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## FIELD REPORT

### Customer

|                                  |                     |                               |
|----------------------------------|---------------------|-------------------------------|
| <b>Name:</b> Cardinal Energy Ltd | <b>Site:</b> Mitsue | <b>Contact Name:</b> Scott L. |
|----------------------------------|---------------------|-------------------------------|

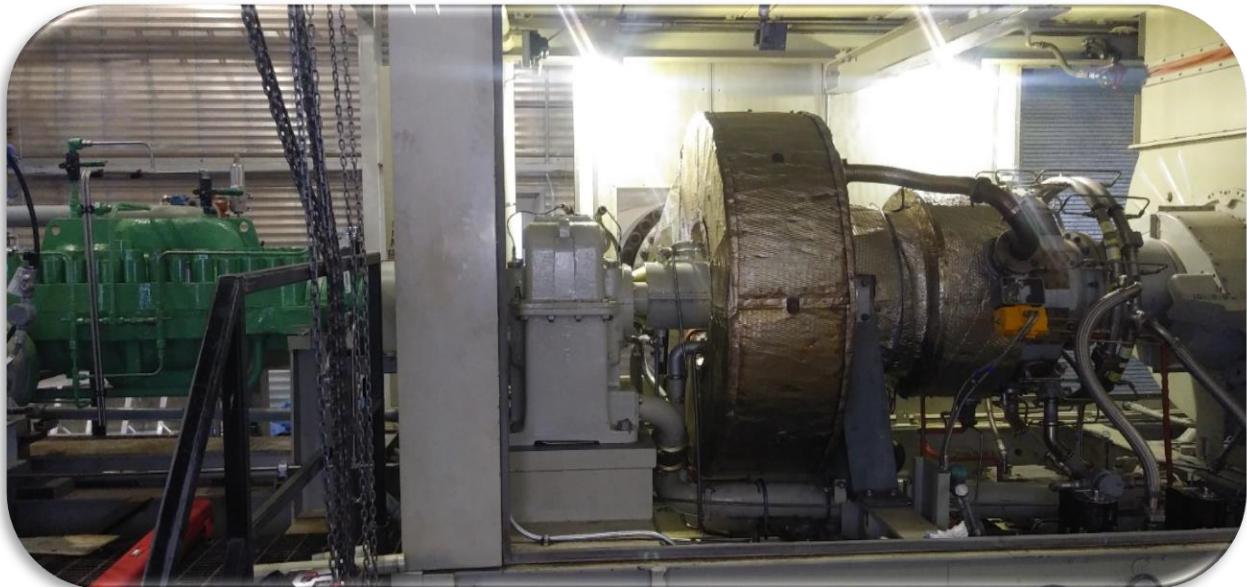
### Field Support

|                                |               |                            |
|--------------------------------|---------------|----------------------------|
| <b>Date:</b> August 17th, 2021 | <b>PO/WO:</b> | <b>FSR Name:</b> JJ / Jeff |
|--------------------------------|---------------|----------------------------|

### Turbine Engine

|                             |                                  |                         |
|-----------------------------|----------------------------------|-------------------------|
| <b>Model:</b> Centaur 4702S | <b>Customer ID:</b> Turbine P980 | <b>S/N:</b> OHE09-C1259 |
|-----------------------------|----------------------------------|-------------------------|

|                       |                       |                   |
|-----------------------|-----------------------|-------------------|
| <b>Overhaul date:</b> | <b>Hours:</b> 15606.5 | <b>Start:</b> 209 |
|-----------------------|-----------------------|-------------------|



# Contents

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Section 2: Executive summary

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Section 7: Conclusion and recommendations

## Section 1:

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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

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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

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## Monday, August 16<sup>th</sup>, 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 26<sup>th</sup>, 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 18<sup>th</sup>, 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

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### Detailed Borescope Report

Productivity through inspection solutions



## Inspection Details

|                         |                     |
|-------------------------|---------------------|
| <b>Menu Directed</b>    | CENTAUR40           |
| <b>GP Serial Number</b> | OHE09-C1259         |
| <b>PT Serial Number</b> | TUI00-C0885         |
| <b>Customer</b>         | CARDINAL ENERGY LTD |
| <b>Site</b>             | mitsue              |
| <b>Model</b>            | 4702 SOLONOX        |
| <b>Package Hours</b>    | 15606.5             |
| <b>Engine Hours</b>     | 15606.5             |
| <b>Engine Starts</b>    | 209                 |
| <b>Inspector</b>        | JJ / JEFF           |
| <b>Date</b>             | 17 August 2021      |
| <b>Time</b>             | 11:15:43            |

| <b>Inspection Summary</b>                                                                               |                          |               |                       |
|---------------------------------------------------------------------------------------------------------|--------------------------|---------------|-----------------------|
|                                                                                                         | <b>Inspection Points</b> | <b>Images</b> | <b>Flagged Images</b> |
|  <b>AIR INLET</b>       | 1                        | 13            | 0                     |
|  <b>COMBUSTOR</b>       | 1                        | 72            | 0                     |
|  <b>TURBINE</b>        | 1                        | 7             | 0                     |
|  <b>TRUNNION BOLT</b> | 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.<br><br>Significant contamination.<br><br>Some Flaking Paint Chips from the Air Inlet Duct stopped by the Intake Mesh Screen. |



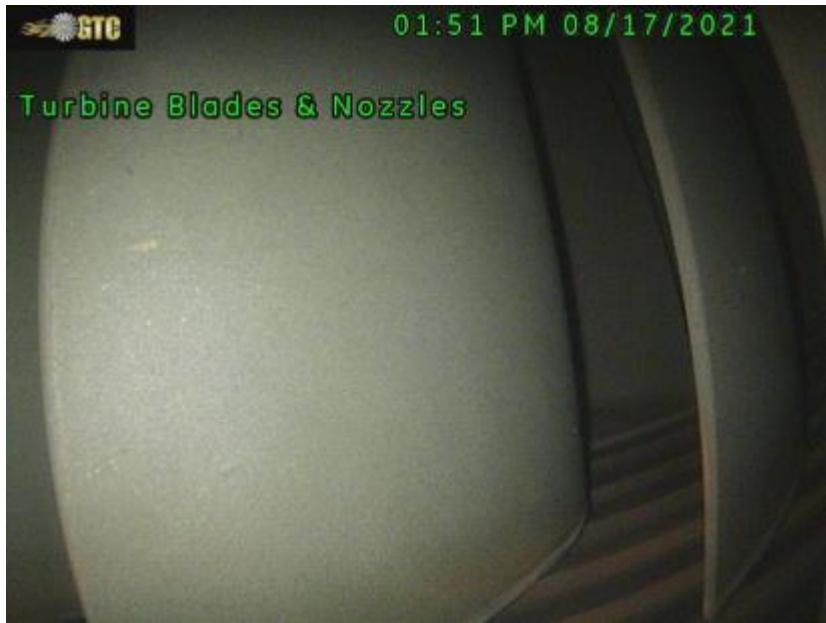
IGV\_Comp\_Rotor\_Stator006.JPG

|                                                                                                                               |                                                                                                                                                             |
|-------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 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.<br><br>Significant contamination.<br><br>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.<br>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. |



01:53 PM 08/17/2021

Turbine Blades &amp; Nozzles



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). |



02:38 PM 08/17/2021

PT Blades &amp; Exhaust Struts



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. |



11:49 AM 08/17/2021

Exit Guide Vane-Combustor & Turbine Area



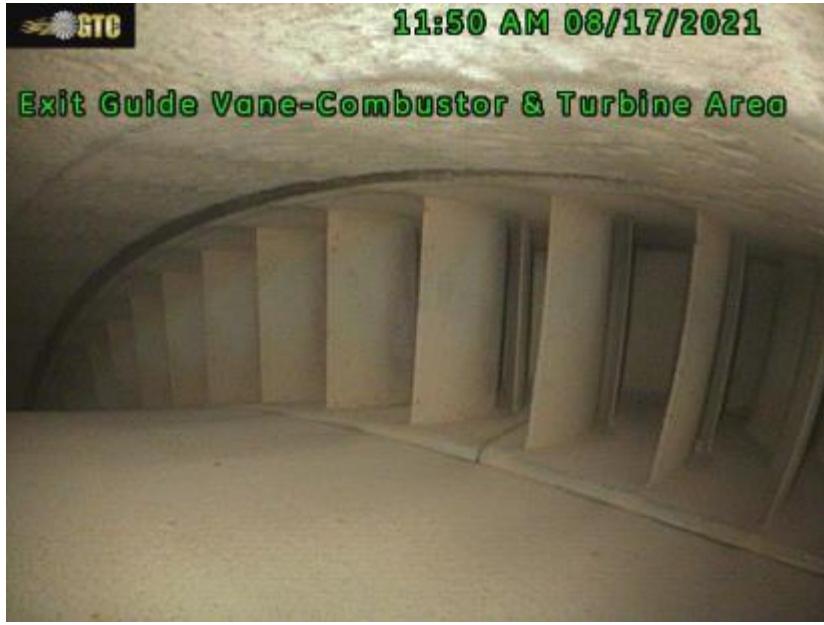
Injectors\_Comp\_Exit\_Comb\_Turb\_1st\_Stg002.JPG

|                                                                                                                  |                                                                            |
|------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| 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. |



11:50 AM 08/17/2021

Exit Guide Vane-Combustor & Turbine Area



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. |



12:17 PM 08/17/2021

Exit Guide Vane-Combustor & Turbine Area



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. |



12:19 PM 08/17/2021

Exit Guide Vane-Combustor & Turbine 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<br>Cracks, Thermal<br>Erosion, Hot Spots, Fuel<br>Main & Pilot Holes<br>Contamination or<br>Blockage & Swirlers<br>blockage or Cracks on<br>Fuel Injectors. | No Visible Signs of<br>Blockages.<br><br>Removed Injectors<br>#4, #8 & #11 to<br>access the<br>Combustion<br>Chamber Area<br>during Borescope<br>Inspection. |



Injectors\_Comp\_Exit\_Comb\_Turb\_1st\_Stg041.JPG

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



03:07 PM 08/17/2021

Exit Guide Vane-Combustor & Turbine Area



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. |



03:08 PM 08/17/2021

Exit Guide Vane-Combustor & Turbine 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

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***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           |

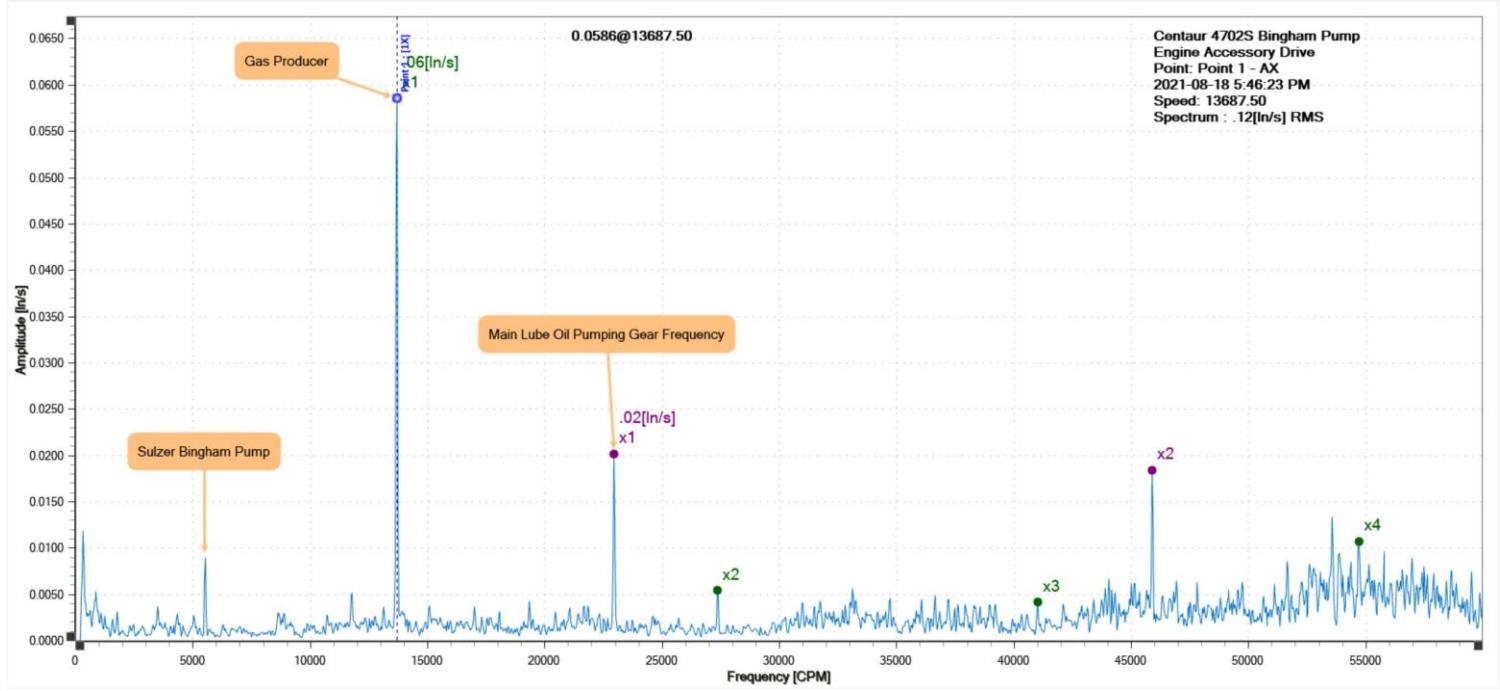
## Notes & Recommendations:

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.

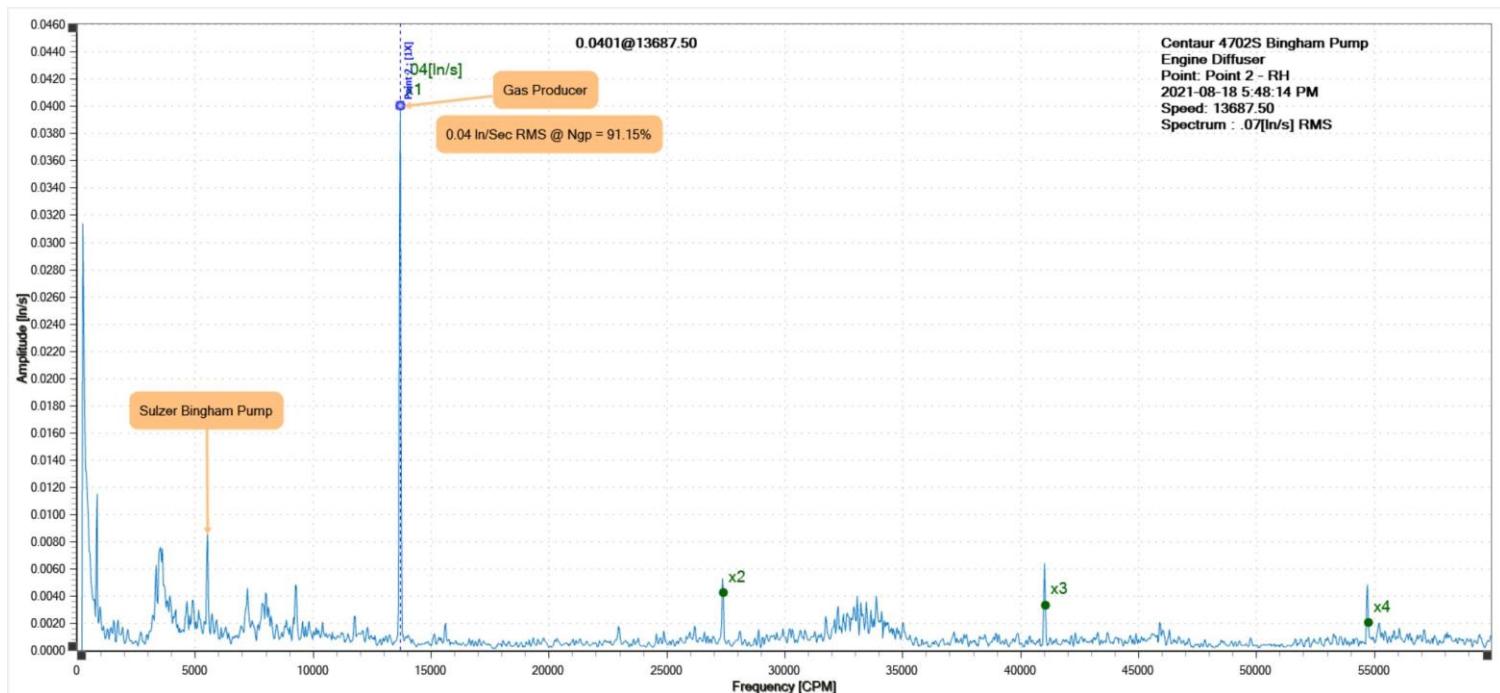
## Various Data Points Vibration Signatures are as follows:

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

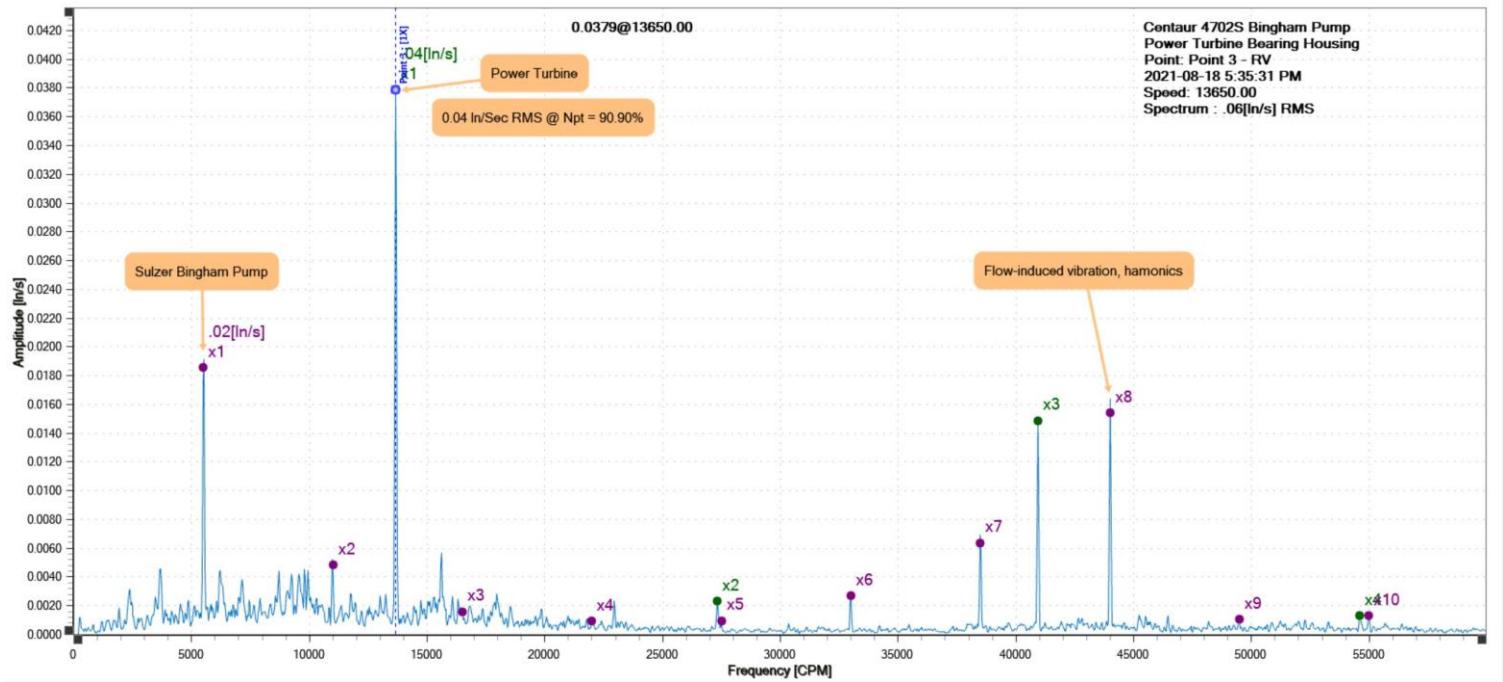
## 1 - ACCESSORY DRIVE, AD



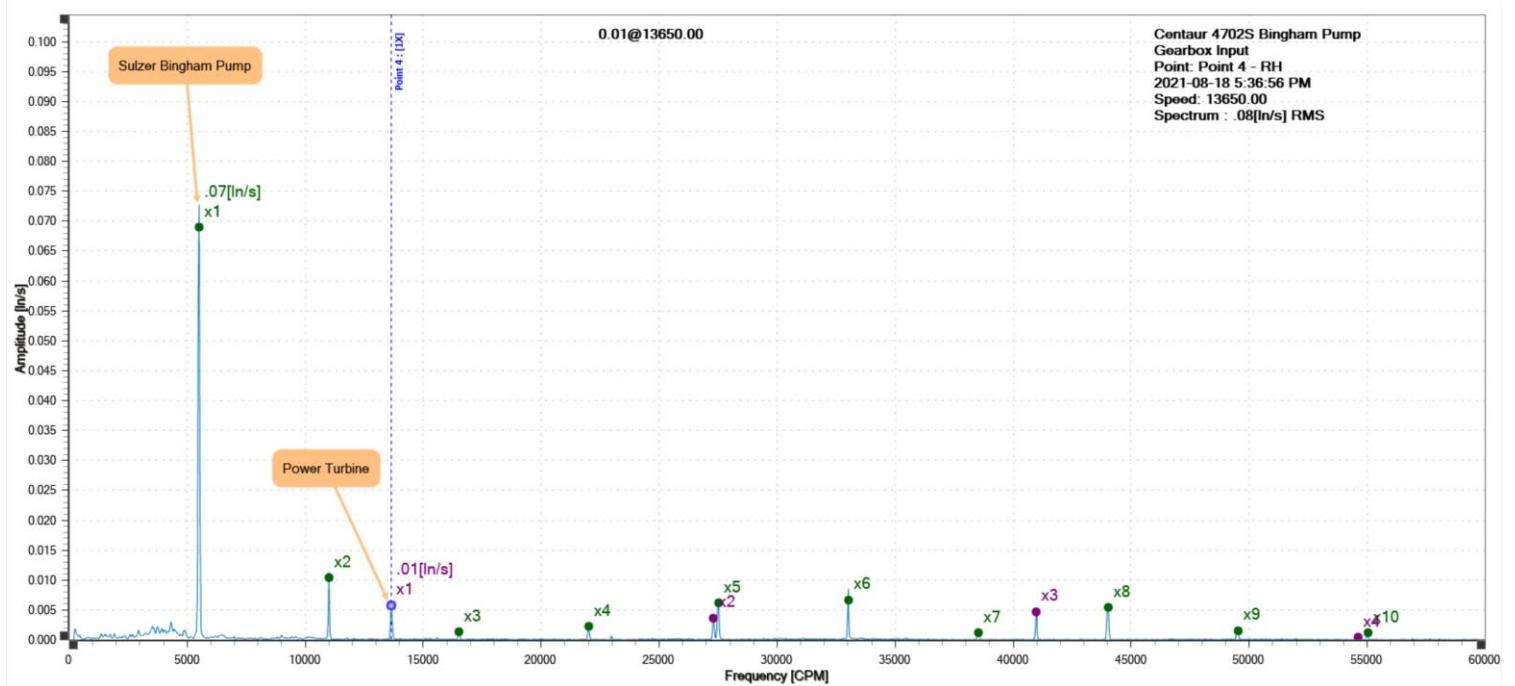
## 2 - ENGINE DIFFUSER, GP



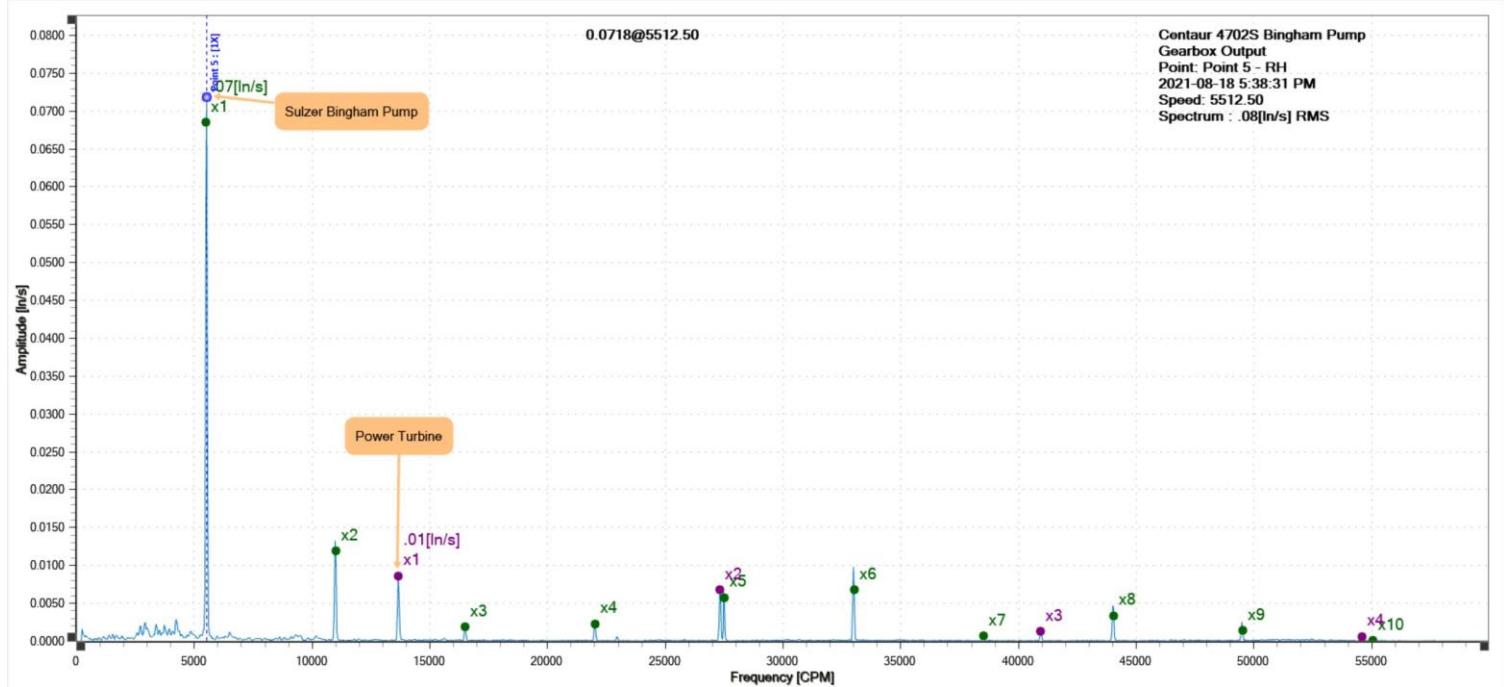
### 3 - POWER TURBINE BEARING HOUSING



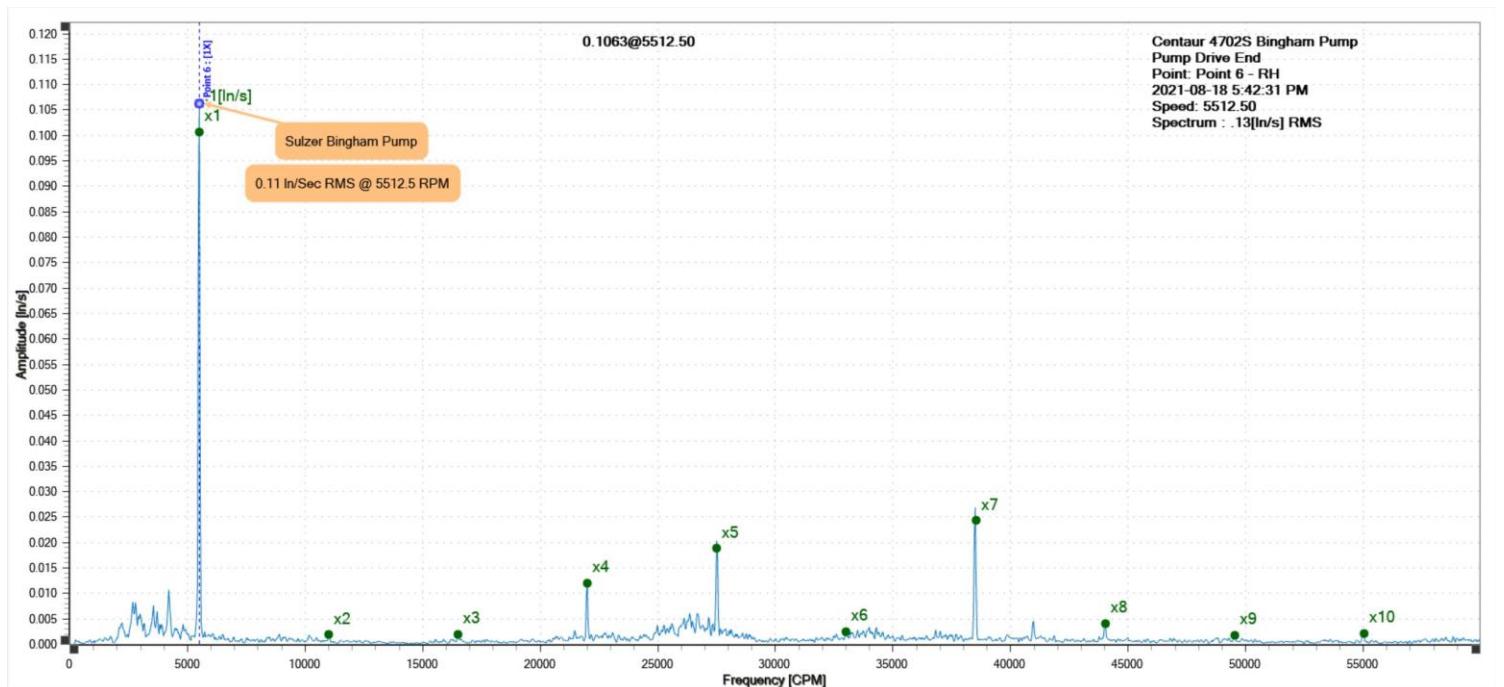
### 4 - GEARBOX INPUT



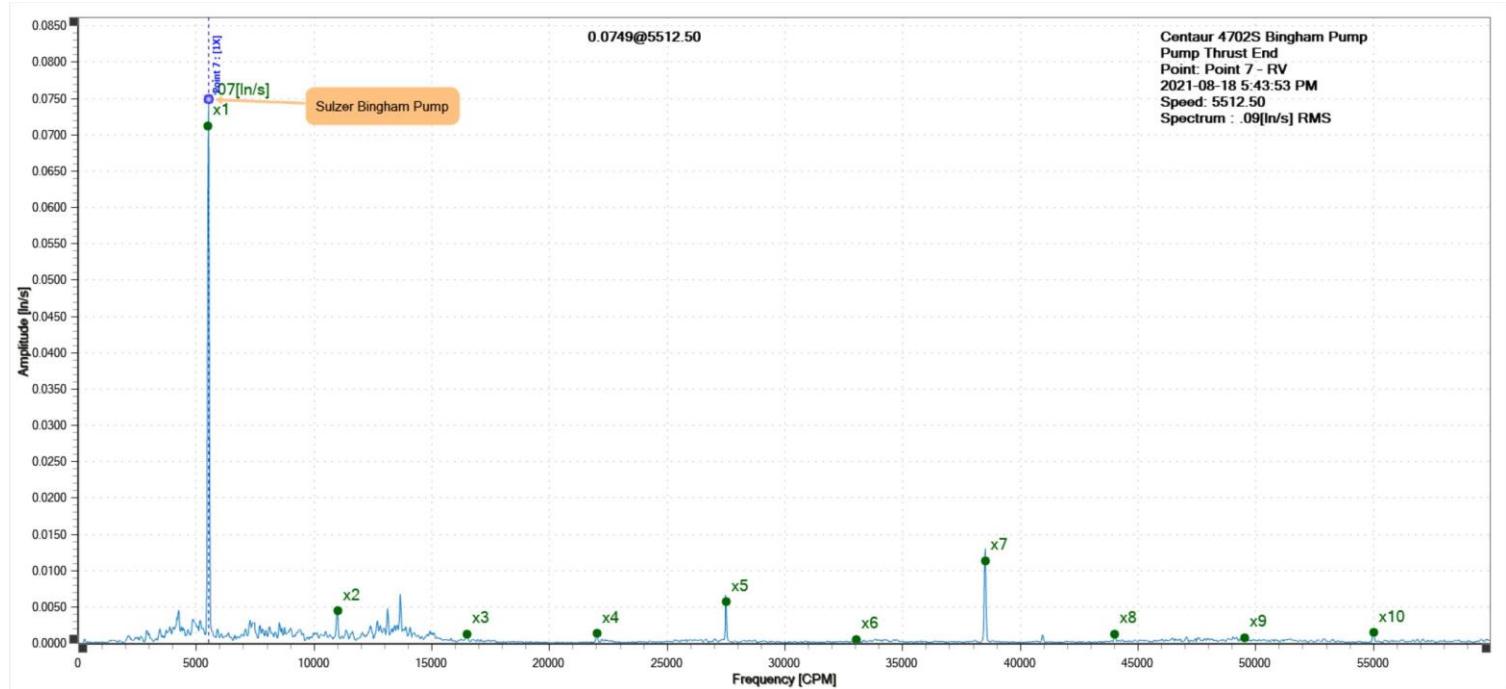
## 5 - GEARBOX OUTPUT



## 6 - PUMP DRIVE END



## 7 - PUMP THRUST END



## Section 6

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| 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   |
| XL Vu                  | Borescope, specialty equipment               |  |  | 1   | \$799,95    |
|                        | Centaur Field Inspection Parts, Consumable   |  |  | 1   | \$895,00    |
| 1027930-701            | Bleed Valve Actuator Assembly                |  |  | 1   | \$17 365,51 |
|                        | Trailer rental/mileage (Air filter delivery) |  |  | 1   | \$198,87    |
| VibWorks               | Annual Vibration Analysis Survey             |  |  | 1   | \$620,00    |
| Zok 27                 | Turbine Compressor Cleaning Detergent        |  |  | 1   | \$490,00    |

## Section 7

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- 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.