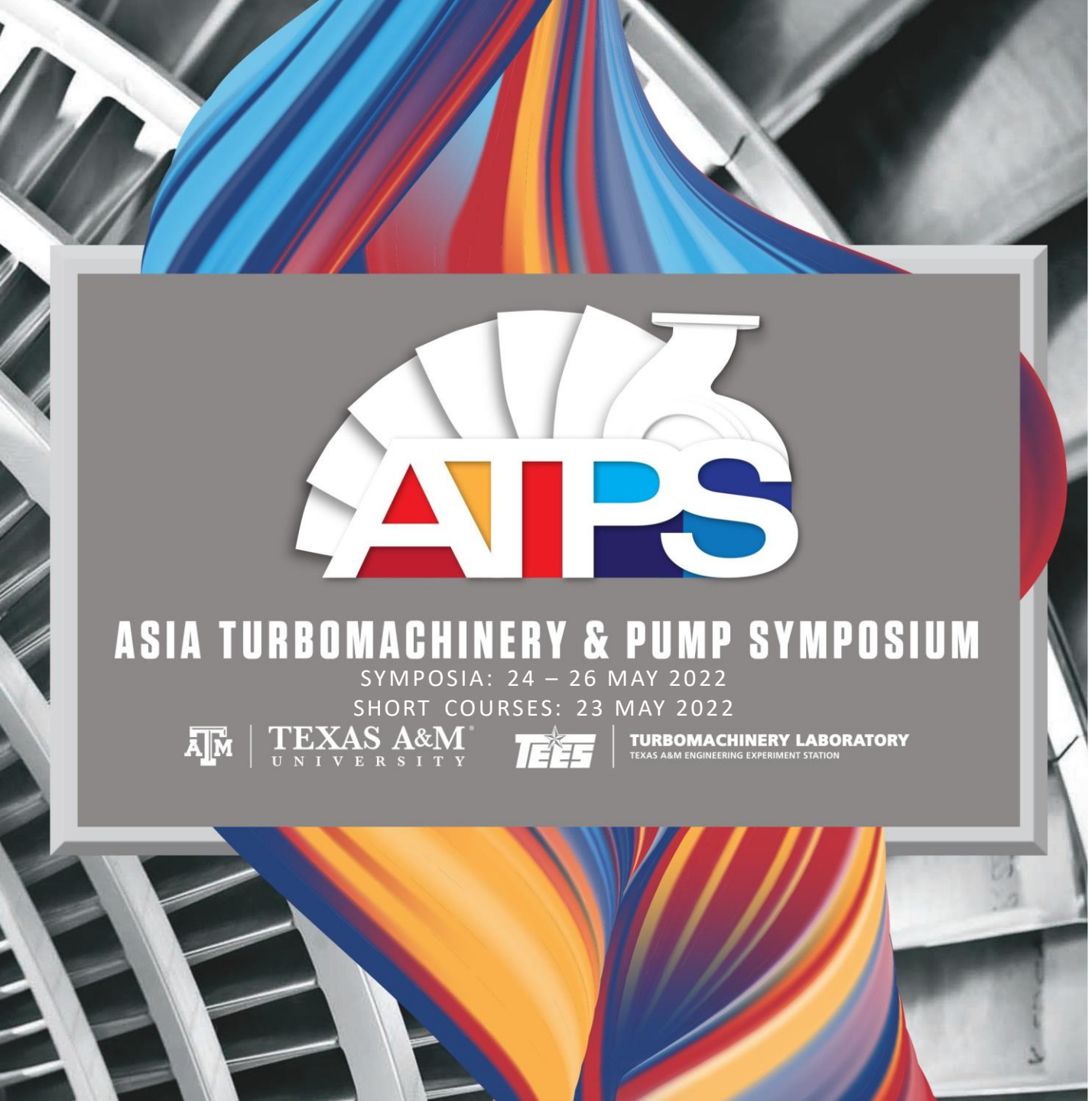

Steam Turbine High Axial Displacement due to Governor Actuator Filter Clog

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Abstract

The governor actuator for a steam turbine was observed to be hunting and failed to maintain stable operating speed. The steam turbine is used to drive a centrifugal compressor for H2 service in a recycle loop. The extent of speed oscillating was exaggerating over time and caused excessive turbine axial movement. The unit was forced to shut down to prevent secondary damage due to turbine high axial movement.

The steam turbine was overhauled approximately 9 months prior to the incident. Oil flushing was performed, lube oil was changed out and main oil filters were replaced as part of machinery overhaul scope. The main oil filter elements were inspected during troubleshooting of this event and were badly fouled with blackish substance.

The governor actuators were inspected and the internal filters for the oil supply line were clogged with soft, blackish substance. Foulant analysis was performed using Energy Dispersive X-ray (EDX) which identified the main component to be Carbon. De-gassing tank oil was drained out and observed layer of blackish substance. EDX identified the main component to be identical to that found in main oil filter. Water sample from de-gassing tank bottom drain was tested and the pH was 3-4 (i.e. acidic).

Further troubleshooting revealed that fine carbon particles were carried over from upstream and mixing with the process gas prior to the unit shut down for the compressor train overhaul. The presence of carbon particles had contaminated the seal oil and control oil circuit which then clogged up the actuator internal fine filters (~40um). This case study presents the unusual phenomenon, troubleshooting tools, recovery process and key learnings which provide user operating with similar service a reference.

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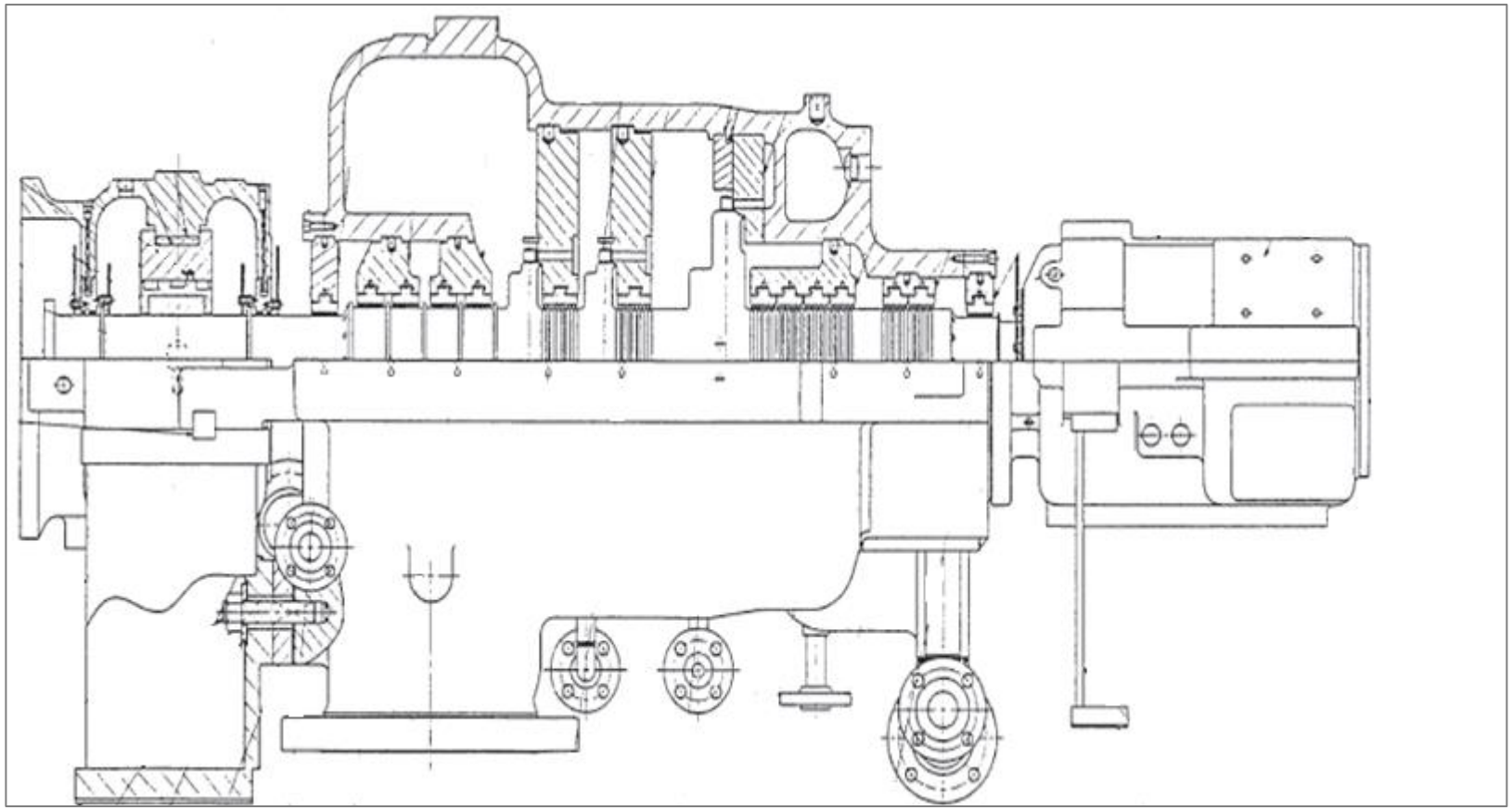
Agenda

1. Case Study Background
2. Problem Description
3. Findings
4. Analysis
5. Key Learning

Equipment General Info

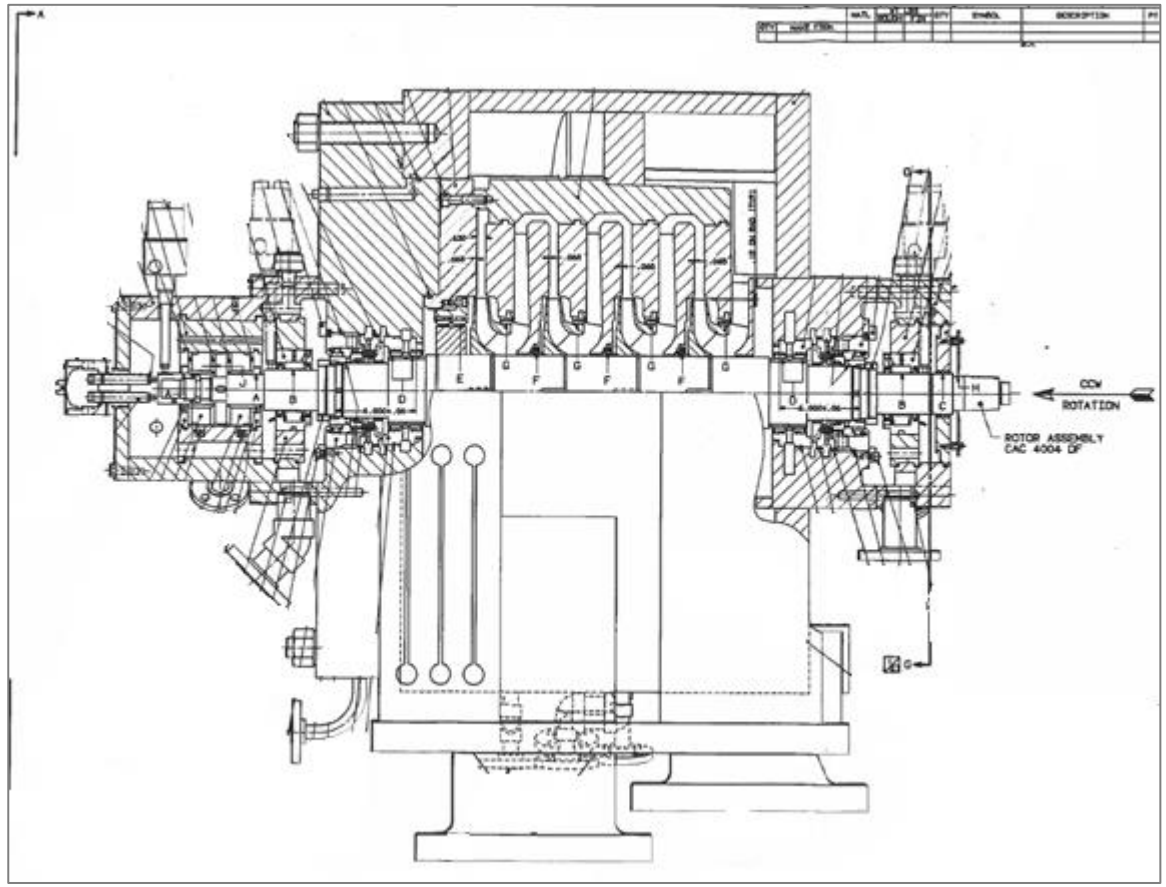


Steam Turbine Details

Type:	Back pressure turbine
Frame:	1U2R
Rating:	1.2MW (3 stages)

Rated Speed:	9,500 RPM
Max. Speed:	11,550 RPM
Min. Gov.:	6,050 RPM
1st Critical:	5,000 RPM
Trip Speed:	12,705 RPM

Equipment General Info



Compressor Details

Type:	Centrifugal
Model:	4B26 (4 stages)
Suction:	17 barg @43degC
Disch:	23 barg @79degC
Power:	1,050kW
Bearing:	Tilting pad
Seal:	Mechanical oil contact seal

Lube Oil System

- Common circuit for lube oil, seal oil and control oil
- Lube Oil: 138kpa @145L/min
- Seal Oil: 2,240kpa @76L/min
- Control Oil: 828kpa @19L/min
- Oil Filter: 10um

Equipment General Info

External
40um filter

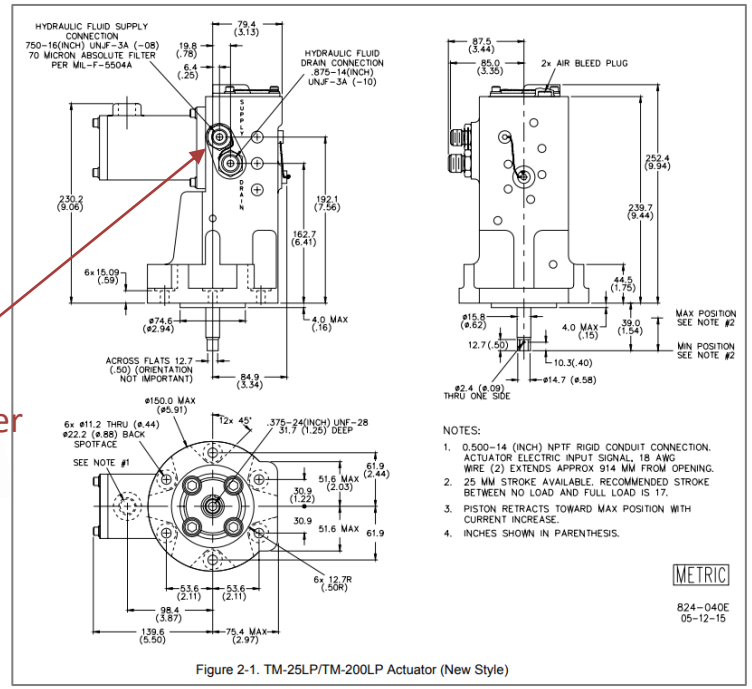


Figure 2-1. TM-25LP/TM-200LP Actuator (New Style)

Model: TM-25LP
External filter: 40um (nominal) @ oil inlet
Internal filter: 70um (nominal) @ coil inlet
Control oil press: 552kpag
Control oil flow: 3.8L/min

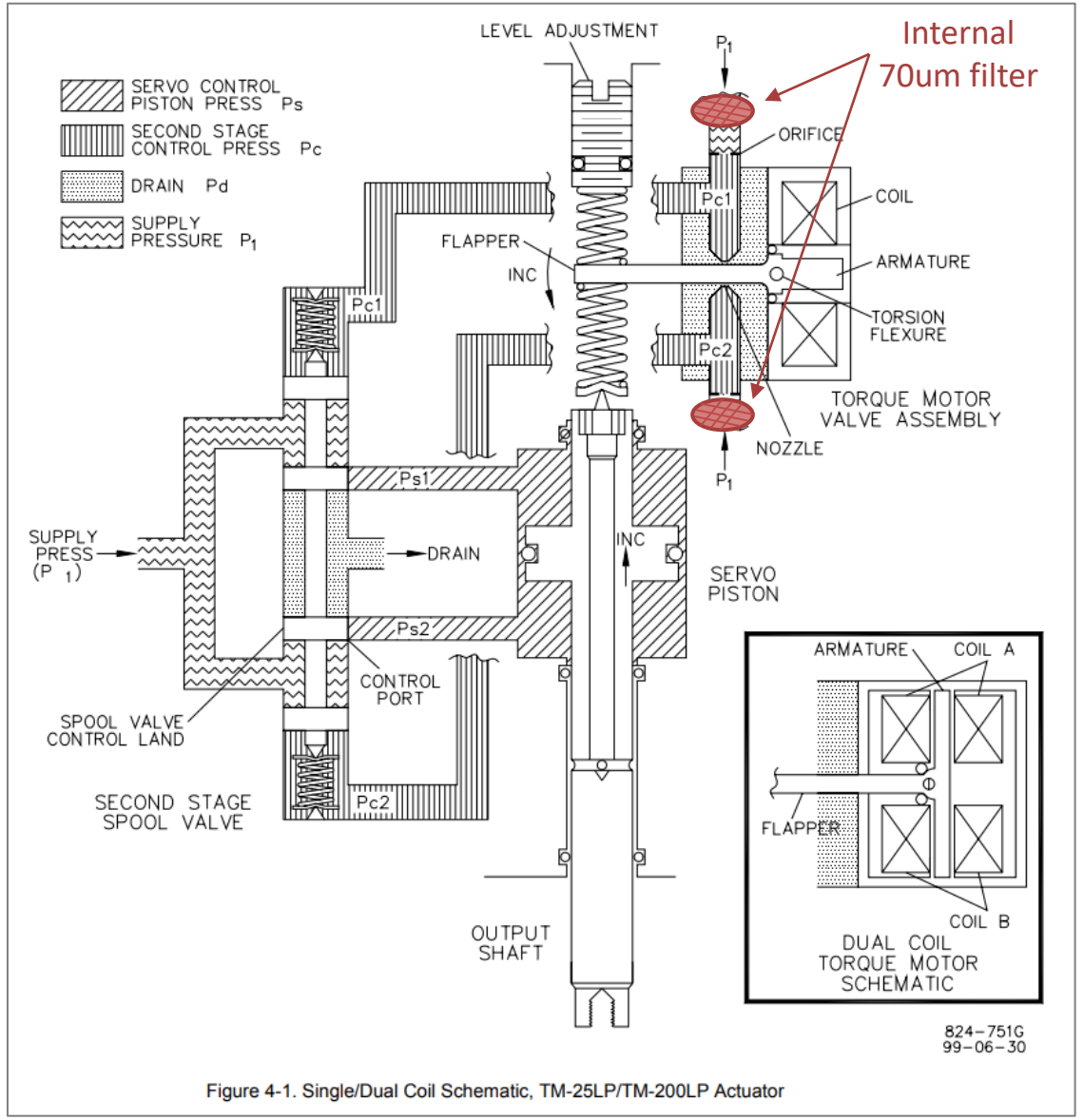
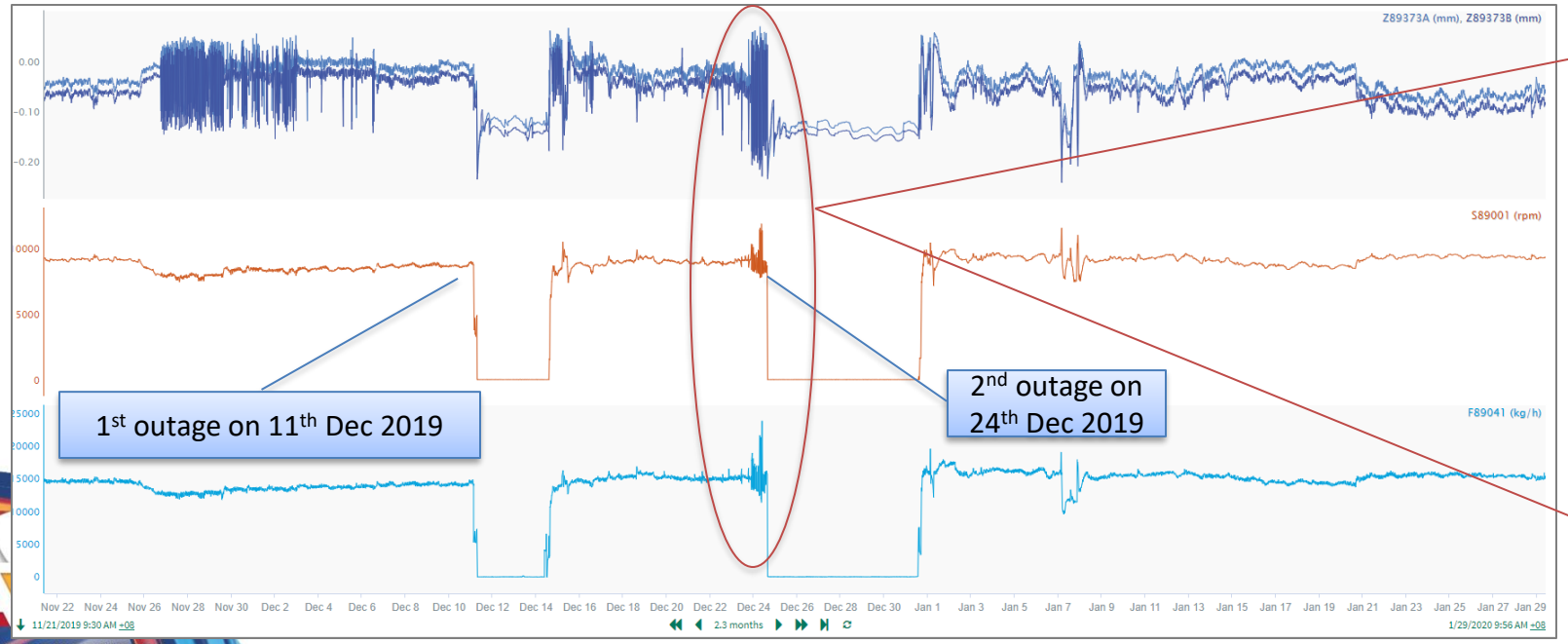
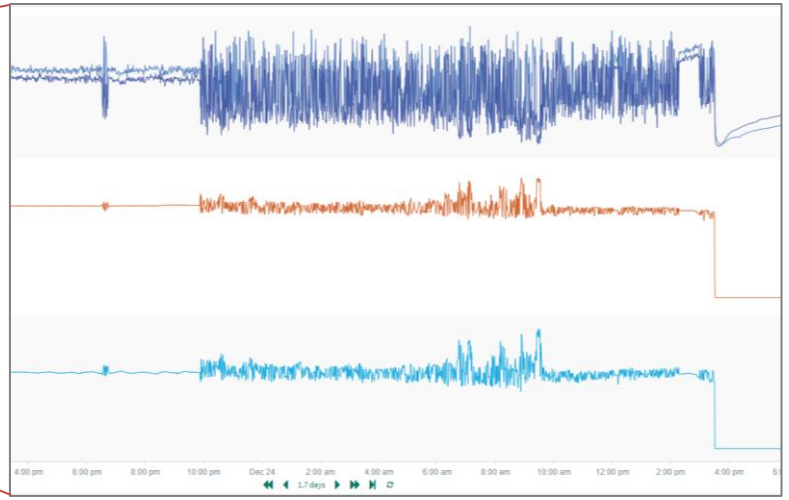


Figure 4-1. Single/Dual Coil Schematic, TM-25LP/TM-200LP Actuator

Problem Description

- The steam turbine governor valve actuator had failed twice in the space of two weeks.
- First failure on 11th Dec 2019 (5 days outage):
  - Turbine sudden loss of speed from 8,800 RPM to 3,800 RPM. Speed gradually picked-up to close to 1st critical speed of 5,000 RPM due to compressor load reduction.
  - Speed was considerably stable prior to the loss of control, but rapid fluctuation in axial displacement was observed 1 – 2 weeks prior to the incident
- Second failure on 24th Dec 2019 (7 days outage):
  - Turbine speed started to fluctuate wildly between 8,800 RPM and 11,500 RPM (max. continuous speed)
  - Axial vibration swing violently between -0.15mm to +0.10mm. Abnormal sound can be heard at site
- In both events, turbine was manually shut down to prevent any secondary mechanical damage (which can be very costly to repair with long outage)

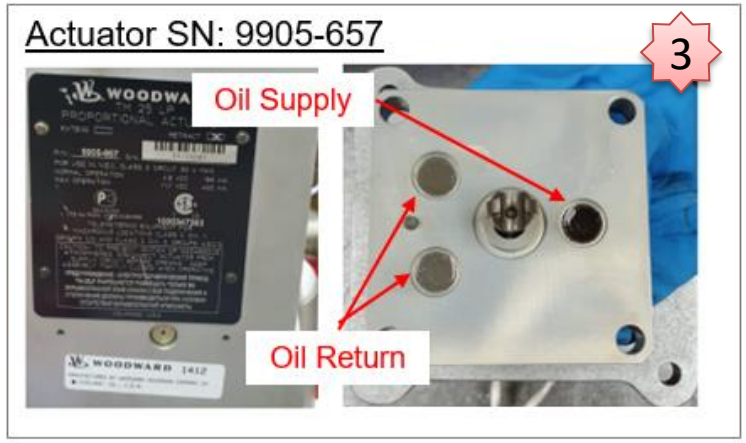


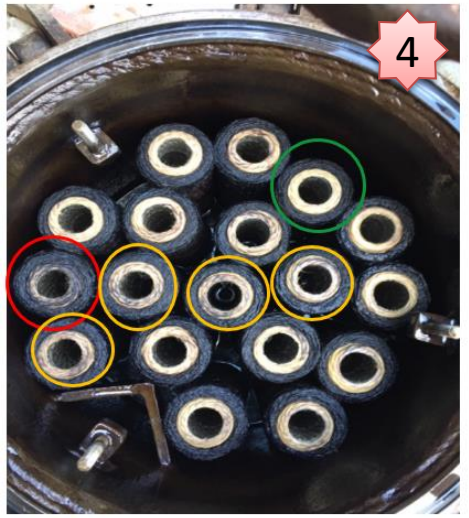


Speed and axial displacement rapid fluctuation prior to shutdown

Key Findings

1. Turbine was just overhauled in April 2019, approximately 8 months prior to the failure.
2. As part of overhaul, governor valve actuator was replaced with new. Oil flushing was performed and lube oil and oil filters were replaced.
3. Actuator internal coil filters were inspected and found to be badly clogged with blackish substance.
4. Lube oil filter elements were inspected and found to be badly coated with similar blackish substance.
5. Draining of degassing tank found similar layer of blackish substance which float on oil when left to settle.
6. EDX analysis shows blackish substance was mainly carbon.
7. Degassing tank bottom draining found water and tested to be slightly acidic (suspect carbonic acid)





Legend:
- by-passed filter
- partially by-passed filter
- good filter without by-pass

Key Findings

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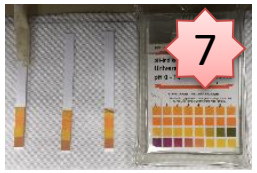

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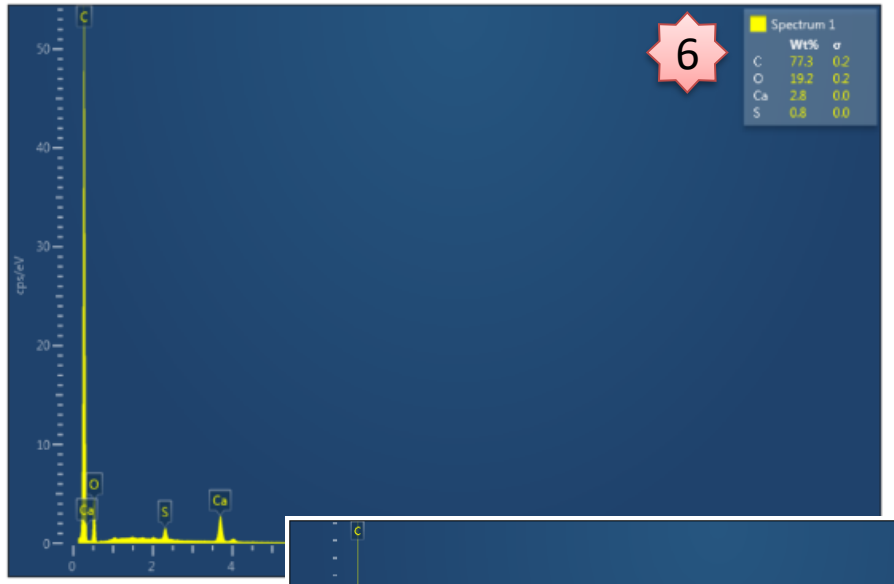
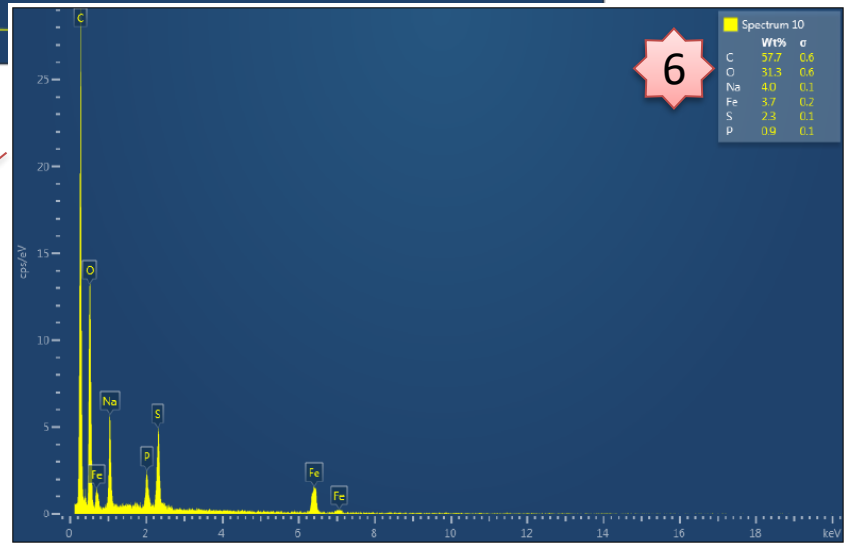
Degassing tank – think layer of blackish substance and acidic water sample





EDX analysis of blackish particles shows main composition of carbon

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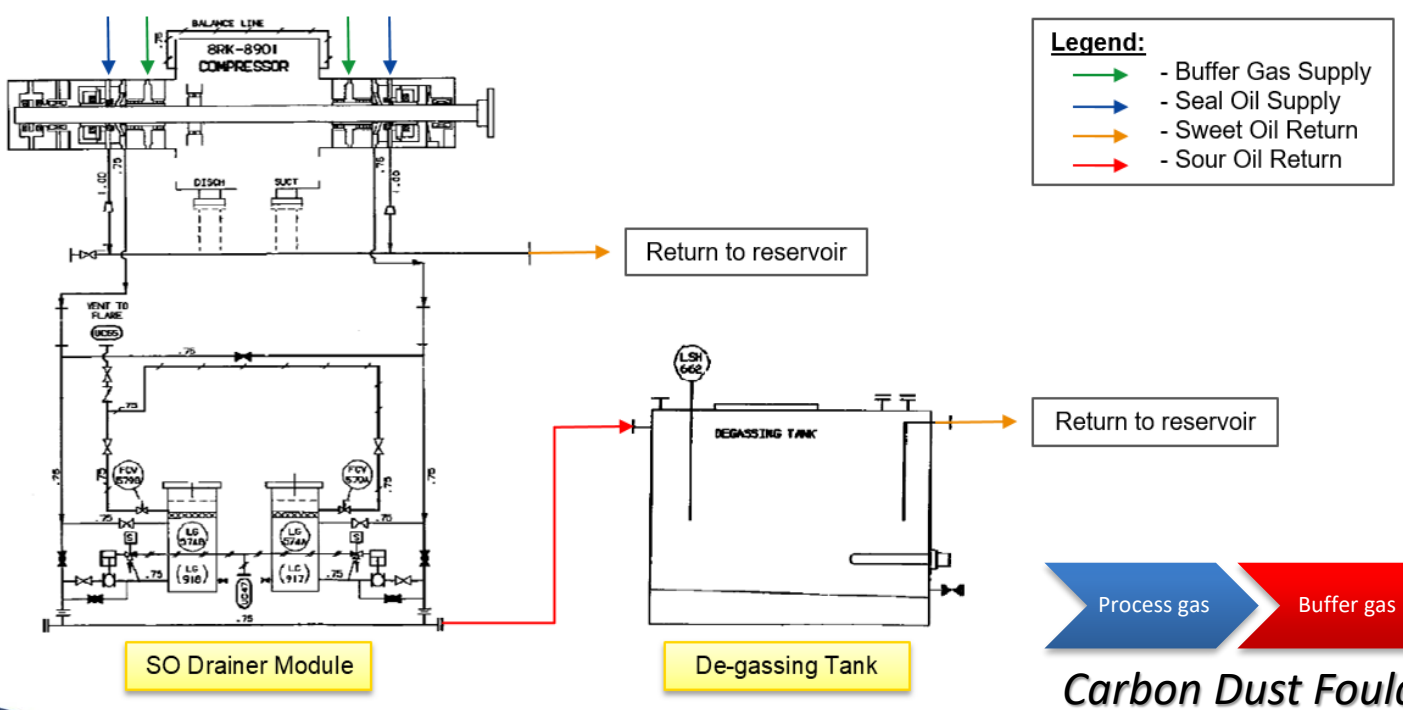
Analysis

1. Prior to shutting down the turbine for overhaul, the compressor was used for “Coke Burn” operation to avoid catalyst poisoning.
2. By product of “Coke Burn” are soot (fine carbon dust), carbon dioxide and water.
3. During “Coke Burn” process (unit shutting down), the Nitrogen at buffer gas header was only maintained at 700kpag vs. design 1,375kpag for effective operation of buffer gas system.
4. During “Coke Burn”, the compressor suction pressure was 600kpag. Taking into account the pressure drop from battery limit to compressor, the buffer gas pressure will not be adequate to prevent “Coke Burn” process gas to come in contact with the seal oil.



Legend:
- Buffer Gas Supply
- Seal Oil Supply
- Sweet Oil Return
- Sour Oil Return

Process gas → Buffer gas → Sour oil system → Seal oil drainer module → Degassing tank → Lube oil reservoir → Circulated in oil system

Carbon Dust Foulant path into oil system

Analysis

Why carbon dust in degassing tank was not identified during overhaul?

- Degassing tank inspection and cleaning was not included in the overhaul work scope
- During oil flushing, the sour oil return circuit, including the degassing tank was not flushed

Why only after 8 month of operation?

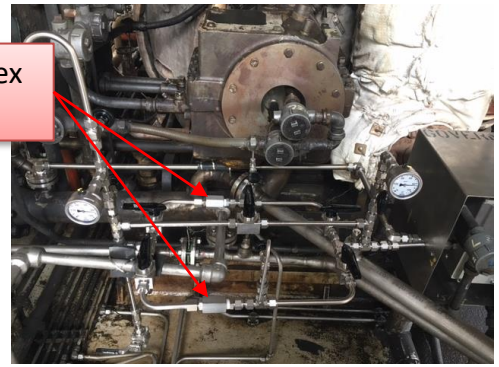
- Compressor is equipped with mechanical contact oil seal
- Under normal circumstances, the seal oil leakage rate is very low
- It takes time for the carbon dust to be flushed to degassing tank and overflow back to oil reservoir

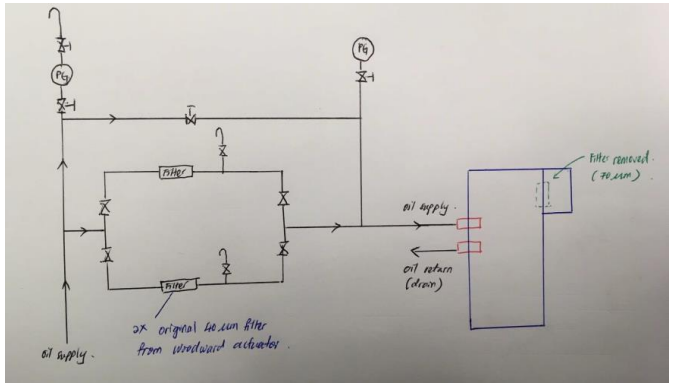
Why carbon dust was not fully trapped by lube oil filter (10um)?

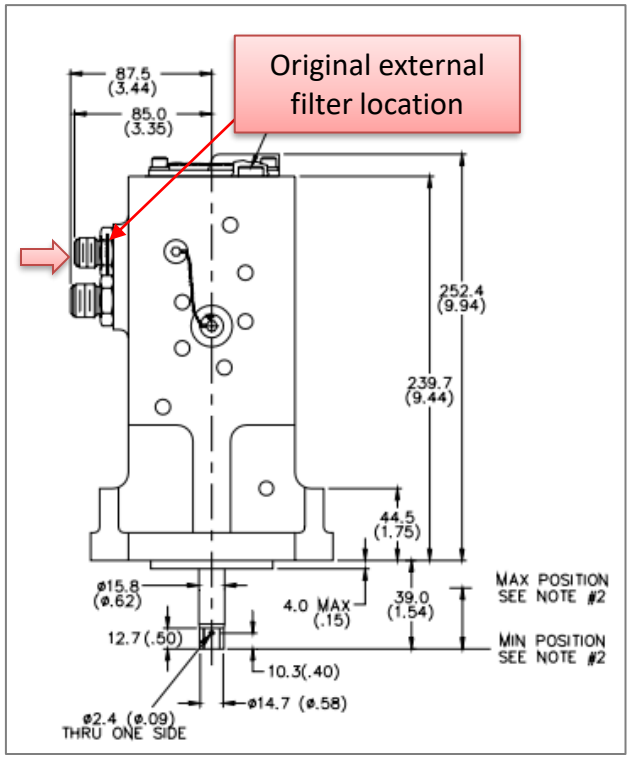
- Carbon dust particle size range is between 5 – 15um
- Carbon dust smaller than 10um can still pass through the filter and coagulate forming bigger particle size downstream of the filter
- Inspection showed potential by-pass of some of the filter elements

Action Taken & Results

- Performed oil flushing prior to restart – using mesh as well as Swagelok 7um hydraulic filter
- Replaced oil filter elements
- Full replacement of lube oil with fresh oil
- Replace the governor valve actuator with tested and calibrated spare
- Modified TM-25LP governor actuator external filter to be of duplex design with dP monitoring. Online replacement is feasible.
- Steam turbine successfully restarted and governor actuator in stable and healthy operation to date.







Key Learnings

1. Risk of abnormal operation (i.e. “Coke Burn” operation) was not fully recognized and understood.
2. Oil flushing should be planned to cover all sub-circuits / oil paths in the oil system.
3. Both lube oil reservoir as well as degassing tank should be inspected during overhaul, clean if required.
4. Clean and adequate supply of buffer gas is critical not only for mechanical seal reliability, but also to prevent lube oil contamination due to sour oil contact with dirty process gas.