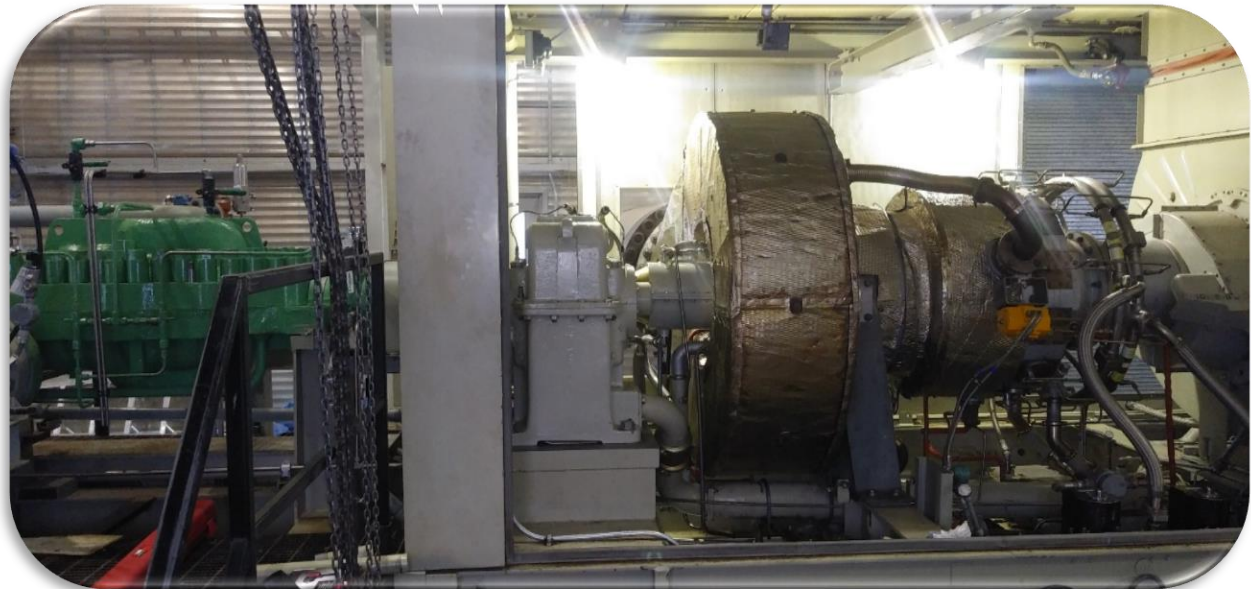


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FIELD REPORT		
Customer		
Name: Cardinal Energy Ltd	Site: Mitsue	Contact Name: Scott L.
Field Support		
Date: August 17th, 2021	PO/WO:	FSR Name: JJ / Jeff
Turbine Engine		
Model: Centaur 4702S	Customer ID: Turbine P980	S/N: OHE09-C1259
Overhaul date:	Hours: 15606.5	Start: 209



Contents

Section 1: Site visit purpose

Section 2: Executive summary

Section 3: Task execution details

Section 4: Detailed Borescope Report

Section 5: Vibration Analysis Survey

Section 6: Timesheet, charges, and parts record

Section 7: Conclusion and recommendations

Section 1:

Perform the annual preventive maintenance through borescope inspection, oil filter elements replacement, axial compressor blade wash to recover performance and maintain efficiency, also ensure overall package safe operating conditions.

Collect vibration data for subsequent equipment health condition monitoring.

Section 2

After commissioning, besides the irremediable mechanical and thermal-related wear and tear, the axial compressor's frequent detergent wash is the only method to recover and maintain overall engine performance. A spring and fall frequency to perform blade wash will preserve optimum engine operation and minimize the excessive performance degradation due to compressor blade fouling in conjunction with the air inlet filters replacement every year or send out for professional cleaning.

The borescope inspection revealed no visible damage, no noticeable cracks, or signs of abnormal operation of hot section components. The air inlet had significant contamination traces, possibly from the turbine oil tank vent or surrounding equipment exhaust, similar to the previous year. A corrective action to identify the contamination source is crucial to prevent reoccurrence (***Please refer to inspection pictures section 4 – Detailed Borescope Report***).

Overall vibration data are within the OEM specifications (***Please refer to various points signature on section 5 – Vibration Analysis Survey***). The high vibration malfunction occurring on the reduction gearbox output was superficial and addressed after resolving the engine's overall poor performance issue. The slight change on the pump drive end readings could result from the visible inboard pump seal leakage (damage) and process water laying in the bottom on the entire gas turbine skid.

The start system hydraulic motor developed a leak while in operation. The entire start system reliability issue is a priority right now. There are no alternative means to start and run the unit without it. Addressing the high-pressure transmission line's hard piping issue should be the most pressing matter; otherwise, keep repairing multiple oil leaks is precarious and unsustainable.

Considering the parts availability and lead time delays, some spare parts must be available on-site to minimize downtime. We strongly suggest a follow-up on the previously submitted spare parts list.

Section 3

Monday, August 16th, 2021

- Picked up Air Inlet Filters Elements and traveled from Edmonton to Site.
- Unhook the trailer (Air Inlet Filters Element Delivery) and traveled to Slave Lake.

Tuesday, August 26th, 2021

- Traveled back and forth from Slave Lake to site.
- Obtained permit to work, ensured unit was isolated correctly.
- Removed borescope access ports (Injectors #4, #8 & #11 etc.), disconnected various drain lines and sensing lines in preparation for both borescope inspection and blade wash. Removed and inspected the spark plug gap.
- Replaced oil filter elements on filter pot #2 after thoroughly cleaned and purge air lock. The filter pot #1 was put into is in service.
- Removed old and installed new bleed valve assembly kit.
- Third parties retrofitted the actuator and solenoid on the electrohydraulic start system for the proper and safer operation to avoid close contact with high-pressure transmission lines during start-ups.
- Performed borescope inspection (***please refer to section 4 – Detailed Borescope Report***).
- Restored all previously removed borescope access ports.
- Carried out two cycles of blade washing, rinsed, and dried out unit.
- Reassembled previously removed drain and sensing lines.
- Pre-start checks, noticed an oil leak from the start system hydraulic motor, a successful start-up with no change on the CDP (abnormal after blade wash).
- Noticed bleed valve fail to open, forced to open using the HMI.
- Carried out housekeeping.

Wednesday, August 18th, 2021

- Troubleshoot persisting very low CDP indication, found a partially plugged line, and used a spare available line which restored the CDP from 76 PSIG to around 100 PSIG.
- Troubleshoot bleed valve malfunction, rerouted bleed valve system oil supply. Disassembled, inspected, cleaned, and reassembled the two stop solenoids (suspect Control/PLC or directional Versa valve malfunction).
- Pre-start checks, start-up, and test run.
- Monitored operating data.
- Carried out housekeeping.

- Collected vibration data.
- Traveled back to Edmonton.

Section 4



Detailed Borescope Report








Productivity through inspection solutions



Inspection Details

Menu Directed
GP Serial Number
PT Serial Number
Customer
Site
Model
Package Hours
Engine Hours
Engine Starts
Inspector
Date
Time

CENTAUR40
OHE09-C1259
TUI00-C0885
CARDINAL ENERGY LTD
MITSUE
4702 SOLONOX
15606.5
15606.5
209
JJ / JEFF
17 August 2021
11:15:43

Inspection Summary			
 No Images  No Flagged Images  Flagged Images			
	Inspection Points	Images	Flagged Images
 AIR INLET	1	13	0
 COMBUSTOR	1	72	0
 TURBINE	1	7	0
 TRUNNION BOLT	1	16	0



IGV_Comp_Rotor_Stator005.JPG

Section	AIR INLET
Borescope Port	Air Intake Screen
Inspect for Damage Mesh, Foreign Object Damage (FOD), Cracks, Nicks and Dents, Excessive Fouling, Pitting Corrosion, Tip Rub.	No Visible Signs of Damage. Significant contamination. Some Flaking Paint Chips from the Air Inlet Duct stopped by the Intake Mesh Screen.



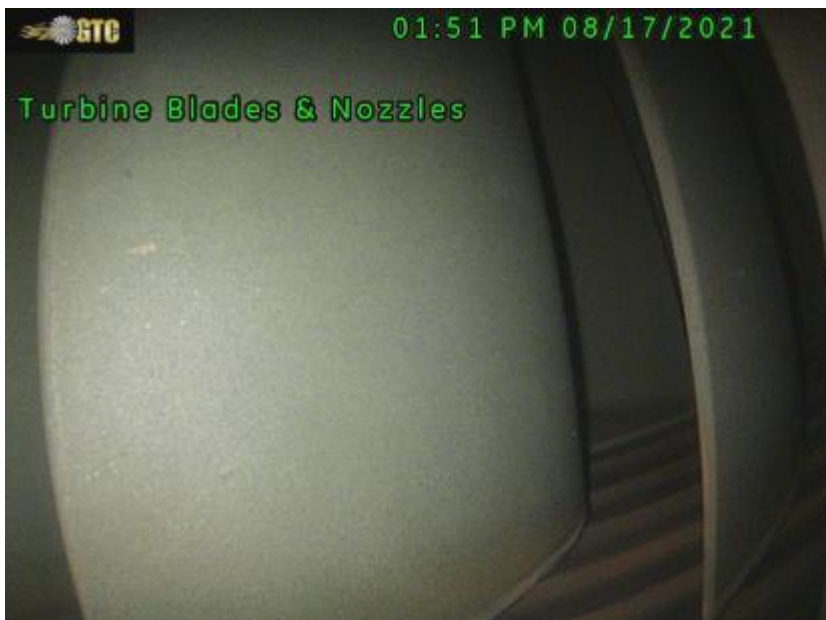
IGV_Comp_Rotor_Stator006.JPG

Section	AIR INLET
Borescope Port	Air Intake Screen
Inspect for Damage Mesh, Foreign Object Damage (FOD), Cracks, Nicks and Dents, Excessive Fouling, Pitting Corrosion, Tip Rub.	No Visible Signs of Damage. Significant contamination. Most likely Turbine Oil Tank Vent or close by equipment Oil Mist Contamination Traces.



IGV_Comp_Rotor_Stator010.JPG

Section	AIR INLET
Borescope Port	Air Intake Screen
Inspect for Damage Mesh, Foreign Object Damage (FOD), Cracks, Nicks and Dents, Excessive Fouling, Pitting Corrosion, Tip Rub.	No Visible Signs of Damage. Significant contamination. Most likely Turbine Oil Tank Vent or close by equipment Oil Mist Contamination Traces.



Blades_Nozzles_Tip-Shoes002.JPG

Section	TURBINE
Borescope Port	T5 Thermocouples
Inspect for Cracks (Trailing Edge, Leading Edge & Vane Profile), Thermal Erosion, FOD, Excessive Tip Rub, Severe Dents & Corrosion.	No Visible Signs of Damage on Second Stage Turbine Blades (FWD view) and Tip Shoe.



Blades_Nozzles_Tip-Shoes005.JPG

Section	TURBINE
Borescope Port	T5 Thermocouples
Inspect for Cracks (Trailing Edge, Leading Edge & Vane Profile), Thermal Erosion, FOD, Excessive Tip Rub, Severe Dents & Corrosion.	No Visible Signs of Damage on Third Stage Turbine Blades (AFT view).



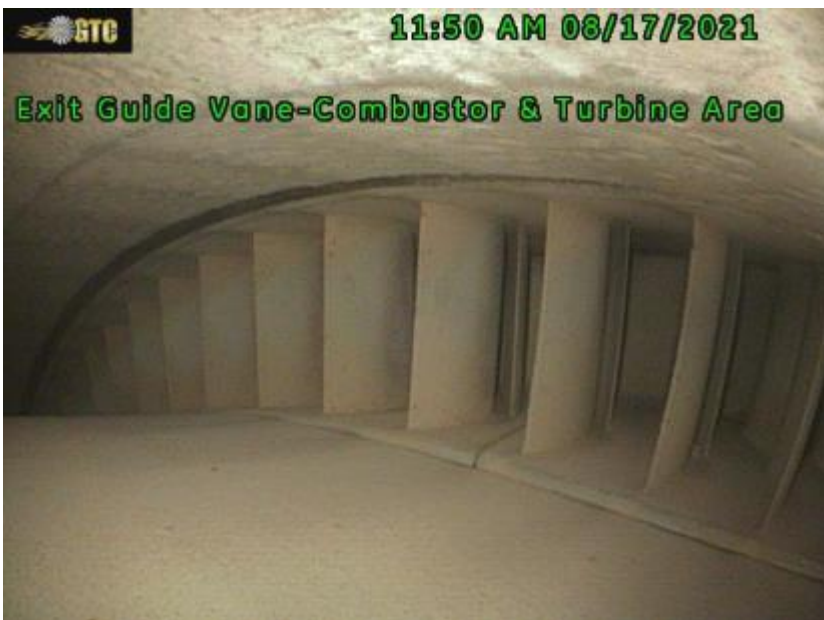
PT-Blades_Exhaust-Diffuser007.JPG

Section	TRUNNION BOLT
Borescope Port	AFT Trunnion Bolts Holes
Inspect for Cracks (Trailing Edge, Leading Edge & Exhaust Struts), Thermal Erosion, FOD, Excessive Tip Rub, Severe Dents & Corrosion.	No Visible Signs of Damage on Third Stage Nozzle and Power Turbine Blades (FWD view) and Tip Shoe.



Injectors_Comp_Exit_Comb_Turb_1st_Stg002.JPG

Section	COMBUSTOR
Borescope Port	Fuel Injectors
Inspect for Foreign Object Damage (FOD), Cracks, Nicks and Dents, Excessive Fouling, Pitting Corrosion, Tip Rub.	No Visible Signs of Tip Rub on Blade Tip or Damage on the Exit Guide Vane.



Injectors_Comp_Exit_Comb_Turb_1st_Stg003.JPG

Section	COMBUSTOR
Borescope Port	Fuel Injectors
Inspect for Foreign Object Damage (FOD), Cracks, Nicks and Dents, Excessive Fouling, Pitting Corrosion, Tip Rub.	No Visible Signs of Damage on Exit Guide Vane.



Injectors_Comp_Exit_Comb_Turb_1st_Stg018.JPG

Section	COMBUSTOR
Borescope Port	Fuel Injectors
Inspect for Cracks (Trailing Edge, Leading Edge, Airfoil Surface & Vane Profile), Thermal Erosion, FOD, Excessive Tip Rub, Severe Dents & Corrosion.	No Visible Signs of Damage on First Stage Turbine Nozzle Assembly and Combustion Chamber Area.



Injectors_Comp_Exit_Comb_Turb_1st_Stg019.JPG

Section	COMBUSTOR
Borescope Port	Fuel Injectors
Inspect for Cracks (Trailing Edge, Leading Edge, Airfoil Surface & Vane Profile), Thermal Erosion, FOD, Excessive Tip Rub, Severe Dents & Corrosion.	No Visible Signs of Damage on First Stage Turbine Nozzle Assembly.



Injectors_Comp_Exit_Comb_Turb_1st_Stg040.JPG

Section	COMBUSTOR
Borescope Port	Fuel Injectors
Inspect for Liners Cracks, Thermal Erosion, Hot Spots, Fuel Main & Pilot Holes Contamination or Blockage & Swirlers blockage or Cracks on Fuel Injectors.	No Visible Signs of Blockages. Removed Injectors #4, #8 & #11 to access the Combustion Chamber Area during Borescope Inspection.



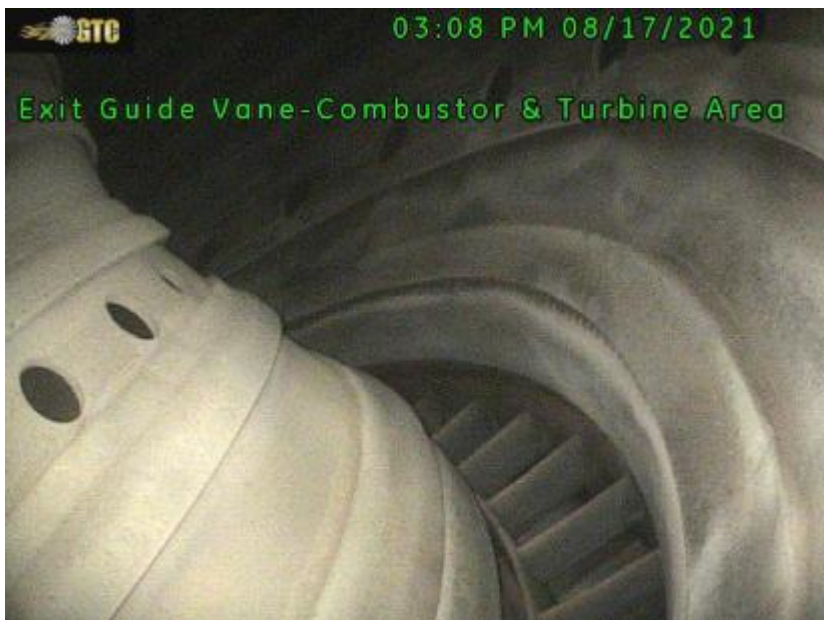
Injectors_Comp_Exit_Comb_Turb_1st_Stg041.JPG

Section	COMBUSTOR
Borescope Port	Fuel Injectors
Inspect for Liners Cracks, Thermal Erosion, Hot Spots, Fuel Main & Pilot Holes Contamination or Blockage & Swirlers blockage or Cracks on Fuel Injectors.	No Visible Signs of Blockages. Removed Injectors #4, #8 & #11 to access the Combustion Chamber Area during Borescope Inspection.



Injectors_Comp_Exit_Comb_Turb_1st_Stg062.JPG

Section	COMBUSTOR
Borescope Port	Fuel Injectors
Inspect for Cracks (Trailing Edge, Leading Edge, Airfoil Surface & Vane Profile), Thermal Erosion, FOD, Excessive Tip Rub, Severe Dents & Corrosion.	No Visible Signs of Damage on First Stage Turbine Nozzle Assembly and Combustion Chamber Area.



Injectors_Comp_Exit_Comb_Turb_1st_Stg063.JPG


Section	COMBUSTOR
Borescope Port	Fuel Injectors
Inspect for Cracks (Trailing Edge, Leading Edge, Airfoil Surface & Vane Profile), Thermal Erosion, FOD, Excessive Tip Rub, Severe Dents & Corrosion.	No Visible Signs of Damage on First Stage Turbine Nozzle Assembly and Combustion Chamber Area.

Section 5

The following report is base on what we found at the time of the survey, and it's issued in good faith.

 Shutdown condition, as per OEM settings. Possible unplanned machine failure.

 Alarm condition, as per OEM settings. The machine required attention.

 Within Normal operating range, as per OEM settings. No action is required.

TURBINE P980 - Ngp = 91.15% & Npt = 90.90%				
DATA POINT	ACTUAL	ALARM	SHUTDOWN	REMARK
1 - Accessory Drive, AD	0.16 IPS	0.6 IPS	0.7 IPS	SLIGHTLY ROUGH
2 - Engine Diffuser, GP	0.09 IPS	0.6 IPS	0.7 IPS	FAIR
3 - Power Turbine Brg Hsg	0.08 IPS	0.6 IPS	0.7 IPS	FAIR
4 - Gearbox Input	0.11 IPS	0.6 IPS	0.7 IPS	FAIR
5 - Gearbox Output	0.11 IPS	0.6 IPS	0.7 IPS	FAIR
6 - Pump Drive End	0.18 IPS	0.6 IPS	0.7 IPS	SLIGHTLY ROUGH
7 - Pump Thrust End	0.12 IPS	0.6 IPS	0.7 IPS	FAIR

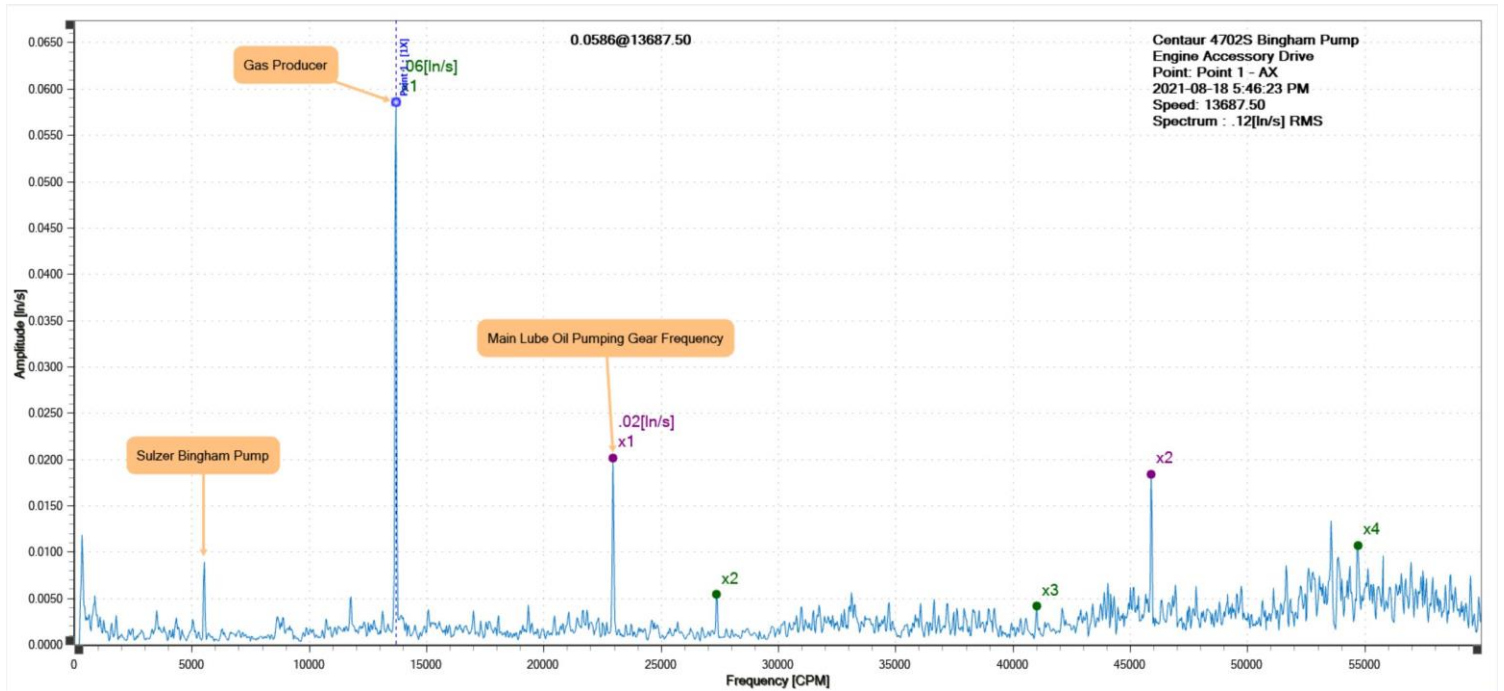
Notes & Recommendations:

Overall's vibration data are all within the OEM specifications. The high vibration malfunction occurring on the reduction gearbox output was superficial and addressed after resolving the engine's overall poor performance issue. The slight change on the pump drive end readings could result from the visible inboard pump seal damage and, as a result, leaking water on the entire skid.

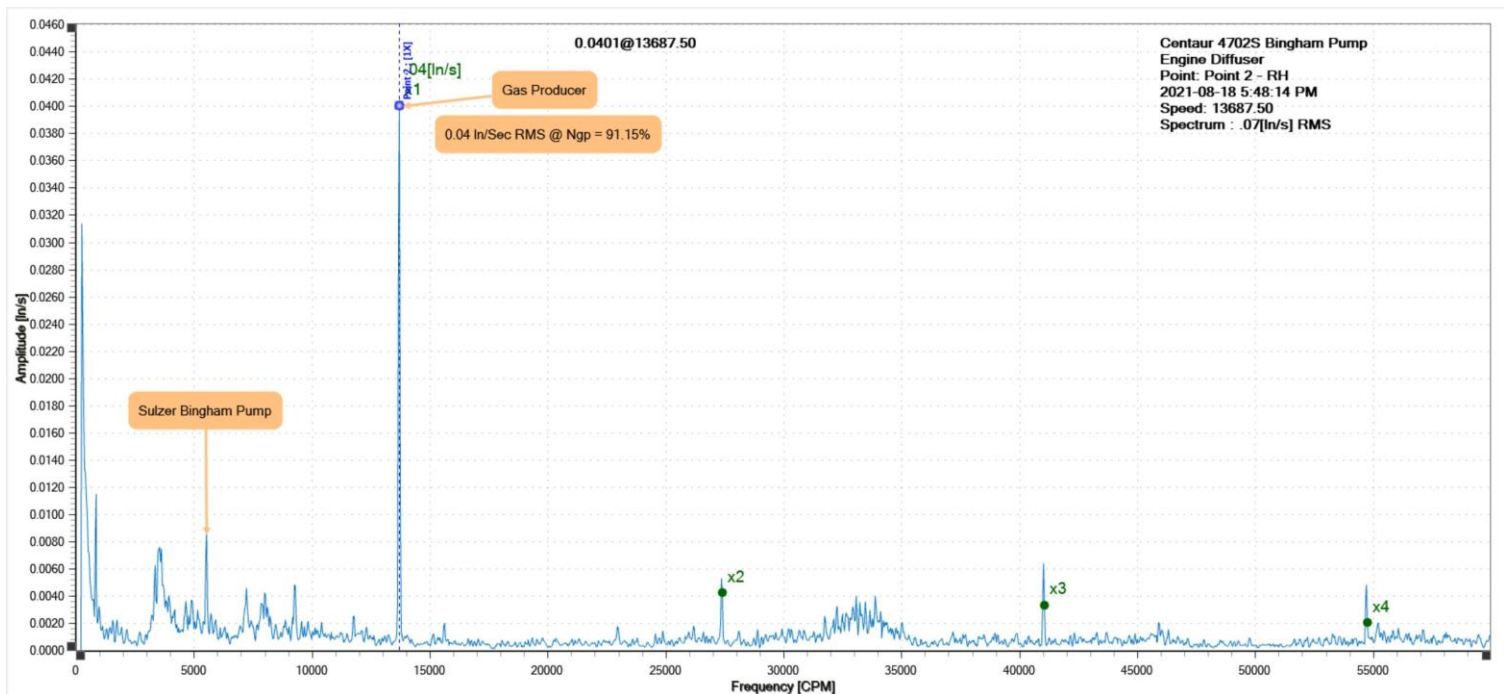
Various Data Points Vibration Signatures are as follows:

Actual overall RMS signatures are corrected to Peak (RMS x Square Root of 2)

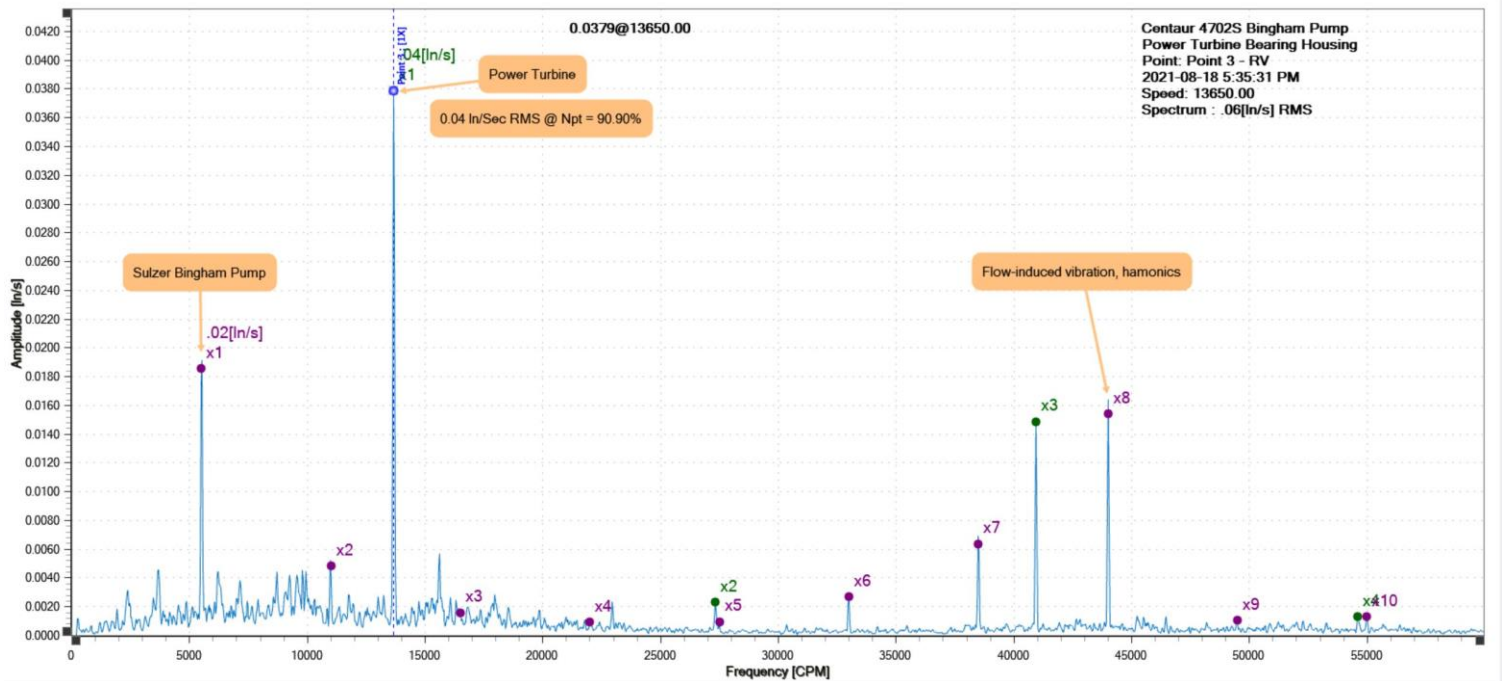
1 - ACCESSORY DRIVE, AD



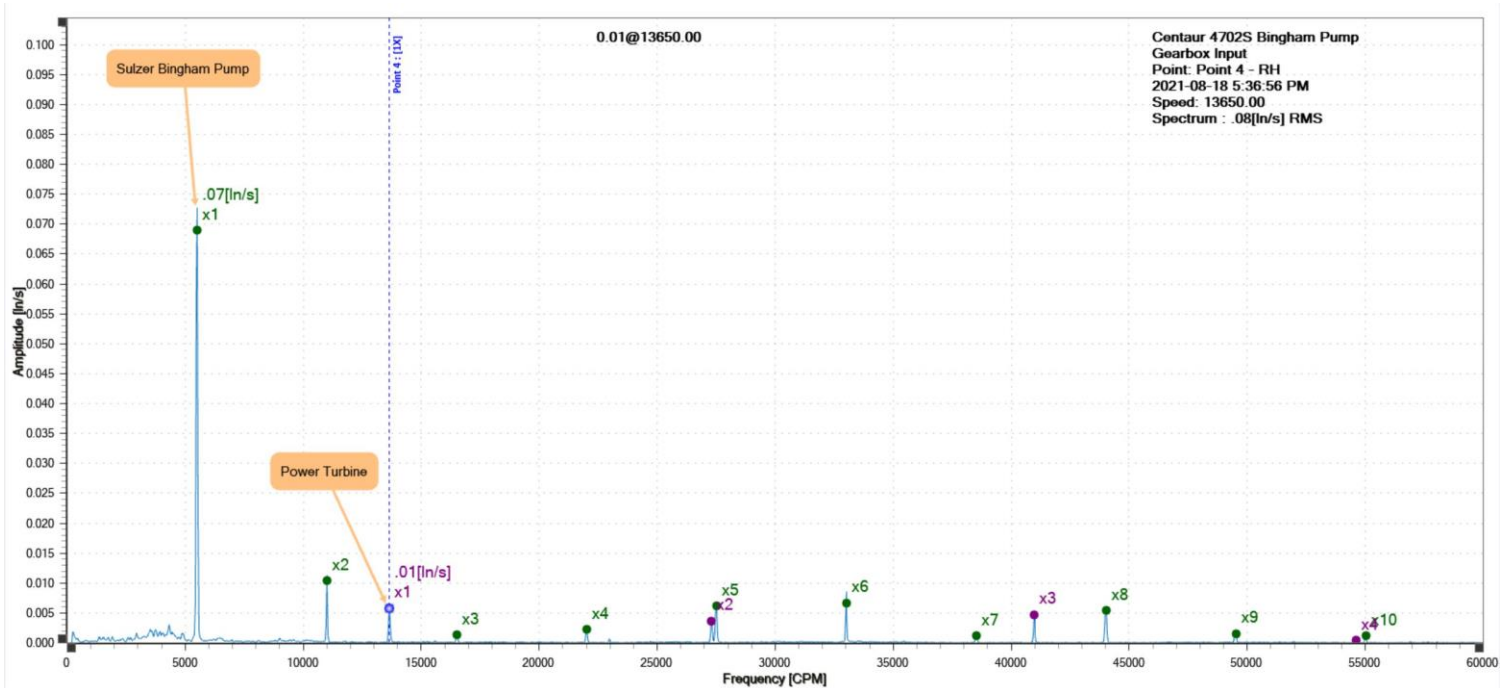
2 - ENGINE DIFFUSER, GP



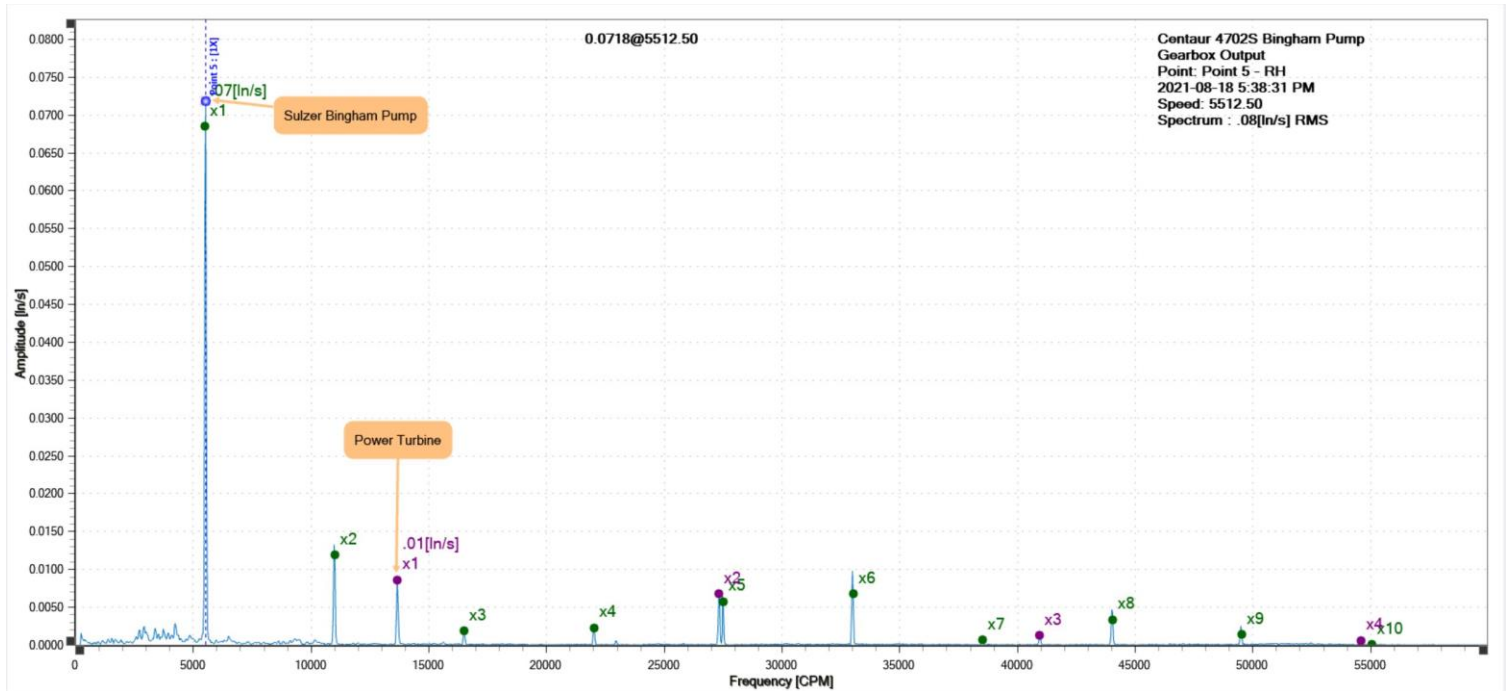
3 - POWER TURBINE BEARING HOUSING



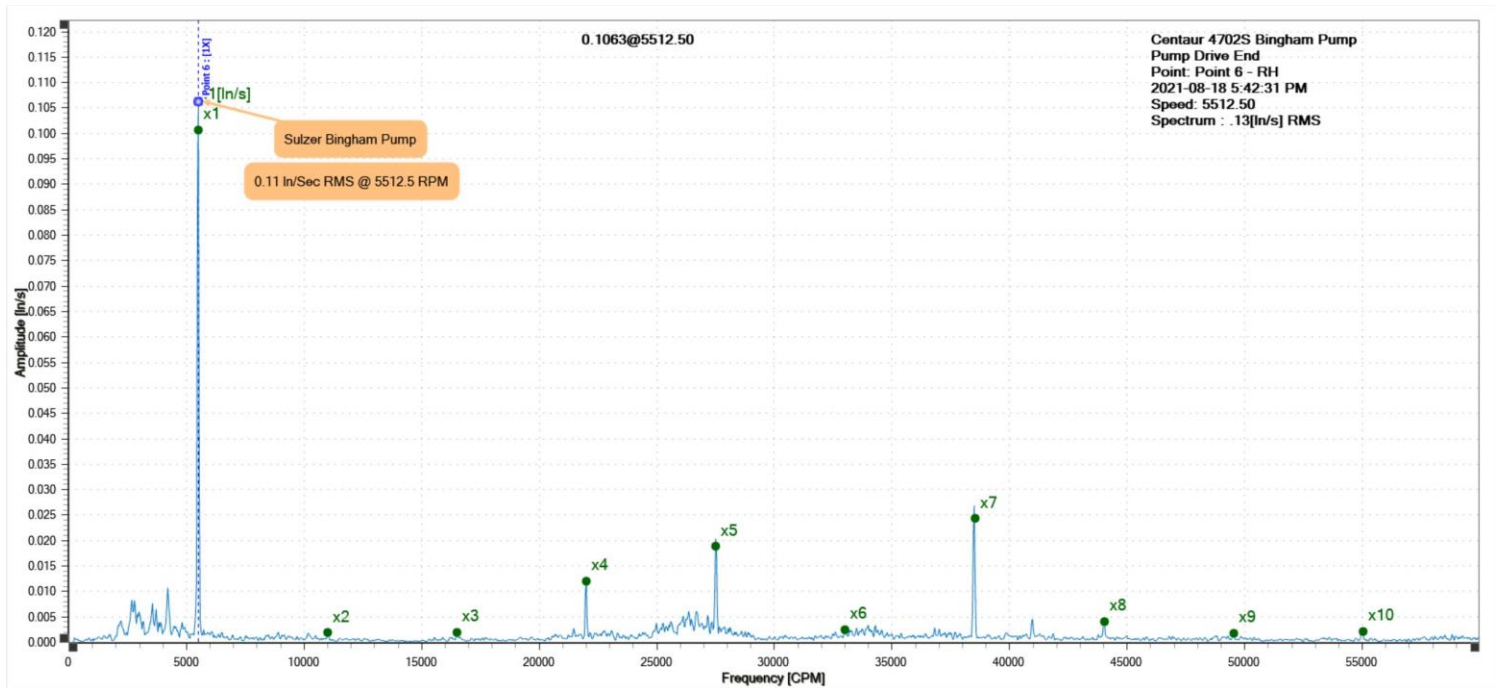
4 - GEARBOX INPUT



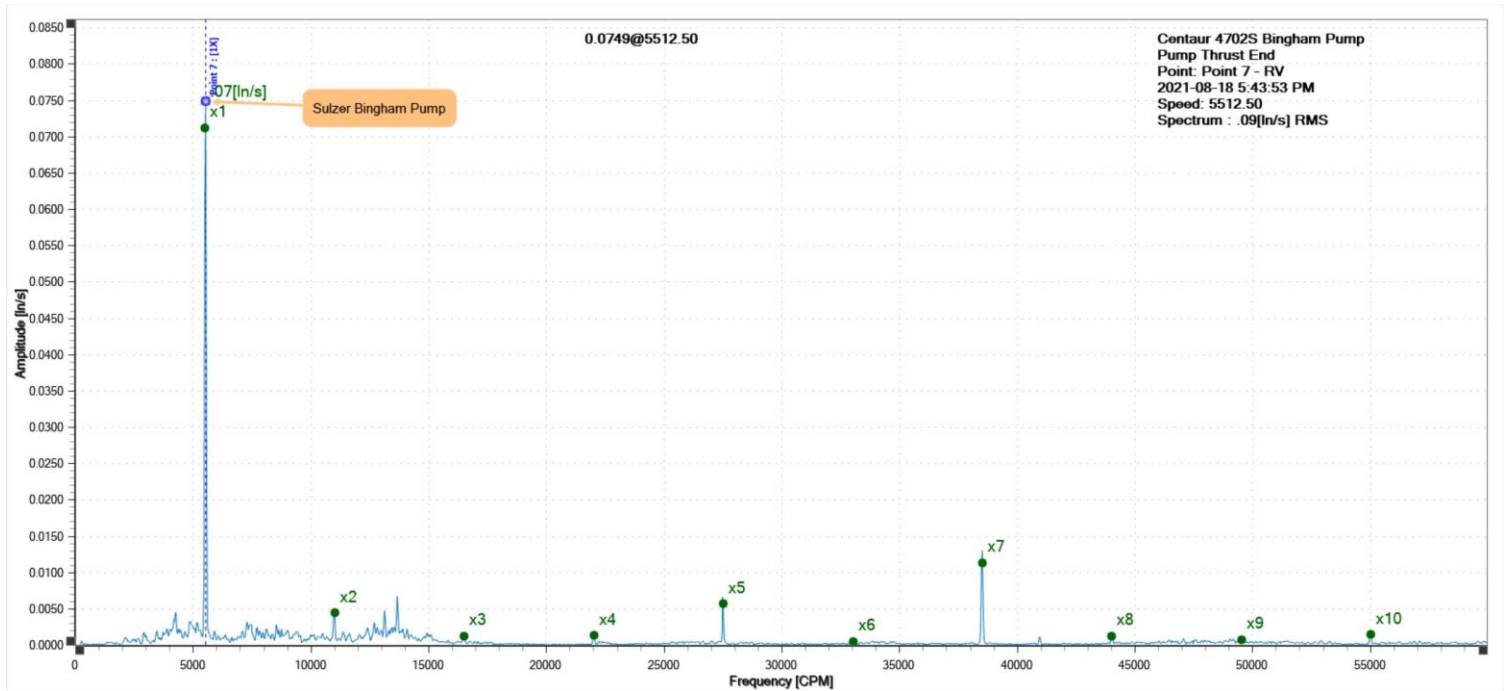
5 - GEARBOX OUTPUT



6 - PUMP DRIVE END



7 - PUMP THRUST END



Section 6

Daily Time				Action Taken		
Date	Staff	ST	OT			
16-Aug-2021	JJ Missango	7	0	Picked up air intake filters and traveled from Edmonton to Slave Lake.		
	Jeff Buckley	7	0			
17-Aug-2021	JJ Missango	8	5	Performed P980 annual Preventive Maintenance and collected vibration data. Installed new Bleed Valve.		
	Jeff Buckley	8	5			
18-Aug-2021	JJ Missango	8	7	Troubleshoot & resolved low CDP issue. Collected vibration data. Traveled back to Edmonton.		
	Jeff Buckley	8	7			
Charges						
	Days	Tech	Unit Cost	Total Cost		
Hotel Room	2	2	\$136,50	\$546,00		
Per Diem	3	2	\$75,00	\$450,00		
Transport				\$853,02		
Materials & Parts Used						
P/N	Description			Qty	Unit Cost	Total Cost
XL Vu	Borescope, specialty equipment			1	\$799,95	\$799,95
	Centaur Field Inspection Parts, Consumable			1	\$895,00	\$895,00
1027930-701	Bleed Valve Actuator Assembly			1	\$17 365,51	\$17 365,51
	Trailer rental/mileage (Air filter delivery)			1	\$198,87	\$198,87
VibWorks	Annual Vibration Analysis Survey			1	\$620,00	\$620,00
Zok 27	Turbine Compressor Cleaning Detergent			1	\$490,00	\$490,00

Section 7

- We recommend a follow-up trip to address some of the following pending issues: The electrohydraulic start system retrofit commissioning, lube oil tank demister coalescing elements replacement, troubleshoot bleed valve failure to open on shutdown (suspect Control/PLC or directional Versa valve malfunction), installation of the air intake differential pressure gauge though still on backorder for another two weeks; also, possibly address the crucial oil leakage on the hydraulic starter motor and replace the high-pressure transmission lines with flexible lines.
- Increase the blade wash frequency to twice a year; spring and fall. Combined with the yearly replacement of air filter elements will preserve optimum engine operation and minimize the excessive performance degradation due to compressor blade fouling; acquirement of a spare set of air filters is imperative at this point.