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July 4, 2017

Board of Commissioners of Public Utilities
Prince Charles Building
120 Torbay Road, P.O. Box 21040
St. John's, NL A1A 5B2

**Attention: Ms. Cheryl Blundon**
**Director of Corporate Services & Board Secretary**

Dear Ms. Blundon:

**Re: A Report by Newfoundland and Labrador Hydro (Hydro) pursuant to Order No. P.U. 22(2016) regarding the refurbishment of the gas generator engines at the Hardwoods Gas Turbine Plant and the Stephenville Gas Turbine Plant –Updated Report**

Enclosed please find the original plus 9 copies of Hydro's updated report on the failure analysis, including recommendations for long-term reliability.

Should you have any questions, please contact the undersigned.

Yours truly,

***NEWFOUNDLAND AND LABRADOR HYDRO***

Michael Ladha
Legal Counsel & Assistant Corporate Secretary

TLP/bs

cc: Gerard Hayes – Newfoundland Power
Paul Coxworthy – Stewart McKelvey Stirling Scales
Sheryl Nisenbaum – Praxair Canada Inc.
Dennis Browne, Q.C. – Consumer Advocate
Thomas J. O'Reilly, Q.C. – Cox & Palmer
ecc: Larry Bartlett – Teck Resources Ltd.

# Gas Turbine Failure Analysis Recommended Actions

# Implementation Update

July 4, 2017

*A Report to the Board of Commissioners of Public Utilities*

newfoundland labrador hydro
a nalcor energy company

## Executive Summary

During the winter of 2016, in-service engine failures occurred at Newfoundland and Labrador Hydro's (Hydro) Stephenville and Hardwoods gas turbine facilities. On February 8, Hardwoods End A suffered a combustion can failure. On March 26, Stephenville End A suffered a low pressure compressor number 2 bearing failure. In both cases, damage was extensive and the units required refurbishment.

A failure analysis was completed for each engine failure to determine the root cause(s) and through the process of investigation and analysis a number of potential causes were identified, as well as a number of recommendations for improvement. In addition, a consultant, Performance Improvements Limited (PI), was engaged to review Hydro's operation and maintenance practices and provide recommendations for improvement of these practices to ensure reliable operation into the future. The final report by PI has now been received, which includes their final recommendations related to the aspects of operation, monitoring, control and maintenance of the gas turbines.

This report provides a further update on the progress of implementation of the recommendations arising from the root cause analyses and from PI's review, as committed to in the Gas Turbine Failure Analysis Recommended Actions Implementation Update submitted to the Board of Commissioners of Public Utilities (the Board) on April 17, 2017.

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## 1.0 Background

During the winter of 2016, in-service engine failures occurred at Newfoundland and Labrador Hydro's (Hydro) Stephenville and Hardwoods gas turbine facilities. Both engines were shipped to Alba Power Limited (Alba Power) for detailed inspection and refurbishment. In addition to this work, analysis was carried out to determine the root cause(s) of the failures, and recommendations were investigated to improve reliability of the two generation plants.

This report is the further update committed in the update report submitted to the Board on April 17, 2017. This report provides an update of continued progress of the implementation of recommendations resulting from the root cause analyses of the engine failures.

Through AMEC Foster Wheeler, Hydro engaged consultant Performance Improvements Limited (PI), with expertise in gas turbines, to oversee the failure analysis process for the Stephenville engine and expanded the engagement with this gas turbine expert to review Hydro's operational and maintenance practices with the aim of confirming existing practices and making recommendations for improvement.

## 2.0 Failure Analysis Recommendations

The root cause analyses of the engine failures were completed by Alba Power, with input from Hydro technical staff and the involvement of PI. These analyses resulted in the identification of potential root causes of the failures as well as a number of recommendations for improving the protection, operation and reliability of the engines as described in the following sections.

The potential contributing factors in the Hardwoods failure were determined to be related to fuel quality, nozzle/burner defects or contamination, and changes in operating temperature within the engine. PI suggested the most probable cause of the Stephenville engine failure to be lube oil condition (breakdown of the oil's capability to maintain a lubricating film), and offered a potential secondary cause of lube oil contamination (particulate in the oil). While

vibration monitoring was not identified as a root cause of the Stephenville engine failure, PI recommended a review and potential improvement related to this aspect of unit monitoring. As a result of the investigation and failure analysis into both engine failures, the following recommendations were made:

1. Initiate fuel sampling to ensure fuel quality.
2. Review and adjust alarm and trip settings for exhaust gas temperature spread and adjust as necessary.
3. Increase borescope inspection frequency to identify any indications of combustion chamber deterioration.
4. Review the control system logic related to acceleration/deceleration curves to ensure they are within specifications.
5. Carry out a review of the vibration protection settings and adjust as necessary.
6. Review maintenance schedule for appropriate actions for step changes in vibration and appropriate actions for alarms.
7. Review the complete oil system to ensure oil cleanliness and that filtration is adequate.
8. Continue to clean and flush oil system prior to re-installation of the gas turbines post overhaul.
9. Consider the addition of an off engine filter between the lube oil tank and the engine.
10. Review and adjust as necessary maintenance schedules for oil sampling and analysis, and oil replacement to remove any potential future concern with oil quality.

These recommendations, while provided in relation to specific failures, apply to both the Hardwoods and Stephenville sites. All items, with the exception of items 4 and 9 have been completed, as discussed in Section 4 of this report.

# 3.0 Performance Improvements Limited Operational and Maintenance Review

PI's operational review of the Hardwoods and Stephenville facilities has generated the following observations and recommendations, in addition to those resulting from the failure analyses. The following is a summary of the recommendations by system only, with further discussion related to these recommendations located in the PI report, included as Appendix A of this report.

## 3.1 Vibration Monitoring

1. Configure relay outputs as high vibration trips and incorporate into a trip string (see Section 4.9).
2. Consider installing a compliant monitoring system and incorporate into a safety instrumented system.

## 3.2 Lube Oil System

1. Do not install a new filter in the lubricating oil supply line but ensure the filter in the scavenge return is effective:
    a. Install a differential pressure transmitter measuring the differential across the lubrication oil (LO) filter, display the reading at the control room and provide high and low alarms.
    b. Monitor the filter differential pressure (DP) throughout the service life of the cartridge. Install analogue reading device so that high, low, and healthy DP can all be confirmed.
    c. Check the set points of the filter internal bypass and high pressure/differential alarm against the filter elements being used.
    d. Adjust alarm points based on operational experience to allow adequate headroom over operating conditions but maximize sensitivity.

e. Ensure documentation is updated; for example, the Curtiss Wright manual specifies 15 psig[1], which is too high.
f. Carry out regular element changes.

2. Monitor condition of oil by sampling. Changes in the following parameters are possible indicators of developing problems:
   a. Iron content.
   b. Oxidation and increased acidity indicate deterioration, which may be associated with, or may lead to, bearing failure.
   c. Presence of $NO_x$, $CO_x$ and $SO_x$ is likely to result from contact with combustion gases and is likely to be associated with oxidation of the oil.
3. Lubricating oil takeoff and check lubricating oil before machine start:
   a. Install a valve on the gas generator lubricating oil tank drain point, e.g., reduce and use ½" instrument valve.
   b. If practical, change the draw off point to elevate it above the tank bottom.
   c. If b above cannot be achieved, when there has been a downtime period of days or more for the turbine, sample oil at the tank drain point to ensure cleanliness.
4. Continue to check chip detectors after each running period.
5. Consider installing online chip detection of a type which will detect the type of debris characteristic of rolling element bearings. If the engines are to run for extended periods this could give warning of a developing fault.

## 3.3 Fuel system

1. Install an additional liquid fuel shut off valve downstream of the mechanical fuel pumps, such as the Woodward LSOV25 Liquid shutoff valve, which is IEC 61511 compliant.
2. Control fuel shut off valves independently from the Basic Process Control System (BPCS) using a trip string.
3. Replace LF-7 (Atkomatic 32480) liquid fuel recirculation valve with a fail close valve.
4. Install check valves in the recirculation lines to back up the new LF-7 valve.

[1] Pounds per square inch gauge.

5. Remove the supplemental fuel pump from the fuel system at Stephenville. Remove redundant pipework from both sites to reduce potential for fuel leakage.
6. Implement logic to trip the turbine on significant mismatch between fuel demand, fuel valve position and fuel flow.

## 3.4 Manual Shut Down and Trip

1. Install a trip string as a second layer of protection independent of the BPCS.
2. Install clearly labelled E-Stop push buttons at the package.
3. Install clearly labelled E-Stop push buttons at the office, workshop buildings, and near exit gates.
4. Incorporate all E-Stop push buttons into the trip string.
5. The external fuel block valve with manual activation should be identified with clear instruction on how to shut in an emergency.
6. Related to the Hardwood site, the gas generator A external fuel valve LF-8 position switch should be wired back to the fire panel.
7. Related to the Hardwood site, gas generators A and B external fuel valve arrangements should be modified to make access to the handles straightforward.

## 3.5 Fire Protection

1. Install flame detectors and also consider oil mist detection, reporting to the existing fire system, if compatible (otherwise provide the necessary signal processing).
2. Verify that the fire protection system is routinely inspected and tested, and that inspection includes checks that ensure the enclosure is sufficiently leak tight and ventilation dampers operate for the extinguishant to be effective.
3. Ensure there are sufficient manual extinguishant release points.
4. Incorporate a fire trip into the trip string.
5. Install locks on the enclosure doors under control of the site operator.
6. Consider providing door open indication at the control room.

### 3.6 Mechanical Aspects

1. Install independent over speed protection.
2. Consider replacement of the bellows with new.

PI's review of Hydro's maintenance strategy and procedures has resulted in recommendations related to maintenance scope, frequency, and documentation. Further discussion of the specifics of the review and the resulting recommendations is contained in Section 5 of this report.

These items have been considered and several changes, as detailed in Section 5, have been made. Further review of the maintenance strategy, preventative maintenance program, and documentation is ongoing to ensure that it is complete and adequate. The preventative maintenance strategy is reviewed annually and revised, as required, based on operational experience and maintenance information.

## 4.0 Operational Improvement

As a result of the analyses and reviews completed, a number of operational changes have been identified, which are expected to improve the operation of both units and enhance their future short and long term reliability. The following sections describe the current status of the various systems and components and the recommended changes.

### 4.1 Vibration Monitoring

Hydro's gas turbine vibration monitoring systems conform to the original equipment manufacturer (OEM) recommendations for vibration monitoring, with the exception of vibration monitoring location. These systems utilize accelerometer-based monitoring with protection settings as recommended by the OEMs for the engines. Through the engine failure analyses and site reviews, further upgrades have been recommended and investigated to enhance the current systems' operation and effectiveness.

### 4.1.1 Vibration monitoring location

During a review of the vibration monitoring system for the engines, an alternate vibration monitoring location recommended by the engine OEM, Rolls Royce, was investigated. The original location for the vibration monitoring was recommended by the package (power turbine and all off engine auxiliaries) OEM, Curtiss Wright Power Systems (Curtiss Wright). Due to the design of Curtiss Wright supplied pipes and ductwork, it is not possible to measure vibration at the Rolls Royce recommended location with the accelerometer design currently installed at the original location. Review of alternative low profile, high temperature accelerometers, which might fit in the recommended location, has resulted in several potential accelerometers that may fit the recommended location and be able to be incorporated into the vibration monitoring system. Hydro is in the process of procuring the equipment necessary to test an accelerometer at this location to ensure its suitability. Should the test prove successful, Hydro will install this accelerometer at the recommended location on all units. It is expected that this work will be completed prior to the 2017/2018 winter operating season.

### 4.1.2 Vibration settings

Review of the vibration alarm and trip settings has confirmed that the current alarm and trip settings are in agreement with the OEM recommended limits (Rolls Royce Service Bulletin 402, May 2000). However, further review has indicated that there are time delays associated with the activation of these alarms and trips that impact the timing of their activation. PI's recommendation is to limit the delay to a maximum of 1 second on both the alarm and trip settings. However, Rolls Royce recommends a 0.2 second delay be applied to the alarm and trip settings. Hydro has implemented the Rolls Royce recommended settings.

## 4.2 Lube Oil System

The existing engine lube oil systems are original to the units and have not been modified since their initial installation and commissioning. A review of the entire system, its monitoring, operation, and maintenance, has resulted in improvements being identified and implemented to enhance the operation and effectiveness of these systems.

### 4.2.1 Lubricating oil

The lube oil being used in the engines has been reviewed and confirmed to be appropriate for the service. Rolls Royce Service Bulletin 429, dated September 2007, includes Mobil Jet II as approved oil for Olympus C-rated engines.

### 4.2.2 Lube oil sampling and analysis

Due to concerns raised related to oil handling, sampling, and analysis, specifically the condition of the lube oil prior to failure, a review of Hydro's procedures related to oil sampling and analysis has been initiated and Hydro has included this review in the engagement with PI.

Hydro has increased the frequency of its lube oil sampling and analysis to monthly, from previous intervals of first annually and then quarterly. While this is a frequency greater than the OEM recommended level of monitoring (three month intervals), Hydro has taken this step to allow consistent review of oil quality and to inform the eventual decision on the appropriate monitoring frequency based on the current level of operation.

Additionally, a review of the analysis performed on the oil samples was undertaken to confirm that the analysis being completed is appropriate and being conducted in accordance with OEM recommendations and industry standard practice. Rolls Royce service bulletin 429 (September 2007) provides guidance related to oil sampling. Hydro has decided to perform a complete analysis package on all lube oil samples. Once sufficient data has been obtained, this level of analysis may be adjusted to include only those items that are of specific concern to the operation of the gas turbines.

Hydro has also previously initiated annual lube oil replacement and lube oil system cleaning, including filter replacement, which is completed prior to the winter operating season each year.

### 4.2.3 Lube oil filtration

Alba Power recommended that Hydro install additional lube oil filtration on the outlet of the tank before the engine. The review of this proposal was included in PI's scope of work.

PI's initial review did not produce a definitive recommendation; however, further evaluation has resulted in a recommendation in the final report to not add the proposed filter to the existing system. PI has provided specific recommendations for improvements to the existing system related to monitoring and control of the scavenge filter. Hydro is reviewing the implementation of these recommendations and will implement as it deems practical and appropriate. This implementation will require engineering design and procurement prior to completion.

In addition, Hydro has procured and now utilizes filter carts that incorporate water removal as well as particulate filtration to the 5 micron levels that are used in filtering the oil as it is pumped into the lube oil reservoir during oil changes. This ensures the quality of oil entering the unit during operation.

### 4.2.4 Lube oil heating

The engine lube oil is heated by a thermostatically controlled heater located in the lube oil tank. The function of the heater has been previously tested and proven to be operating correctly in all engine lube oil systems.

Additional testing and monitoring of the lube oil tank heater during site commissioning of engine number 202205 in Hardwoods End A has confirmed that it functions within specified limits during operation. Therefore, it was concluded not to have had a detrimental effect on oil condition and no further changes to this system are required or planned. Further testing of the heater control on both units at Stephenville confirmed that the heater controls were operating as they should on both units.

### 4.2.5 Lube oil tank modifications

PI has proposed modifications to the lube oil tank to limit carry over of lube oil contaminants to the oil being delivered to the engines. Hydro will review the practicality of making this modification. If the modification cannot be made, additional monitoring of the oil related to contamination will be implemented as recommended by PI.

### 4.2.6 Magnetic chip detectors

PI has recommended that Hydro consider the installation of an online magnetic chip detection system, which will detect the type of debris characteristic of rolling element bearings and has provided information on systems that may be appropriate. Hydro will investigate the installation of online monitoring of engine wear debris in the lube oil system. In the interim, Hydro has commenced monthly inspection of the magnetic chip detectors on all its units and will continue to check after every run of the engines.

## 4.3 Borescope Inspections

It is recommended that the frequency of borescope inspections be increased to help identify any potential issues with combustion section components. Hydro was completing these inspections once a year and has now increased the frequency of borescope inspections to twice a year, as recommended by Alba Power. To date, inspections have been completed on both units in Stephenville and inspections are planned for the units at Hardwoods. The units at both sites will be inspected again in the fall, prior to the 2017/2018 winter operating season.

## 4.4 Exhaust Gas Temperature Spread

A review of all alarm and trip settings related to combustion section operation has been completed. The alarm and trip settings as found were in accordance with OEM recommendations, as noted in Rolls Royce Service Bulletin 188 (April 1977) and were set as follows:

Alarm – 50°C;

Shut down – 60°C; and

Trip – 65°C.

While the settings were found to be in accordance with OEM recommendations, given the experience of the combustion can failure, the settings have now been modified as follows:

Alarm – 40°C;
Shut down – 50°C; and
Trip – 55°C.

Further, an operating instruction has been implemented that requires shut down of the unit when the exhaust gas temperature (EGT) spread reaches the alarm set point. A borescope inspection of the unit is then to be completed to determine the condition of the combustion section and its suitability for further operation prior to returning the unit to service.

## 4.5 Fuel Systems

A number of recommendations have been made related to the fuel systems for the units. The fuel systems at all sites are being inspected and components replaced as necessary as part of the life extension projects at each site this year. These projects include the replacement of obsolete components and the addition of improved monitoring and control of the fuel system.

### 4.5.1 Fuel sampling and analysis

Hydro has completed fuel sampling and analysis to ensure the quality of fuel being delivered to its gas turbine facilities. Fuel samples were taken at Hardwoods, in a location recommended by Alba Power, and sent for analysis to ensure the fuel meets Hydro's specifications and also to ensure that the fuel was within the additional specifications/limits that Alba Power recommended for contaminants. The fuel supplied to both sites is from the same supplier and thus would generally be expected to have the same quality. The analysis results have confirmed that the fuel meets Hydro's specification and also that the fuel has not been contaminated. Hydro plans to conduct fuel sampling and analysis on an annual basis to ensure that the fuel

being supplied meets the specification. In addition, Hydro is considering testing the fuel at each site to ensure that fuel contamination is not occurring within the local fuel systems.

### 4.5.2 Liquid fuel shut off valve

PI has indicated that the Altair 3-way shut off valves utilized in the units' fuel systems, while still functioning, are no longer supported by an OEM and has recommended that this valve be replaced by a current model. PI has suggested the Woodward LSOV25 as a potential replacement and Hydro is reviewing the use of this valve. Once an appropriate replacement valve is found, the Altair valves will be replaced in both sites.

### 4.5.3 Fuel recirculation valves

PI has indicated that the fuel recirculation valves installed at Stephenville pose a potential path to bypass the fire shut off valve. This situation has been rectified by the installation of normally closed recirculation valves rather than the normally open valves that were previously installed, which prevent the bypass of the fire fuel shut off valve.

### 4.5.4 Fire Fuel shut off valves

PI has made recommendations related to the fire fuel shut off valves installation and identification. The fire fuel shut off valves are being replaced at Hardwoods in 2017 and these recommendations will be considered in the installation.

### 4.5.5 Supplemental fuel pumps

PI has recommended that the supplemental fuel pumps be removed from the fuel system at Stephenville and also the removal of the pipework from both sites to reduce the potential for fuel leakage. This has been completed.

### 4.5.6 Logic changes

PI has recommended that control system logic be implemented to trip the units on mismatch between fuel demand, fuel valve position, and fuel flow. Hydro is reviewing the requirements related to implementation of this logic.

## 4.6 Acceleration/deceleration Curves

A review of the control system logic related to engine acceleration and deceleration started in December 2016. The initial recommendation from Alba Power was not feasible as the Hardwoods and Stephenville instrumentation and control systems do not have the necessary equipment to incorporate the recommended changes. Alba Power has modified their recommendation to match the installed equipment at Hardwoods and Stephenville. ABB Incorporated (ABB), the control system vendor, has been engaged to complete the logic changes and test them using a simulator prior to making modifications to the logic in the field. It is expected that site modifications to the logic will be completed prior to the 2017/2018 winter operating season.

## 4.7 Emergency Stop Pushbuttons

During its onsite review of the gas turbine facilities, PI identified that emergency stop pushbuttons were not available outside the engine enclosures to allow for immediate manual shut down of the units if an emergency condition should occur within the enclosure. These will be installed as part of the instrumentation upgrades being completed at both sites this year.

## 4.8 Fire Protection

PI has recommended upgrades to the fire protection system for the engine enclosures including consideration of the installation of flame detectors and oil mist detection for inclusion into the existing fire protection system if compatible. A detailed review of how these types of detection can be included into the existing system is required prior to implementation. Hydro will consider this recommendation and determine the potential for implementation.

Hydro inspects the fire protection system regularly, as well as the operation of the dampers and associated equipment. Based on this recommendation, Hydro will review the maintenance schedule for these items and ensure that the requirements are met for reliable operation.

## 4.9 Trip String[2]

PI has recommended the use of a trip string as a means of integrating independent layers of protection into the existing system. This trip string would include a series of machinery protection shut downs that would activate in the event of a control system failure. The trip string would include trips as a result of the following:

- Fire;
- Emergency stop push button activation;
- Engine over speed;
- Fuel valve deviation from set point;
- High enclosure temperature; and
- High vibration.

Hydro will review the introduction of a trip string to provide added protection into the existing system.

## 4.10 Mechanical Aspect - Bellows

PI has identified the bellows coupling (expansion joint) between the engine and power turbine as a weak point, due to repeated weld repairs over the years, and has recommended that the bellows be replaced. Hydro will propose the purchase of an additional spare bellows and refurbishment of the existing spare in the 2018 Capital Budget Application. This will provide one spare bellows for each site.

[2] A trip string offers a means of integrating independent layers of protection into existing systems. A series of relays (or safety relays) would have their normally open contacts connected in series forming a "string". The coils of these relays are each energized by separate elements of a protection system, such as vibration, over speed, devices for sensing pressures and temperatures, etc. The result is that if any one of the detection devices senses a parameter out of specification, it de-energizes its relay, cutting power to the fuel shutoff valve.

## 5.0 Planned Maintenance Review

PI's engagement included completing a review of Hydro's preventative maintenance program for its gas turbines and to provide recommendations for improvement. The review included a comparison of the preventative maintenance program for Hardwoods with the maintenance information provided in the Curtiss Wright manuals for the units. The Stephenville unit was then also checked for consistency with the Hardwoods unit. Thus, the commentary related to the maintenance review applies to both sites. The following short term and long term recommendations were made with respect to the review of the preventative maintenance program.

### 5.1 Shorter Term Improvements

1. Make an assessment of which systems and equipment are critical to safety, production and the environment and ensure that they are subject to some form of maintenance plan.
2. Whilst the cause of early bearing failure is under investigation, continue to check magnetic chip detectors after each run comparing quantity and appearance of debris collected with the previous test and between detectors.
3. Carry out monthly (suggested) sampling and quality checks on the gas generator lubricating oil. Readjust when confidence is gained that adequate quality is being maintained.
4. Monitor the pressure upstream of the gas generator lube oil (GGLO) scavenge return filter (in the absence of a direct measurement of DP across it) daily, investigate any "off trend" behaviour.
5. Carry out regular proof tests on safety critical instrumented functions.

These shorter term items have already been implemented, are planned to be implemented, or are under review, as discussed in Section 6.

## 5.2 Longer Term Improvements

1. Ensure that key documentation such as reference drawings, maintenance routines and operating procedures are "as-built".
2. Ensure all equipment is included in the maintenance plan. Use the relevant system drawings to identify.
3. Ensure all potential hazardous scenarios are identified and hence which instrumentation is critical.
4. Adjust proof testing and maintenance regime to reflect the assessed criticality of the function.
5. Ensure that full detail is included in or referenced from the maintenance check documents so that the user has sufficient information to carry out the task effectively, including:
   - Specific and unambiguous references to the equipment by tag numbers, etc.
   - Instructions in sufficient detail to ensure adequacy and consistency of the work carried out.
   - Clear instructions on the records to be kept and a convenient way of recording (Log sheets and fields in the work order as appropriate).

   This information may be provided as work orders stored in the existing Oracle/JD Edwards system.
6. Ensure proof test results and other maintenance records are stored in a way that allows easy access for review and comparison with previous tests and other similar equipment.
7. Ensure spares holdings are appropriate to allow repair within acceptable timescales.
8. Apply the IEC 61511 "SIL" approach retrospectively to determine whether the protection systems are adequately designed and their optimum test and maintenance frequency. Proof test interval is determined as part of this process.

These longer term items will be reviewed by Hydro in a prioritized manner. Some items have been addressed since the documents were provided for review and as part of other parallel

review activities. Hydro is in the process of reviewing these recommendations and incorporating them into its maintenance strategy and program for the gas turbines, as appropriate.

## 6.0 Implementation Status Summary

Hydro has made a number of process and operational improvements following the root cause investigations and since PI completed their initial review. Hydro continues to implement improvements to its operation and maintenance processes related to the Hardwoods and Stephenville gas turbines as these improvements are identified. Since the filing of the April 17, 2017, report, the following progress has been made:

1. Vibration monitoring location – An accelerometer has been found that will fit in the recommended monitoring location with minor adjustment of the pipework and is compatible with the existing vibration monitoring system. An accelerometer and associated equipment has been ordered to allow a test of the new system prior to implementation across all units.
2. Vibration settings – Planned changes to time delay settings have been made in all systems. No further recommendations have been made related to vibration settings and thus no further changes are planned at this time.
3. Lube oil filtration – PI has recommended improved scavenge oil filter monitoring rather than the installation of an additional filter on the supply side of the lube oil system. Hydro will review this recommendation and complete the engineering necessary to determine whether this can be incorporated within the existing system.
4. Fuel sampling and analysis – Results have been reviewed in detail and the fuel being supplied meets Hydro's specification. In addition, the fuel is within the limits specified for the contaminants analysis.
5. Acceleration/Deceleration changes – the logic changes required have been determined and are being developed by the system vendor and will be tested prior to field implementation.

6. Altair valve replacement – A replacement valve has been proposed for the Altair valve, and this is being reviewed for suitability with the systems. If appropriate, these valves will be replaced at both sites.
7. Fuel recirculation valves – The recirculation valves have been replaced in Stephenville with current normally closed valves, as recommended. The existing valves at Hardwoods are normally closed valves and replacement of these valves will be completed as part of the fuel system upgrades this year.
8. Fire fuel shut off valves – The fire fuel shut off valves are being replaced at Hardwoods during the planned fuel system upgrades this year. The replacement valves are now on site.

PI has completed their review of all aspects of unit operation, monitoring, control and maintenance, and have provided recommendations that may further improve the reliability of these units going forward. This report has been reviewed and an implementation plan and schedule is being developed for further investigation, review and implementation of these recommendations as appropriate.

The items remaining to be investigated further or implemented at this time include:

1. Vibration monitoring location change;
2. Lube oil tank modifications;
3. Review of additional lube oil scavenge filter monitoring;
4. Acceleration/Deceleration schedule logic changes;
5. Review the use of the Woodward LSOV25 as a replacement for the Altair 3-way valve;
6. Review of the addition of fuel system logic changes;
7. Review of the introduction of a trip string related to protection trip of the engines;
8. Review of improvements to the fire protection system; and
9. Detailed review and revision of the planned maintenance strategy and program.

It is expected that these remaining recommendations resulting from the failure analyses performed and PI's review will be able to be implemented prior to the 2017/2018 winter operating season, with the exception of items 6, 7, 8 and 9. These items require varying degrees of engineering review, detailed design, procurement, and implementation and will require considerable resources and time to complete.

## 7.0 Conclusion

Hydro's investigation into the root cause of the failures of the engines at Hardwoods and Stephenville in the winter of 2016 is complete and has resulted in a number of recommended operational, maintenance, and design improvements. Many of the recommended improvements have already been implemented and most of the remaining improvements are expected to be implemented prior to the 2017/2018 winter operating season.

PI's assessment of the Hardwoods and Stephenville gas turbines has also been completed. Their findings have been discussed previously in this report. As indicated in Section 6 of this report, some of PI's recommendations have been implemented and others will require further engineering review to determine if they are feasible and appropriate before they can be implemented.

Hydro is committed to continued reliable operation of these units and to implementing the various recommendations contained in this report as well as any further improvements that are identified through ongoing review and investigation. Hydro will keep the Board informed on the progress of implementation of the remaining recommended improvements to operation, maintenance, monitoring, and control of the gas turbines with submission of a further update to the Board within its Winter Readiness Report, to be filed prior to the 2017/2018 winter operating season.

Performance Improvements (PI)

# Technical and Engineering Reviews of Hardwoods and Stephenville Gas Turbine Operation, Maintenance and Protection

## NEWFOUNDLAND AND LABRADOR HYDRO

newfoundland labrador hydro
a nalcor energy company

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# Document Revision History

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| 1.0 | Issued for Client Comment | 20/04/2017 | JW | DU | CS |
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| A.0 | Issued for Use | 26/6/2017 | JW | SB | CS |

# Abbreviations

| | |
|---|---|
| BPCS | Basic Process Control System |
| CAD | Canadian Dollars |
| CW | Curtiss Wright |
| DCS | Distributed Control System |
| DP | Differential Pressure |
| DVP | Digital Valve Positioner |
| EGT | Exhaust Gas Temperature |
| E-Stop | Emergency Stop |
| FMV | Fuel Metering Valve |
| GG | Gas Generator |
| GGLO | Gas Generator Lube Oil |
| HAZOP | Hazard and Operability Study |
| HMI | Human Machine Interface / SCADA |
| HWD | Hardwoods |
| I/O | Input/Output |
| IP | Intellectual Property |
| ISSOW | Integrated Safe System Of Work |
| IPF | Instrumented Protective Function |
| LO | Lubricating Oil |
| LOTO | Lock Off Tag Off |
| LOPA | Layer of Protection Analysis |
| MLO | Main Lube Oil |
| NO | Normally Open |
| OS | Operating System |
| PC | Personal Computer |
| PSI | Pounds per Square Inch |
| PT | Power Turbine |
| PTW | Permit To Work |
| QNX | Quantum Software Systems UNIX abbreviation |
| RR | Rolls-Royce |
| SIF | Safety Instrumented Function |
| SIS | Safety Instrumented System |
| SIL | Safety Integrity Level |
| SVL | Stephenville |
| TMEL | Target Mitigated Event Level |
| USD | US Dollars |

# Table of Contents

**APPENDICES**

1. Marked Copies of:
   a. HWDGT Operators Daily Checks
   b. HWD Semi-annual Maintenance
   c. HWDGT & SVLGT Annual Inspection
   d. HVYGT Operators 5 Year Check
   e. HVYGT P & C 6 Year Check
   f. Maintenance Gas Turbine Insp & Maint. Curtiss Wright 4.3.2.33
   g. Drawing No 183481: Air Start System.

2. Brochures for chip detection systems:

   a. Gastops Metalscan MS4000
   b. Poseidon DM 4500

3. OIM Manual for Sensonics DN2011 Dual Channel Vibration Monitor

4. AGAT Oil Analysis Reports

**REFERENCES**

| | Title | Drawing numbers: | |
|---|---|---|---|
| | | **HWD** | **SVL** |
| 1 | Schematic, Liquid fuel system (P&ID) | 183511 | 183392 |
| 2 | Gas Turbine Controls Schematics | 373-E-XXX | 374-E-XXX |
| 3 | Air Start System | 183481 | |
| 4 | Common Gas Turbine Insp & Maint. Curtiss Wright | 4.3.2.33 | 4.3.2.33 |
| 5 | Curtiss Wright Operations and Maintenance Manual for Hardwoods Section 0 to 8 | | |
| 6 | HWDGT Operators Daily Checks | | |
| 7 | HWD Semi-annual Maintenance | | |
| 8 | HVYGT Operators 5 Year Checks | | |
| 9 | HVYGT P & C 6 Year Check | | |
| 10 | HWD & SV Maintenance Strategy Manual - 4.3.2.32 | | |
| 11 | Machinery Protection Systems, API STANDARD 670, FIFTH EDITION, NOVEMBER 2014 | | |
| 12 | IEC 61511:2014 , Functional safety — Safety instrumented systems for the process industry sector | | |

# 1 Overview

## 1.1 Geographical location

Hardwoods site is located near to Paradise, St John's, Newfoundland
Stephenville Site is located south of Stephenville, Newfoundland

**Fig 1. Stephenville generator package**

Curtiss Wright power generator sets are installed at SVL and HWD.

They consist of two RR Olympus GG's acting upon two free power turbines, which are connected via clutches to a central Brush alternator.

They can be operated in the following modes:

- One GG (generating approx. 25MW)
- Both GG's (generating approx. 50MW)
- Synchronous Condense (Power Factor Correction).

## 1.2 Background

PI Gas Turbines have been asked to assist with reviewing the current systems that operate the two gas turbine power generating stations, regarding safety and reliability.

This work required a detailed site survey of both sites, and a review of the maintenance / inspection procedures and schedules. This report details the findings of the review.

## 1.3 Scope

The scope of this review covers the gas turbine, and driven equipment from a rotating machinery point of view. Generator electrical control and protection is outside the scope of this study and is already well managed by Hydro.

## 1.4 Use of Review Findings

This report highlights areas for improvement however it is not exhaustive. A thorough review, eg HAZOP would be expected to find other potential improvements. Similarly PI would recommend re-engineering of safety instrumented systems to IEC 61511 using LOPA to define SIL requirements and loop architecture, but acknowledge that significant improvements can be made without full compliance with IEC 61511.

# 2 Executive Summary

The two generating plants at Hardwoods and Stephenville have recently suffered a number of issues. These include fire in turbine enclosures, a fire in the machine itself, and a bearing collapse in one of the Olympus gas generators. This report discusses these events and surrounding facts and makes recommendations as to improvements which can be made.

A number of weaknesses has been found in the design and operation, some have been illustrated by the observed events. It is recommended that these are addressed by engineering change.

The intermittent and irregular nature of the operating periods of the engines with long periods of downtime between starts should be considered in engineering and operation, including the effect on familiarity of personnel (human factors).

It is recommended that instructions for fuel shutoff by local manual operation of the LF-8 valves are posted conspicuously close to the valves themselves, also that emergency stop and fire extinguishant release call points are sufficient in number and correctly positioned.

The sites are more than 4 decades old so tend not to comply with some modern standards, in particular instrumented protective functions are not designed to the IEC 61511 "SIL" approach. Where improvements are needed PI would recommend use of this approach where possible; however improvements to instrumented protection have been identified and can be implemented whether or not IEC 61511 is used.

It is recommended that a trip string is introduced to the power to the shutoff valve, to provide independent protection against critical deviations such as fire and overspeed. The following would be included:

- Fire
- Overspeed
- Fuel valve deviation
- Additional emergency stop buttons
- High enclosure temperature
- High vibration

It is recommended that critical safety functions such as overspeed protection are implemented independently of the process control system, and that unreliable and obsolete components such as the Altair 3 way fuel shut off valve, and the Atkomatic fuel recycle valve on the Stephenville site are replaced with current types. The replacement fuel shut off valves would be incorporated into the trip string as the main means of engine shutdown.

The fuel recirculation route through the LF-7 Atkomatic valve provides an unintended route for fuel to reach the machine and which defeats the LF-8 fire valves. This presents greater risk to the Stephenville site where the LF-7 valves are fail open types. Replacement with normally closed types and backed up by check valves would mitigate this risk.

The Instrumentation Upgrade and Fuel System Upgrade projects currently in progress may provide an opportunity to implement some of the improvements recommended in this report.

Fire detection in the enclosure is by temperature probes. Flame detection and external manual activation points are recommended as an enhancement. Fire indication in the enclosure should trip the machine.

A logic function to compare fuel flow demand, and fuel flow feedback from the control valve position would provide protection against gross overfuelling.

The high vibration trip operates via the BPCS; this function should be implemented separately and input to the trip string. The existing AB vibration monitors have relay contact outputs which could be configured for that purpose, however the monitors are not IEC 61511 compliant. The setpoints correspond to the values from the CW manuals, however there may be scope to tighten the trip limits to detect any incipient failure as early as possible.

The gap analysis done between the operations routines and the CW instructions generally showed current maintenance frequencies to be less than CW suggest. However it is understood that certain items such as inspection of the chip detection have been increased in light of recent events.

A detailed study based on as built drawings would be needed to ensure that all critical items are included in a maintenance plan.

The existing filtration in gas generator lubricating oil system scavenge return should be capable of keeping the oil sufficiently clean, however the monitoring arrangement is currently inadequate and should be improved, specifically the recommended maximum operating differential pressure is 15 psi DP whilst the bypass opens at 10 psi DP. This is recommended in preference to installing a new filter in the LO supply line. Raising the offtake from the LO tank above the tank bottom would reduce the risk of a slug of solids being drawn into the engine at start up.

Two vendors have been found who can supply equipment which appears suitable for wear debris monitoring. They have a large price difference, the more expensive having the greater experience and acceptance for gas turbine applications.

# 3 Applicable Standards

The following standards define practices applicable to operating gas turbines safely. By following the guidance laid down in them in re-engineering parts of the systems, and following their guidance over operating the units, Hydro would be in a much better position regarding safety.

## 3.1 IEC 61511 Functional Safety – Safety Instrumented Systems for the Process Industry

IEC 61511 is considered best practice based on combined industry experience and is the benchmark standard for functional safety for gas turbines in it is used in Canada, UK and elsewhere. It covers the design and management requirements for Safety Instrumented Systems throughout the entire "Safety Lifecycle" This includes initial concept, design, implementation, operation, and maintenance through to decommissioning.

IEC 61511 is the Process Sector specific version of "IEC 61508, Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems (E/E/PE, or E/E/PES)" published in 1998 by the International Electrotechnical Commission (IEC), updated in 2010. This standard covers Functional Safety for all industries and has had sector specific versions created for Nuclear, Manufacturing and the Process industries. IEC 61511 revision 1 applies to process industries, it was released in 2003. Revision 2 was released in 2016. Various National Standards bodies, Such as BSI in the UK and CAN/CSA in Canada have adopted this standard.

IEC 61511 has been adopted by the National Standard of Canada (Norme Nationale du Canada) as : "Functional safety — Safety instrumented systems for the process industry sector — Part 1: Framework, definitions, system, hardware and application programming requirements" "CAN/CSA-C22.2 No. 61511-1:17" (IEC 61511-1:2016, MOD). Parts two and three are also adopted.

The CSA, Canadian Standards Association list IEC 61511 for functional safety. OSHA, the Occupational Safety and Health Administration endorse ANSI S84 / IEC 61511 as a "national consensus standard" for the application of safety instrumented systems for the process industries. PI work to IEC 61511 under AMEC's approval.

In the United States IEC 61511 was adopted as ANSI/ISA 84.00.01-2004, and was issued in September 2004. This standard primarily mirrors IEC 61511, with the exception of the addition of a grandfather clause being added, detailing how legacy systems should be assessed.

IEC 61511 recommends other standards be adhered to if relevant. This makes it ideal when undertaking projects where several standards may be relevant. In this case API 670 – machinery protection systems, and ISO 21789 Gas turbine applications - safety, are amongst the standards which apply.

As IEC 61511 is a descriptive standard, ie the goal to be achieved is specified. It is left to the user to create a design which achieves that goal with minimum cost and complexity. For example API 670 may be used to design the fuel system, IEC 61511 is then used to validate the design and control the overall lifecycle.

The principle of IEC 61511 is to determine the reliability required for the SIF, this is denoted as a SIL level. SIL stands for Safety Integrity Level, this is the level of risk reduction provided by a safety instrumented function. It is normally denoted as a power of 10 from 1 to 4, so 1 is a risk reduction by a factor of 10 and 2 is a risk reduction by a factor of 100. SIL 1 and 2 are commonly found in plant of this type, SIL 3 is occasionally used. The design of the protection loop follows from the SIL required and the frequency of proof testing. SIL 1 can typically be achieved by a simple loop with annual testing. SIL 2 typically needs dual input and output devices with annual testing.

To apply the IEC 61511 process, the hazards are identified, ideally by following a formalised process such as HAZOP, then the TMELs are established. The loop architecture and proof test frequency they need are determined by LOPA/ SIL evaluation. The safety instrumented system is then designed and implemented and the maintenance regime put in place. Maintenance includes regular proof tests and device maintenance to OEM specifications, to support the safety lifecycle. This process is controlled by the safety lifecycle also described in IEC 61511.

Non-instrumented safety functions such as relief valves and pressure vessel integrity need to perform to a standard and so require proof testing and maintenance. This is not covered by IEC 61511 however performance of those devices can be taken into account in determining SIL levels required for IPFs.

### 3.1.1 Typical Gas Turbine Hazards

Typically for a gas turbine package the hazards that are usually managed by SIF's would include, but are not limited to:

- Overspeed (PT and GG)
- Vibration (PT, GG, and driven equipment)
- Exhaust gas temperature spread
- EGT max temperature
- Flameout
- ESD push button(s)
- Fire / smoke / oil mist
- High enclosure temperature

### 3.1.2 Management of Change and Safety Engineering

Every gas turbine unit is different when considering the severity of risks influenced by factors such as proximity to members of the public. In this respect HWD may come out with higher severity than SVL due to the proximity of a busy highway. It is generally accepted by regulators and operating companies that the risk to 3$^{rd}$ parties is set lower, typically by one or two orders of magnitude, than the equivalent risk to company personnel. This is taken into account when setting SIL levels required of a given safety instrumented function.

To apply IEC 61511 the duty holder (Hydro) must provide or approve TMEL values, target values for frequency of undesirable events. There are industry norms for this.

All controls modifications are managed by Hydro by an engineering team. However there are no functions for safety engineering approval or verification of changes. Third parties making modifications are treated as OEM's, and are therefore fully responsible for the design verification.

A third party is used to validate all mechanical design work for new installations and modifications, but only covers mechanical scopes with respect to design approval, and on-site inspection and verification before commissioning but not Safety / Protection engineering.

## 3.2 API 670 Machinery Protection Systems

Machinery Protection Systems, API Standard 670, Fifth Edition, November 2014 is the machinery protection systems standard for rotating machinery and describes functions such as power turbine overspeed, vibration protection and fuel system design for gas turbines. It is a prescriptive standard, in that it clearly states what design must be followed. In this study its guidance on fuel design and protection systems are of particular interest.

## 3.3 ISO 21789 Gas Turbine Applications – Safety

This standard combines aspects of the previous guidance note PM84 (Control of safety risks at gas turbines used for power generation, guidance note from the UK Health and Safety Executive) and the current API 670.

# 4 Control and Protection System Detail

## 4.1 Gas Turbine Control and Protection System

The BPCS are similar on both sites, apart from processor upgrades at SVL and variations in card layout and I/O. The BPCS performs all control and protection functionality. The main fuel shutoff valve is controlled by a digital output of the BPCS, with no intervention from any independent layers of protection such as relay trip string. (See 7.1 below) At HWD the system is a Bailey Infi90 at SVL it is a Bailey Infi90 with upgraded ABB Symphony-Plus BRC410 dual processors

Currently all hazard protection is performed by the BPCS (the DCS), ABB, the manufacturer of the Bailey Infi90 BPCS stated it cannot comply with IEC 61511 (ie: is not SIL capable) and there is no independent safety system, no independent layer of protection. This is considered a significant weakness in the current design, protection against dangerous upsets such as overspeed should be independent of the control system, this is known as segregation.

To highlight this issue, the power turbine overspeed SIF is examined below in terms of system segregation, to determine whether the SIF can protect the power turbine in the event of Bailey Infi90 failure.

Applying IEC 61511, the speed inputs to the Bailey Infi90 is the field measurement element of the speed control system. This is part of the gas generator unit BPCS. The BPCS is considered a separate layer of protection during SIL setting exercises, claimed to have a significant risk reduction factor. This cannot be claimed twice, therefore any BPCS functions cannot be claimed as part of a SIF. Similarly any probes sending speed signals to the BPCS cannot also be part of a SIF.

API 670, also prohibits using the BPCS as part of any overspeed protection system stating:
“The speed sensors used as inputs to the electronic overspeed detection system shall not be shared with any other system.” (Section 8.3.1) and “Electronic overspeed detection shall be separate and distinct from the speed control system, with exception of final control elements.” (Section 8.3.2) “Combining the overspeed system with any other control, protection, or monitoring systems (except as allowed by 8.3.3) shall not be allowed. This restriction includes the monitoring systems of Section 7.” (Section 8.3.4)

The intent is to ensure overspeed protection in the event of speed control system failure. Combining the overspeed detection with other systems may degrade the overall system response time, impact ease of serviceability and isolation, or otherwise interfere with overspeed integrity.

To be compliant with those standards and achieve segregation certain hazards need to be protected against using an independent layer of protection, which can be added in parallel to the existing system.

## 4.2 Operator interface and HMI

In both HWD and SVL the HMI comprises Bailey PCView HMI software on QNX operating system based PC.

The HMI is an important part of the system, as all operator functions are controlled by it. There are no panel buttons or switches to operate the unit in case of an HMI failure. Hydro have already identified this as a potential weakness, and both sites keep a spare HMI PC ready to exchange if a fault occurs. There are also regular hard disk backups taken, which capture any changes to setpoints, and tuning parameters.

The HMI is not easy to use when compared with more modern HMI systems, it offers basic graphical live information, unit control functions, and a datalogging facility which are difficult to customise for changing needs. ABB offer upgrades for this standard of HMI, however, since it is not safety critical, and judging the expected life of the units left, this may not be worth pursuing.

### 4.3 Instrumentation Upgrade Project.

There is currently a project in progress to improve instrumentation, primarily that associated with the generator, MLO and cooling. This may provide an opportunity to implement some of the instrumentation upgrades recommended in this report.

Hydro have not yet placed orders for the new instruments, giving this project an opportunity to guide the selection process of certain safety critical instruments. It may be possible to use a “prior use” argument to use existing field instruments; pressure and temperature transmitters, pressure switches, valves etc. as part of an upgraded IEC 61511 compliant system. This would be investigated when required SIFs are identified.

# 5 Fuel System

HWD and SVL use a similar fuel system layout, the main difference being the fuel metering valves.

Tanks feed a fuel forwarding building, containing pumps, filters and a heater. The fuel is heated to between 10 and 30˚C to prevent freezing. The heated fuel is circulated round a loop when the units are not running, via bypass valves in the enclosure. The bypass system is activated by a temperature switch outside the enclosure when the fuel temperature falls below 5˚C.

## 5.1 Fuel Valves – General Information

| CW Tagname | DCS Tagname | Description |
|---|---|---|
| LF-38 | LF38 | Tank outlet shutoff motorised valve |
| LF8 | 120LFS | External block valve (Fire system) |
| SV-LF-1 | 220LFSV | Engine driven fuel pump swash plate servo valve |
| AV-LF-1 | 120LFAV | Altair 3-way valve (DCS control system shutdown) |
| FC-LF-1 | FV-2 | (SVL Only) LQ25 internal shutoff (DCS control system start permissive, not trip logic) |

## 5.2 AV-LF-1 Altair 366V200 3-way valve

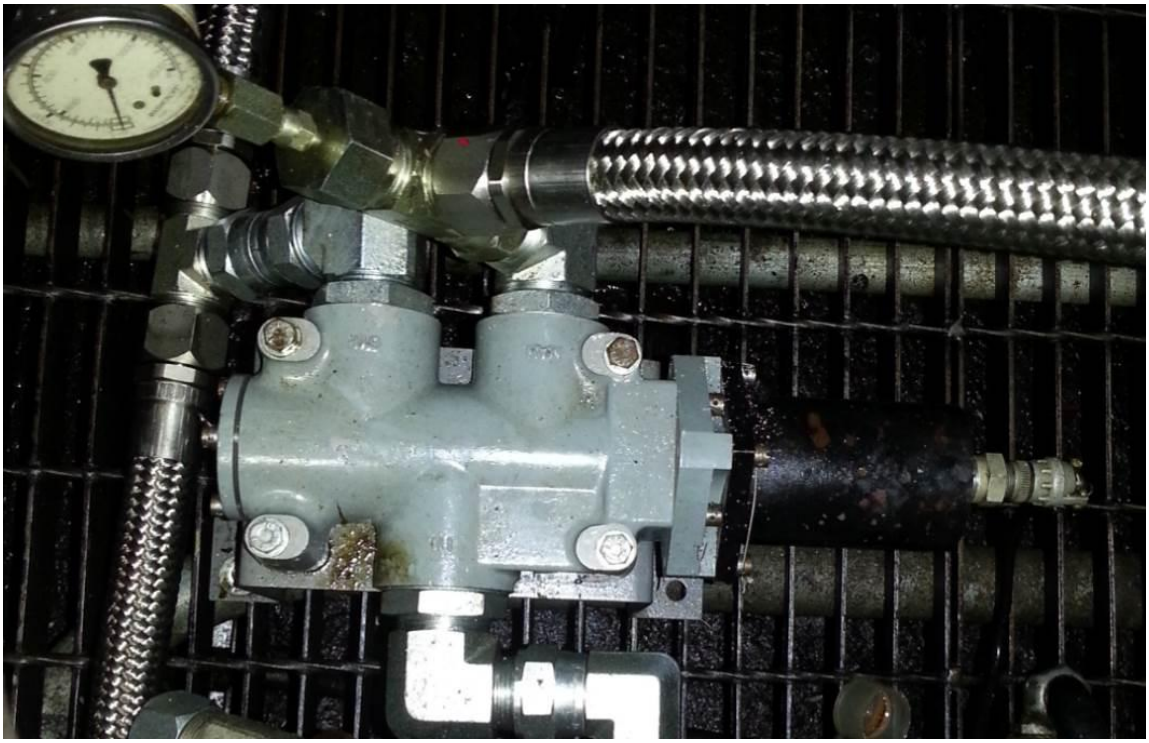


**Fig 2. Altair 3-Way Valve at Hardwoods.**

Hydro employees report the Altair 3-way shut-off valves to have been found to leak past the seals on several occasions and failing to provide adequate isolation. On those occasions Hydro or Alba power have changed the O-rings themselves.

Altair were bought out by Midland Ross approximately 20 years ago, who in turn were bought by Honeywell. Honeywell were unable to provide any information on this valve when asked. Although not substantiated, it was reported that Honeywell no longer support the Altair products which means effectively the OEM no longer exists so overhaul by the OEM is impossible.

This valve cannot be used as part of an IEC 61511 compliant system because no reliability data or failure rate data is available to calculate its probability of failure upon demand (PFD). No data is available to justify a “prior use” argument.

It is recommended that the valve is replaced with a current type

## 5.3 LF-7 Atkomatic Recirculation Valves

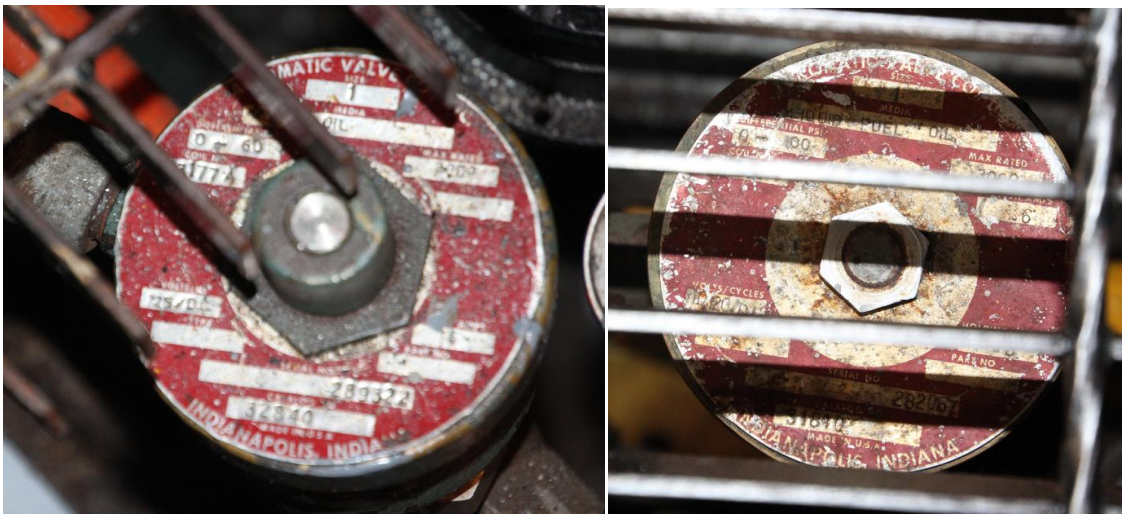


**Fig 3. LF-7 Atkomatic Recirculation Valves SVL 32840 (Left) HWD 31840 (Right)**

This valve allows diesel fuel to recirculate back to the fuel forwarding building, bypassing the on-engine pumps during cold weather periods. The recirculation system is designed to keep the fuel temperature above 5˚C

The fuel recirculation bypass solenoid valves, LF-7, are reported often to fail open allowing fuel to flow during running conditions.

On Stephenville the valve is the Atkomatic 32840 which is a normally open valve (see Fig 4), which means that the valve will open under spring force upon loss of power or solenoid failure. On Hardwoods it is the 31840 valve which is normally closed.

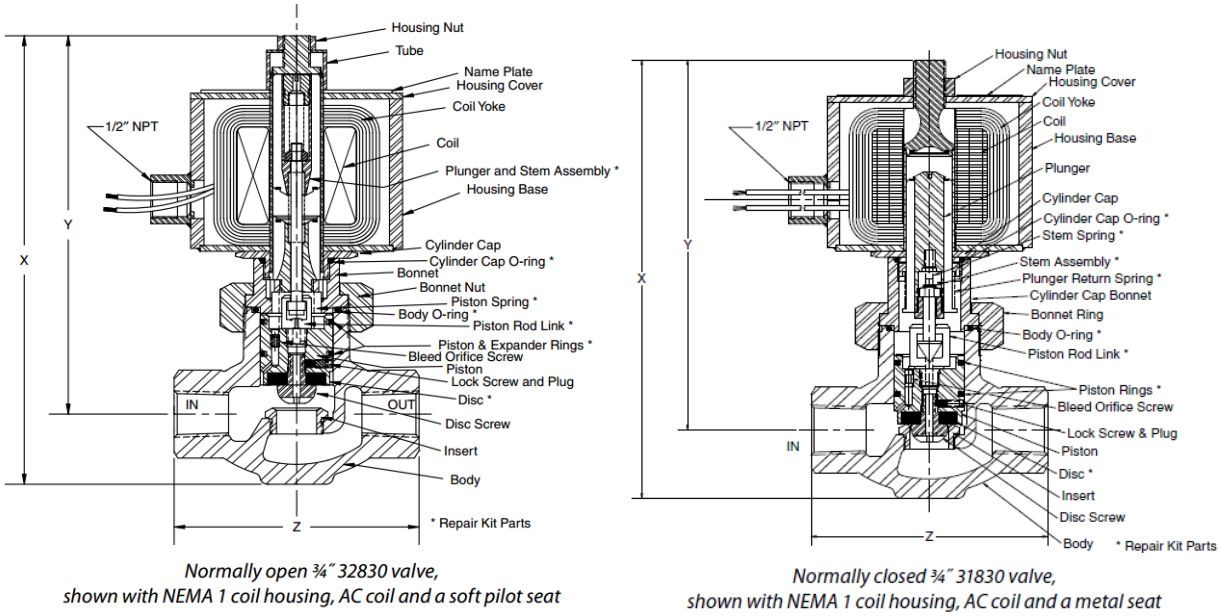
**30800 Series Normally Open Stainless Steel**

| CATALOG NUM. PREFIX | PIPE SIZE | MAIN SEAT ORIFICE | X | Y | Z | SHIPPING WEIGHT *(lbs)* | Cv |
|---|---|---|---|---|---|---|---|
| 32800 | ¼″ | ⅜″ | 8⅝″ | 7⅝″ | 3″ | 10 | 1.1 |
| 32810 | ⅜″ | ⅜″ | 8⅝″ | 7⅝″ | 3″ | 10 | 2.5 |
| 32820 | ½″ | ¾″ | 9½″ | 8″ | 4⅝″ | 13 | 5.1 |
| 32830 | ¾″ | ¾″ | 9½″ | 8″ | 4⅝″ | 13 | 7.3 |
| 32840 | 1″ | 1″ | 10⅛″ | 8⅜″ | 5¼″ | 19 | 12.5 |
| 32851 | 1¼″ | 1½″ | 10½″ | 8½″ | 5⅞″ | 22 | 21.0 |
| 32861 | 1½″ | 1½″ | 10½″ | 8½″ | 5⅞″ | 22 | 21.5 |

## 30800 Series Normally Closed Stainless Steel

| CATALOG NUM. PREFIX | PIPE SIZE | MAIN SEAT ORIFICE | X | Y | Z | SHIPPING WEIGHT (lbs) | Cv |
|---|---|---|---|---|---|---|---|
| 31800 | ¼″ | ⅜″ | 8 1/16″ | 7 1/16″ | 3″ | 10 | 1.1 |
| 31810 | ⅜″ | ⅜″ | 8 1/16″ | 7 1/16″ | 3″ | 10 | 2.5 |
| 31820 | ½″ | ¾″ | 8 1/16″ | 7 9/16″ | 4 5/8″ | 13 | 5.1 |
| 31830 | ¾″ | ¾″ | 8 1/16″ | 7 9/16″ | 4 5/8″ | 13 | 7.5 |
| 31840 | 1″ | 1″ | 9½″ | 8 1/16″ | 5¼″ | 19 | 12.5 |
| 31850 | 1¼″ | 1½″ | 10½″ | 8⅜″ | 7⅝″ | 50 | 21.0 |

**Fig 4. Extract from Atkomatic datasheet showing Catalogue Number 32840 as Normally Open and 31840 as Normally Closed**




*Normally open ¾″ 32830 valve, shown with NEMA 1 coil housing, AC coil and a soft pilot seat*

*Normally closed ¾″ 31830 valve, shown with NEMA 1 coil housing, AC coil and a metal seat*

**Fig 5. Extract from Atkomatic datasheet showing typical cross section of these valve types**

Fail open is inappropriate for LF-7 since the consequence of it failing open or leaking badly is to defeat the action of LF-8 the external block valve intended for fire shutoff. If LF-8 is closed, the turbine will carry on running on fuel drawn in via the open LF-7 and return line with potentially dangerous consequences.

This is described in Fig 6:

- LF-7 has failed open on Turbine A.
- Fuel is being supplied from the fuel forwarding module.
- Turbine A is running.
- Turbine B is not running.
- LF-7 is open on Turbine B, for recirculation due to TS-LF-1 sensing fuel temperature at that point dropping below 5˚C.
- Personnel notice an issue with Turbine A (such as an undetected fire through the window).
- Personnel manually close external block valve LF-8.
- LF-8 closure stops main fuel flow to turbine (Green line illustrates no flow).
- Turbine A engine driven pumps draw fuel backward through return line via failed LF-7 of Turbine A. This fuel is available from Turbine B's open LF-7 and LF-8. (Red line illustrates flow).

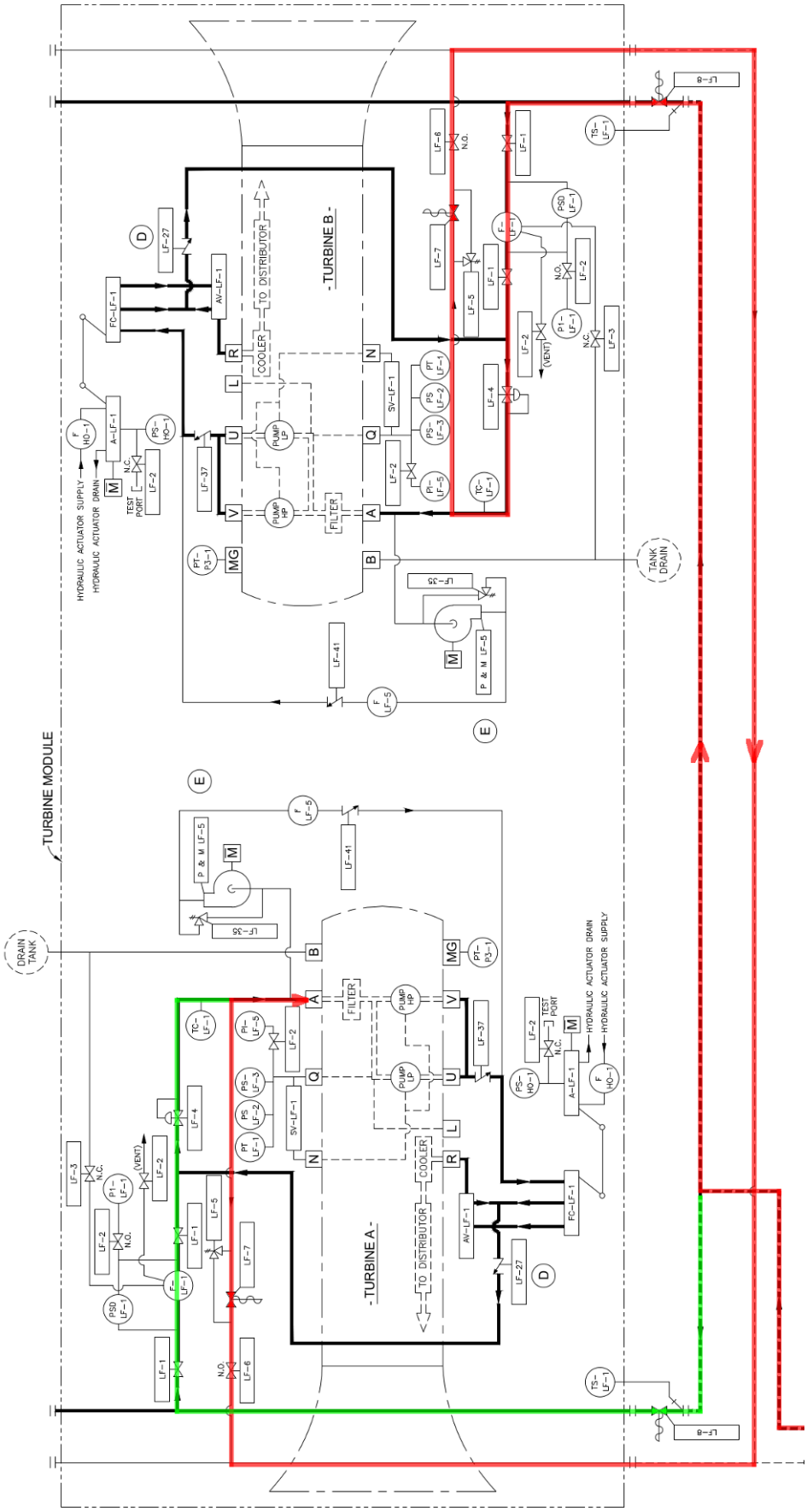



**Fig 6. LF7 Failure Mode Example**

This failure mode has been witnessed at Stephenville, although not in an emergency. One turbine had been successfully started with hand valve LF-1 unintentionally left closed (in the main fuel supply). The unit started, the generator synchronised, however exported electrical power was limited to 2MW by the restricted fuel flow. Investigation found that hand valve LF1 had been left closed, and the fuel had been flowing through the faulty open LF-7 from the other turbines recirculation connection.

The fire detection system closes both external LF8 block valves simultaneously which reduces the chances of this happening when a fire is detected by the system. Manual operation of this valve can be detected by a switch installed on the valve body. However at HWD only one of these switches is actually wired.

Improvements could be made as follows:

- Install a current type of normally closed valve and change the control logic to suit.
- Install check valves in the recirculation lines.
- Implement a test regime.

## 5.4 FC-LF-1 Woodward LQ25 Fuel Metering Valves (SVL)

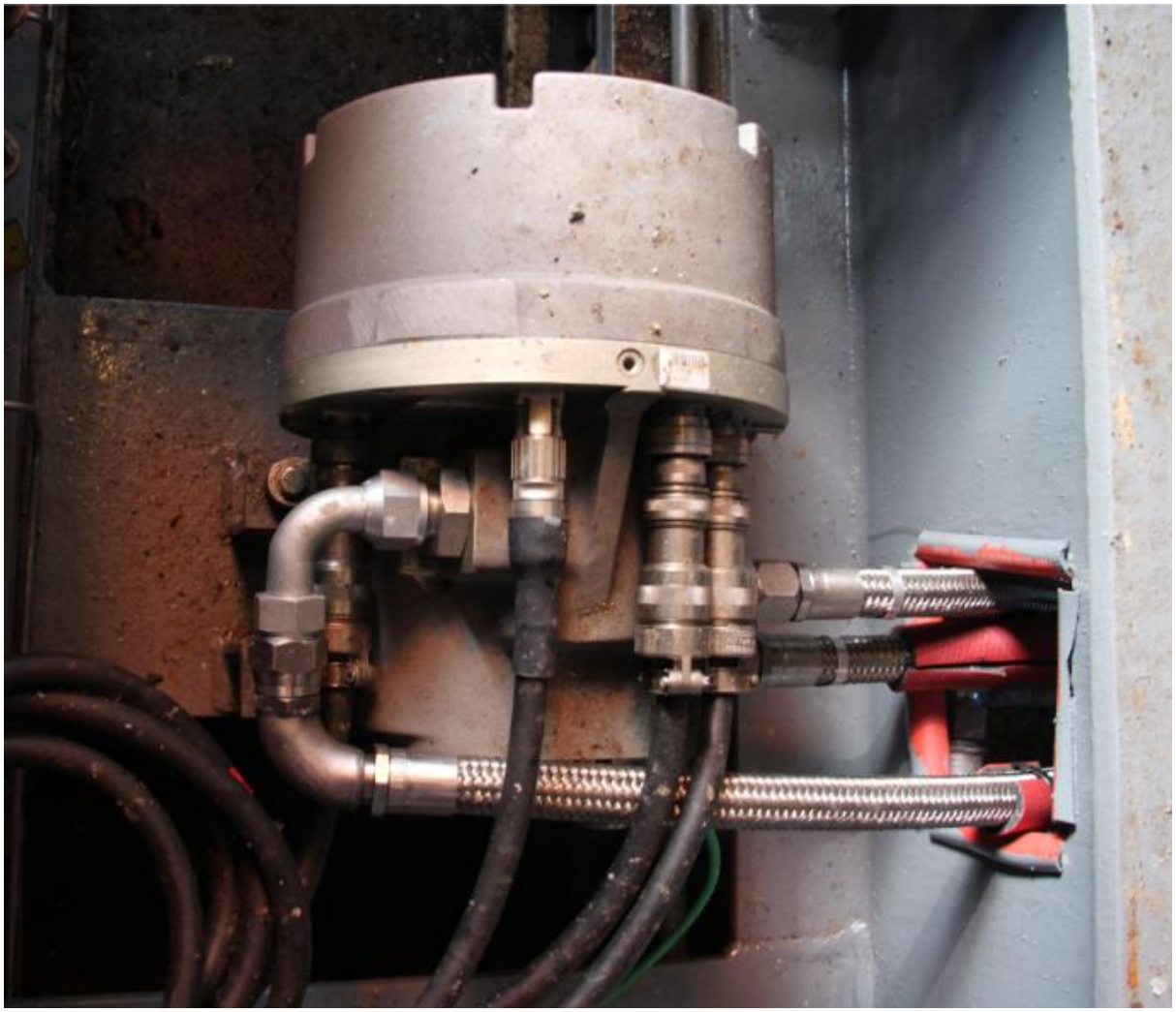


**Fig 7. FC-LF-1 Woodward LQ25 at Stephenville**

The LQ25 9908-233M is used in conjunction with a Digital Valve Positioner (DVP) mounted externally in FCV2-JB. The LQ25 has an internal shut-off valve which is reported to have given problems with sticking, which has caused starting issues. This internal shutoff valve is not currently used as a fuel shutoff valve, it is part of the start permissive logic.

Woodward confirmed the LQ25 (9908-233M) internal SOV is not capable of achieving any SIL rating under IEC 61511. A separate shut off valve should be used to implement a segregated protection function.

## 5.5 FC-LF-1 CCC ALV10 Fuel Metering Valves (HWD)

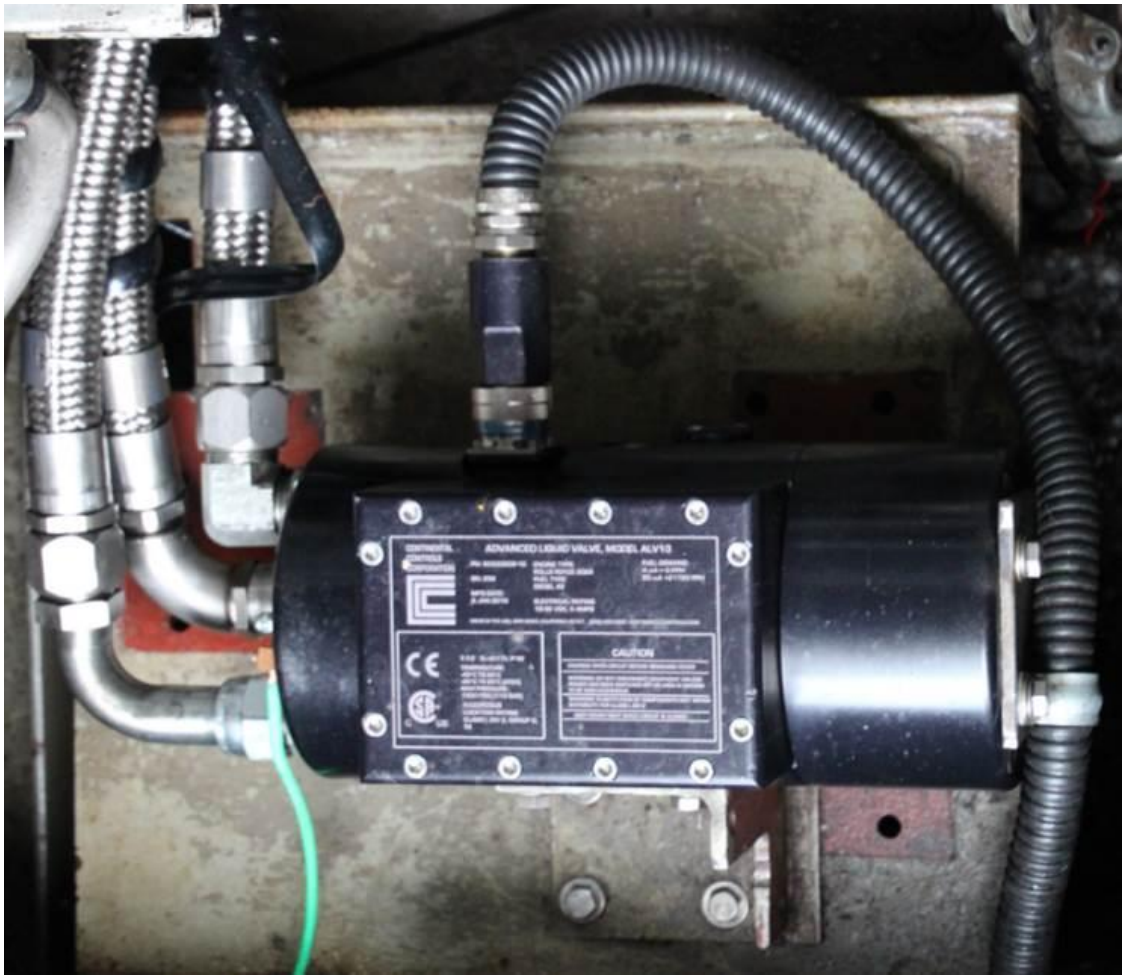
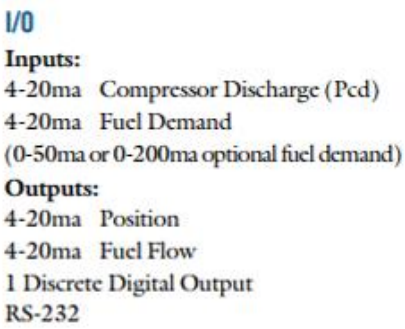


**Fig 8. FC-LF-1 CCC ALV10 at Hardwoods**

Initial issues were experienced with the CCC fuel metering valves. This was due to too great a pressure being presented to the return / spillback line, causing damage to seals in the valve.

One incident saw the CCC valve pass 100% fuel flow to the turbine. The unit had to be manually shut down by personnel pressing an E-Stop button, as no protection system detected the valve issue, nor the fire in the exhaust stack.

There is no monitoring of the CCC valve, for the DCS, or an independent protection system to initiate a unit trip if the 4-20mA flow demand signal does not correspond to the 4-20mA Flow Feedback signal. "Out of position trip" logic (based on fuel flow for this valve) would have prevented the occurrence had it been implemented with the fuel metering valve upgrade.



I/O

**Inputs:**

4-20ma Compressor Discharge (Pcd)

4-20ma Fuel Demand

(0-50ma or 0-200ma optional fuel demand)

**Outputs:**

4-20ma Position

4-20ma Fuel Flow

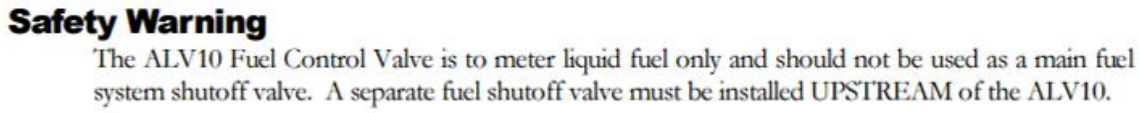
1 Discrete Digital Output

RS-232

**Fig 9. Extract from CCC ALV10 datasheet shows available I/O to implement flow checking**

Hydro have mitigated against repeat occurrences by reconnecting the spillback port to a lower pressure part of the fuel supply system. It has been noted that since changing the fuel pipe connections to the CCC valves, no more seals have failed, and the valves have given reliable service.

The CCC ALV10 does not offer a fuel shutoff function, see Fig 10.



**Safety Warning**

The ALV10 Fuel Control Valve is to meter liquid fuel only and should not be used as a main fuel system shutoff valve. A separate fuel shutoff valve must be installed UPSTREAM of the ALV10.

**Fig 10. Extract from ALV10 Installation and Operation Manual**

## 5.6 PF&M-LF-5 Supplemental Fuel Pump

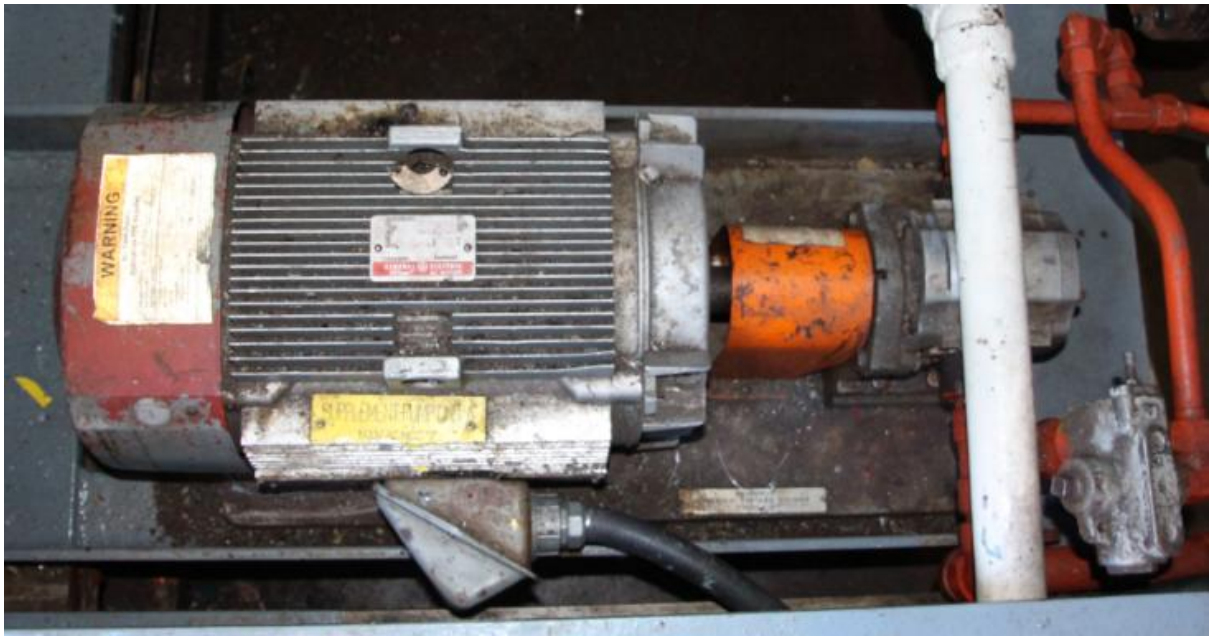



**Fig 11. Supplemental fuel pump and motor at Stephenville**

Supplemental fuel pumps were installed at both sites. These pumps were intended to assist the engine driven fuel pumps, however they are not used or indeed needed and are now considered an unnecessary complexity to the fuel system. At Hardwoods, the pumps have been removed, and fuel lines capped off, but remain in place. The motors remain in place. At Stephenville the system is still in place and connected but not used.

The fuel system redesign project being carried out by Hydro gives an opportunity to remove these pumps and all associated pipework, simplifying the system and removing opportunities for leaks. Removing the motors would allow more space in the enclosure.

## 5.8 Fuel line failures

In December 2014 fires occurred in both SVL and HWD turbine enclosures. These were due to poor manufacturing quality of a set of fuel hoses recently installed on both sites.

Hydro have mitigated against repeat occurrences by defining standards for fuel hose manufacturing and testing.

## 5.9 Recommendations

There is currently a project in progress to upgrade the fuel systems. This may provide an opportunity to carry out some of the improvements recommended below.

1. Install an additional liquid fuel shut off valve downstream of the mechanical fuel pumps such as the Woodward LSOV25 Liquid shutoff valve which is IEC 61511 compliant.
2. Control fuel shut off valves independently from the BPCS using a trip string.
3. Replace LF-7 (Atkomatic 32840) Liquid fuel recirculation valve with a fail close valve.
4. Install check valves in the recirculation lines to supplement the new LF-7 valve.
5. Remove the supplemental fuel pump from the fuel system at Stephenville. Remove redundant pipework from both sites, to reduce potential for fuel leakage.
6. Implement logic to trip the turbine on significant mismatch between fuel demand, fuel valve position and fuel flow.

# 6 Vibration Protection System

Referring to HWD Wiring Diagram 373-008A:

The vibration protection system uses accelerometers on the casings of the GG, power turbine, exciter and generator. These are connected to Allen Bradley XM-120 and XM-161 monitoring modules. The modules are used to produce a 4-20mA signal, which is passed to the DCS. The DCS then compares the value against a setpoint for alarm, and trip functions

Trip setpoints were verified against OEM figures and found to be correct. PI recommends a delay of no more than 1 second to be used for vibration trips.

The safety action is currently carried out by the DCS, also neither the XM-120 nor XM-161 are compliant to IEC 61511. The units have relay outputs which could be configured as trip functions and incorporated into a trip string. A new vibration monitor would be needed to achieve IEC 61511 compliance.

## 6.1 Compliant Vibration Monitoring Systems

Several manufacturers produce vibration monitoring systems which are compliant and can form part of a safety instrumented system.

PI have identified a vibration monitoring system manufactured by Sensonics as an ideal and cost effective monitoring system to form part of a safety instrumented system. The DN2611 Dual channel Vibration monitor is SIL certified product conforming to IEC 61508.

The vibration monitoring unit is dual channel, DIN rail mounted and can accept inputs from a variety of accelerometer and velocity transducers. Each unit offers three alarm relay contacts, for warning, danger and the third for fault monitoring. The unit also has one 4-20mA analogue output per channel. A front panel indicator provides relay status along with a display which shows current vibration, alarm and warning levels. A buffered raw transducer signal from each channel is available through a BNC socket. The safety maximum response time of the monitoring system is 1000ms with measurement update at 100ms. This product is easily installed and can form part of an IEC 61511 compliant safety instrumented system.

The new units would interface with the same I/O as the existing units, using the same sensor inputs and giving the same outputs to the DCS. The new safety trip function would be by relay contact outputs into the trip string.

Four units would be required at each site at a unit cost of GBP 1070, approximately USD 1350, CAD 1800.

The Operation, Installation, Maintenance and Safety Handbook is in Appendix 3.

## 5.4 Recommendations

1. Configure relay outputs as high vibration trips and incorporate into a trip string.
2. Consider installing a compliant monitoring system and incorporate into a safety instrumented system.

# 7 Manual Shutdown and Trip

## 7.1 Trip String

A trip string offers a means of integrating independent layers of protection into the existing system.

A series of relays (or safety relays) would have their normally open contacts connected in series forming a “string”. The coils of these relays are each energised by separate elements of a protection system, such as vibration, overspeed, devices for sensing pressures and temperatures etc. The result is that if any one of the detection devices senses a parameter out of specification, it de-energises its relay, cutting power to the fuel shutoff valve.

Neither Hardwoods nor Stephenville uses a trip string to shut off the fuel supply to the unit upon an emergency shutdown. All machinery protection shutdowns rely on a digital output of the BPCS to shut off the fuel. In the event of a BPCS failure or override being left on there is no protection system in place. A segregated layer of protection is required.

## 7.2 Control Room

There is one manual E-Stop button in the control room on the control panel. It is wired to a digital input of the BPCS so it will have no effect in the event of a BPCS failure. An independent layer of protection is required.

## 7.3 Enclosure

### 7.3.1 Emergency stop pushbuttons

It is common practice to have a set of emergency stop (E-Stop) pushbuttons around the outside of the package enclosure, however there are none on the HWD and SVL sites. Typically these are wired in series to a relay coil, the contact of which is usually connected as part of the trip string to cut power to the fuel shutoff valve. This trip string would also include all SIFs required to shut off fuel to the gas turbine, overspeed, vibration etc.

### 7.3.2 External block valve LF-8 (fire) manual activation

At the unit, the manual levers of the LF-8 external block valves (fire) provide a facility to manually shut down each turbine, however there is no signage to make that clear to anyone without prior knowledge. It is recommended to install signage so that a competent but un-briefed person could use the valve in an emergency.

Closing one LF-8 will only close the fuel off to the one gas turbine, allowing the other to continue running.

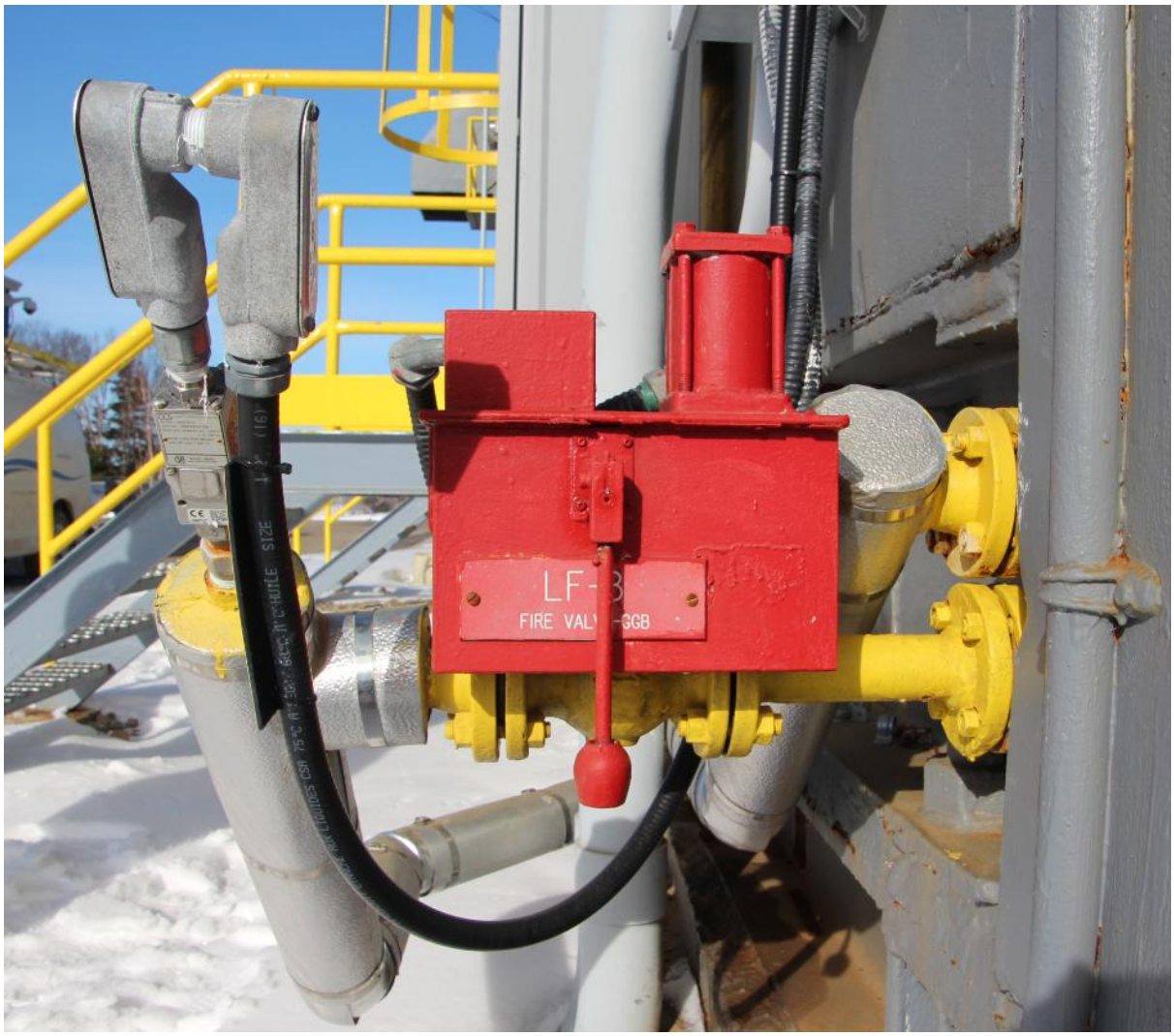



**Fig 12. SVL GGB LF-8 External block valve with manual operation handle.**

At SVL, the position reporting switches of both LF-8 valves are wired, however, at HWD, one is not wired, and the electrical port is blanked off, see Fig 13.

Both HWD LF-8 valves manual activation handles are in relatively inaccessible positions, behind electrical conduit (GGA), and at the rear face of the valve (GGB). See Fig 14 and Fig 15.

**Fig 13. HWD external block valve LF-8 with switch not wired and blanking plug fitted.**

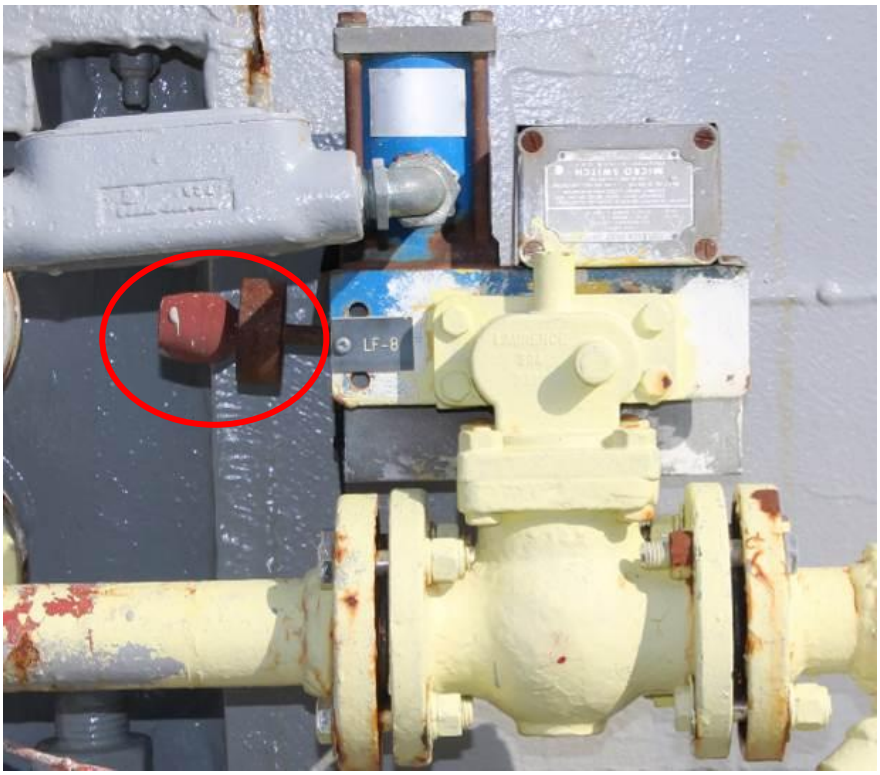



**Fig 14. HWD GGA external block valve LF-8 manual activation handle in a position with restricted access.**

**Fig 15. HWD GGB external block valve LF-8 manual activation handle in a position with restricted access.**


**Fig 16. Spare new external block valve LF-8 stored at HWD**

The LF-8 valves are Laurence 4814 2" CF8M Soli-Con Valve type 810SC678DCWLCPSS1. No response has been received from the manufacturer regarding suitability of this valve for use in an IEC 61511 certified system.

## 7.4 Recommendations

1. Install a trip string as a second layer of protection independent of the BPCS.
2. Install clearly labelled E-Stop push buttons at the package.
3. Install clearly labelled E-Stop buttons at the office and workshop buildings and near exit gates.
4. Incorporate all E-Stop push buttons into the strip string.
5. The external fuel block valve with manual activation should be identified with clear instruction on how to shut in an emergency.
6. Hardwood site, GGA external fuel valve LF-8 position switch should be wired back to the fire panel.
7. Hardwood site, GGA and GGB external fuel valve arrangement should be modified to make access to the handles straightforward.

# 8 Fire Protection

Heat sensors are the only way of detecting a fire in the enclosures. No flame detection or oil mist detection is provided.

Both sites have experienced various fires in the GG enclosures. There was an event when the diesel fuel lines were replaced; the lines installed had welds of inferior quality which as not detected at inspection. They initiated diesel leaks, causing fires, at SVL, and HWD. Recognising that undetected fire could occur and be a hazard to personnel opening the door, windows have recently been added to the doors to allow personnel to see inside the enclosure before opening the door.

A fire occurred at HWD when the CCC fuel metering valve experienced a fault and stuck fully open, possibly contributing to flames leaving the exhaust stack.

In 2002 both HWD and SVL received fire system upgrades, a new Inergen fire extinguishant system is now controlled by an Ansul AutoPulse 442R panel installed by K&D Pratt and certified as "*inspected in accordance with recognised and accepted standards for such inspections and was found to be in proper working order*".


**Fig 17. Typical fire detection and extinguishant activation panel.**

## 8.1 Detection

The fire detection system uses a chain of ceiling mounted heat detectors.

**Fig 18. Ceiling mounted fire heat detector.**

The heat detectors will only activate once a fire is established. Other means of detection such as optical flame detectors which can sense a fire starting could limit damage. Oil mist detectors which can detect a spray of diesel before it has ignited could also be useful. Fire detectors can be prone to false indication, to avoid unwanted shutdowns it is common practice to provide more than one detector and voting logic which initiates the trip when a sufficient number indicate fire to provide a reliable signal.

Flame detectors should give outputs which can be viewed by the operators.

## 8.2 Fire Safety Compliance

NFPA, the National Fire Protection Association, produced the following relevant standards:

- NFPA 37, Installation and Use of Stationary Combustion Engines and Gas Turbines
- NFPA 30, Flammable and Combustible Liquids Code
- NFPA 70, National Electrical Code

These standards may be referred to if required, the IEC 61511 Safety Lifecycle could be used to manage and evaluate any system design and implementation.

## 8.3 Access to Enclosures

Hydro has a policy of no entry to the enclosure while the unit is running, but there is no mechanism in place to control entry. No locks, interlocks, or monitoring for alarms or trips is employed on any of the enclosure doors, meaning the enclosures can be accessed while the units are operational without the operator knowing.

A simple solution would be a lock on the door, where the key is controlled under the existing LOTO procedure. Further to this, switches can be added to the doors to cause system alarm, or shutdown if a door it opened.

## 8.4 Recommendations

1. Install flame detectors, also consider oil mist detection, reporting to the existing fire system if compatible (otherwise provide the necessary signal processing).
2. Verify that the fire protection system is routinely inspected and tested, and that inspection includes checks that the enclosure is sufficiently leak tight and ventilation dampers operate for the extinguishant to be effective.
3. Ensure there are sufficient manual extinguishant release points.
4. Incorporate a fire trip into the trip string.
5. Install locks on the enclosure doors under control of the site operator.
6. Consider providing door open indication at the control room.

# 9 Mechanical Aspects

## 9.1 Bellows Failures

The bellows coupling between the GG and the PT has been identified as a weak point. There are records of bellows repairs dating back as far as 1982. A bellows rupture was occurred at HWD in 2016. The unit ran for several minutes before the enclosure thermocouple shut the unit down on high temperature.

**Fig 19. Ruptured bellows Feb 2017**

A more severe failure of the bellows is not unlikely given the numerous repairs which have been required during the lives of the units, as well as the recent failure. Although not visible in the recent failure event, when the bellows leaks the governor software will try to maintain PT speed against the leak, by running the GG faster by increasing fuel flow, this could lead to a GG overspeed event in the absence of overspeed protection on the gas generator shafts. If overspeed protection is improved as recommended, bellows failure is a likely cause of demand on that system.

Risk would be reduced by replacing the existing bellows which have been extensively repaired with new items.

## 9.2 Recommendations

1. Install independent overspeed protection as described above.
2. Consider replacement of the bellows with new.

# 10 Maintenance

## 10.1 Initial Review

The maintenance instructions referenced by the ORACLE / JD Edwards system were downloaded. The Oracle / JD Edwards database driven system issues work orders for periodic maintenance and checks to the site controllers. The instructions for HWD were reviewed and then compared with the maintenance information in the CW manuals. A cross check against the Stephenville documentation showed the two to be almost identical so observations and conclusions are relevant to both installations.

The daily, semi annual, annual, 5 yearly and 6 yearly checks were reviewed, details are contained in marked copies of the following which are included in the appendices.

- Daily Operator Checks
- Semi-Annual Maintenance
- Annual Maintenance
- Gas Turbine Insp. & Maint. Curtiss Wright 4.3.2.33
- Air Start System Schematic, Dwg. No. 183481

The daily checks are considered suitable for “walk through” type checks, but the required activities are often not specified precisely, with frequent use of “etc.” More detail would be useful and is needed for more complicated checks. Marked drawings and checklists would ensure all items in a group are listed to be checked. This would for example ensure that all chip detectors are examined at the specified interval.

The 5 yearly checks refer to work orders. These are understood to be generated by the Oracle/JD Edwards system and currently reference the maintenance procedures. The Oracle system may be configurable to provide a means of recording detailed maintenance instructions, test results and remarks.

Observations have been marked on the procedures included in the appendices. General observations are summarised below

1. A maintenance instruction template with a set of standard headings, fields for key information and for recording observations would be useful to ensure that all considerations are identified and consistency of implementation.

2. Some paragraphs contain statements about required equipment status, isolations, and permit to work also equipment required to carry out the task. A consistent policy to include these or not would be useful. A subheading “isolation status” might be included in the standard template mentioned above. Knowledge of the required isolation status allows maintenance to be planned to work efficiently alongside production.

3. Sufficient detail needs to be included or cross referenced (eg to relevant sections in the CW manuals) to promote completeness and consistency in the maintenance activities. These could be included in the Hydro procedures or possibly put into the work orders in Oracle. Convenience of use is a consideration; in some cases it may be preferable to include information rather than to reference other documents, however where information uplifted from other documents, consideration must be given to change control.

4. Equipment would best be referred to by tag numbers and drawing reference.

5. The procedures contain fields for remarks and observations. It would be useful for these to be stored in a way which allows results of successive tests to be compared, and hence maintenance intervals to be adjusted and reliability of critical devices to be measured.

## 10.2 Gap Analysis

The Hydro procedures were compared with the CW document "Gas Turbine Insp & Maint. 4.3.2.33" further comments were added to the marked copies of the Hydro procedures and a marked copy of 4.3.2.33 was produced, see appendix 1f. Symbols have been used to indicate tasks included in the daily, semi annual and annual check procedures. Items not found in the Hydro procedures are also marked. Note that where page number references are used these are sequential numbers as would be displayed by an electronic tool such as Adobe rather than the ones marked on the pages. Reference was also made to a study carried out in 2008, "HWD & SV Maintenance Strategy Manual - 4.3.2.32", the primary purpose of which is understood to have been cost reduction.

The comparison is not completely precise because the descriptions in the documents are abbreviated, it can be unclear whether an item in the CW document is actually covered in the Hydro document.

The marking convention used identifies where an activity in the CW Manual is included in the Hydro procedures but at a different frequency. Neither the frequencies listed in the CW document nor in the current hydro procedures are necessarily appropriate, and review is recommended. Higher inspection and test frequencies are believed appropriate for safety and business critical elements, see below regarding lubricating oil and chip detection. The maintenance frequencies given in the Hydro procedures, tend to be consistent with those identified in the HWD & SV Maintenance Strategy Manual - 4.3.2.32. they are not the same as in the CW document.

Some components and systems listed in CW manual 4.3.2.33 look to be absent in the HWD and SVL installations, such as the spray cooling system. Other items listed for maintenance are probably obsolete such as the recorders listed under control sequencer instrumentation, which need bearings and belts changing during their service life. Some of the content is questionable such as page 35 item 4 which recommends checking fan blade pitch setting every month.

Some invasive activities such as inspecting thrust bearings and check blade clearances listed as yearly checks in the CW document 4.3.2.33 might better be scheduled on running hours if the duty cycle is low.

Many activities listed in the CW documentation are manual lubrication. These could be incorporated into a greasing schedule which could be listed to align with a plant walk through. A complete checklist is essential to ensure all lubrication points are covered. Activities such as belt tension checks could also be included.

## 10.3 Considerations about Bearing Failures

A possible cause cited for the recent bearing failures is poor lubricating oil quality. Oil sampling is listed as an annual check in the Hydro procedures, it is recommended that it is made more frequent, the CW Manual 4.3.2.33 lists it as a monthly activity.

Rising pressure differential across the fine filter in the LO return line could be an indicator of bearing failure as debris collects on the element. CW manual 4.3.2.33 pg 26 lists replacement of F-GGLO-1, the fine filter in oil returns, as an annual activity. It is listed a 5 yearly in the Hydro procedures. Given the recent history more frequent replacement may be more appropriate.

High differential across the filter is sensed by the pressure switch PS-GGLO-3 immediate action is needed on alarm activation. Reliable operation and appropriate setting of this switch is important. The limit of 15 psi differential quoted in the CW Manual 4.3.2.33 is higher than the 10 psi differential setpoint of the filter bypass and is inappropriate, (see section 11.5)

The CW document 4.3.2.33 lists inspection of magnetic chip detectors as a monthly activity however it is listed as a semi annual activity in the Hydro procedures. Given the historic bearing failure the frequency might be increased. It is understood that currently the detectors are inspected after every run, which seems adequate but is not reflected in the procedures. CW manual book 2 section 2.1.11.3 gives detail on inspection of the chip detectors and returning to service after contamination has been found, also on inspecting the deposits from the detectors and actions to be taken.

## 10.4 Safety, Business and Environmental Critical Items.

No reference was seen to testing of safety critical mechanical devices such as PSVs, nor inspection of pressure vessels, such as the 500 psi starting air receivers, in the Hydro procedures reviewed. 3 yearly inspection of the start air receivers is listed in the HWD & SV Maintenance Strategy Manual - 4.3.2.32. Maintenance and testing needs to be in place for all safety critical devices.

Electrical checks and calibration of instruments are included in the Hydro procedures as 5 and 6 yearly items however from the detail given it is not clear whether all equipment is covered. All measurement devices require periodic calibration. Safety critical measurements such as speed input to the overspeed shutdown need to be proof tested with a suitable frequency. Proof test procedures can be produced as part of this project.

Whether or not the SIL process is followed it is essential that all plant items including protection and control devices are identified and subject to some form of maintenance and testing. The identification task must be done rigorously with reference to current drawings. Taking the air start system as an example, drawing 183481, the drawing was marked up to show items requiring maintenance and those which are expected to be safety critical, see appendix 1g. Tag numbers on that drawing are not unique PS-CA-3 for example appears on the A and B modules. References must be unambiguous eg in this case by prefixing with A or B. Drawings used must be as built and be accurate with respect to plant modifications.

HAZOP is commonly used to qualitatively identify the undesirable consequences of failure or unintended operation. Test and maintenance schedules can initially be based on such qualitative assessment. SIL type analysis should be applied to engineering changes. For existing equipment it can be applied later to ensure maintenance of items according to their criticality, to give adequate protection and security of production without excessive cost due to over maintaining.

The widely accepted IEC 61508/61511 “SIL” approach is discussed in 3.1 above. It sets performance requirements and appropriate test frequency for individual elements of protection loops based in the risk incurred by failure.

## 10.5 Safety Critical Element Proof Testing.

Test procedures need to be carefully devised to test adequately. For example when testing a level switch the test must prove its performance in the actual application. If the cover is removed and the mechanism operated the test would not reveal a leaking float. The interaction with the process tends to be the source of unreliability rather than the electrical loop. Where switches are used as tripping devices failure tends to be unrevealed and particular attention is needed; transmitters have the advantage that provided their analogue output is suitably displayed it can be easily checked to ensure that the transmitter is working. The test regime needs to assess and record whether the device would have worked as found, recording a fail if it would not, irrespective of the subsequent repair. From the test results over a period actual performance is determined and the test regime adjusted if necessary.

## 10.6 Spares

Spares holdings were not reviewed but they need to be appropriate to allow remediation of a fault, which may mean restoration of production, within an acceptable timescale. The choice of which spares to keep depends on delivery lead time, impact of a failure, their cost and possibly impending obsolescence. It is important that key safety functions can be repaired without undue delay even if their failure does not stop production.

## 10.7 Time Base

Many maintenance activities such as LO quality checks and condition of hot parts of the engine are more dependent on running hours than calendar time passed. Since the stations are often used for power factor correction without the engines in use cost may be saved by scheduling maintenance on hours run.

## 10.8 Recommendations

Shorter Term

1. Make an assessment of which systems and equipment are critical to safety production and the environment and ensure that they are subject to some form of maintenance plan.
2. Whilst the cause of early bearing failure is under investigation, continue to check magnetic chip detectors after each run comparing quantity and appearance of debris collected with the previous test and between detectors.
3. Carry out monthly (suggested) sampling and quality checks on the gas generator lubricating oil. Re adjust when confidence is gained that adequate quality is being maintained.
4. Monitor the pressure upstream of the GGLO scavenge return filter (in the absence of a direct measurement of DP across it) daily, investigate any "off trend" behaviour.
5. Carry out regular proof tests on safety critical instrumented functions.

Longer Term

1. Ensure that key documentation such as reference drawings, maintenance routines and operating procedures are "as-built"
2. Ensure all equipment is included in the maintenance plan. Use the relevant system drawings to identify.
3. Ensure all potential hazardous scenarios are identified and hence which instrumentation is critical.
4. Adjust proof testing and maintenance regime to reflect the assessed criticality of the function.
5. Ensure that full detail is included in or referenced from the maintenance check documents so that the user has sufficient information to carry out the task effectively, this includes:
    a. Specific and unambiguous references to the equipment by tag numbers etc.
    b. Instructions in sufficient detail to ensure adequacy and consistency of the work carried out.
    c. Clear instructions on the records to be kept and a convenient way of recording. (Log sheets and fields in the work order as appropriate.)

    This information may be provided as work orders stored in the existing Oracle/JD Edwards system.
6. Ensure proof test results and other maintenance records are stored in a way which allows easy access for review and comparison with previous tests and other similar equipment.
7. Ensure spares holdings are appropriate to allow repair within acceptable timescales.
8. Apply the IEC 61511 "SIL" approach retrospectively to determine whether the protection systems are adequately designed and their optimum test and maintenance frequency. Proof test interval is determined as part of this process.

## 10.9 Work protection system / permits

No form of PTW or ISSOW system was seen to manage work tasks. However a "Tailboard" is carried out before jobs are started. This is the equivalent to a pre-job toolbox talk. LOTO is employed for isolations. For on-site tasks, "Job safety analysis" and "Job based risk assessments" are used.

# 11 Review of GG Lube Oil System

## 11.1 Background

It has been suggested that the recent bearing failures are due to the lubricating oil leaving the storage tank may have been contaminated. It is therefore proposed by Alba Power to install a fine filter in the suction line to the lubricating oil pump in the Olympus gas generators. Reference proposal dated 10 August 2016. This section considers this proposal and other aspects of oil and bearing health.

Many RR Olympus engines have been in service over several decades. It is to be expected that the lube oil system is well developed and fit for purpose; bearing failures due to design inadequacies in it would be unexpected. Faults in the system or unusual features of the application would be expected as the most likely cause of the failure rather than design shortcomings.

## 11.2 System Description

Fig 20 shows the gas generator and external LO system. Oil is stored in a tank which is maintained at a small positive pressure from a connection to the gas generator. A tank heater keeps the oil warm and mobile when the machine is shut down. Oil is drawn from the bottom of the tank and delivered to the suction of the shaft driven lube oil pump in the gas generator through stainless steel tubing. The gas generator contains scavenge pumps which provide the pressure to drive the return flow through a cartridge filter before being delivered back to the tank. This is a typical arrangement for a lubricating oil system serving an engine.

Low pressure switches PS-GGLO-1 and PS-GGLO-2 provide protection to the engine on loss of oil pressure under running and idling conditions initiating trip. PS-GGLO-3 measures pressure upstream of the return oil filter giving an alarm indication only as a measure of condition of the filter. TC-GGLO-1 measures temperature of oil leaving the tank.

The cartridge filter in the LO scavenge return prevents wear debris from reaching the LO tank where it would otherwise tend to settle. According to the RCA report on the bearing failure, P10854-RPT-004 Rev 2, the scavenge filter was blocked and the relief bypass had opened so metal particles were returned to the tank and found in the supply side of the system. It is understood that after the failure the system was completely cleaned and that the filter bypass and pressure switch are now operating correctly. [e mail M Khalifa/J Wilson 14:35 29 May 17].

## 11.3 Curtiss Wright and Rolls-Royce GGLO Systems Compared

Comparing the Curtiss Wright system with the Rolls-Royce system, they are almost identical.

The RR Drawing (Fig 21) shows a 400µ strainer on the draw-off from the tank additional to the 400µ strainer at the pressure pump suction.

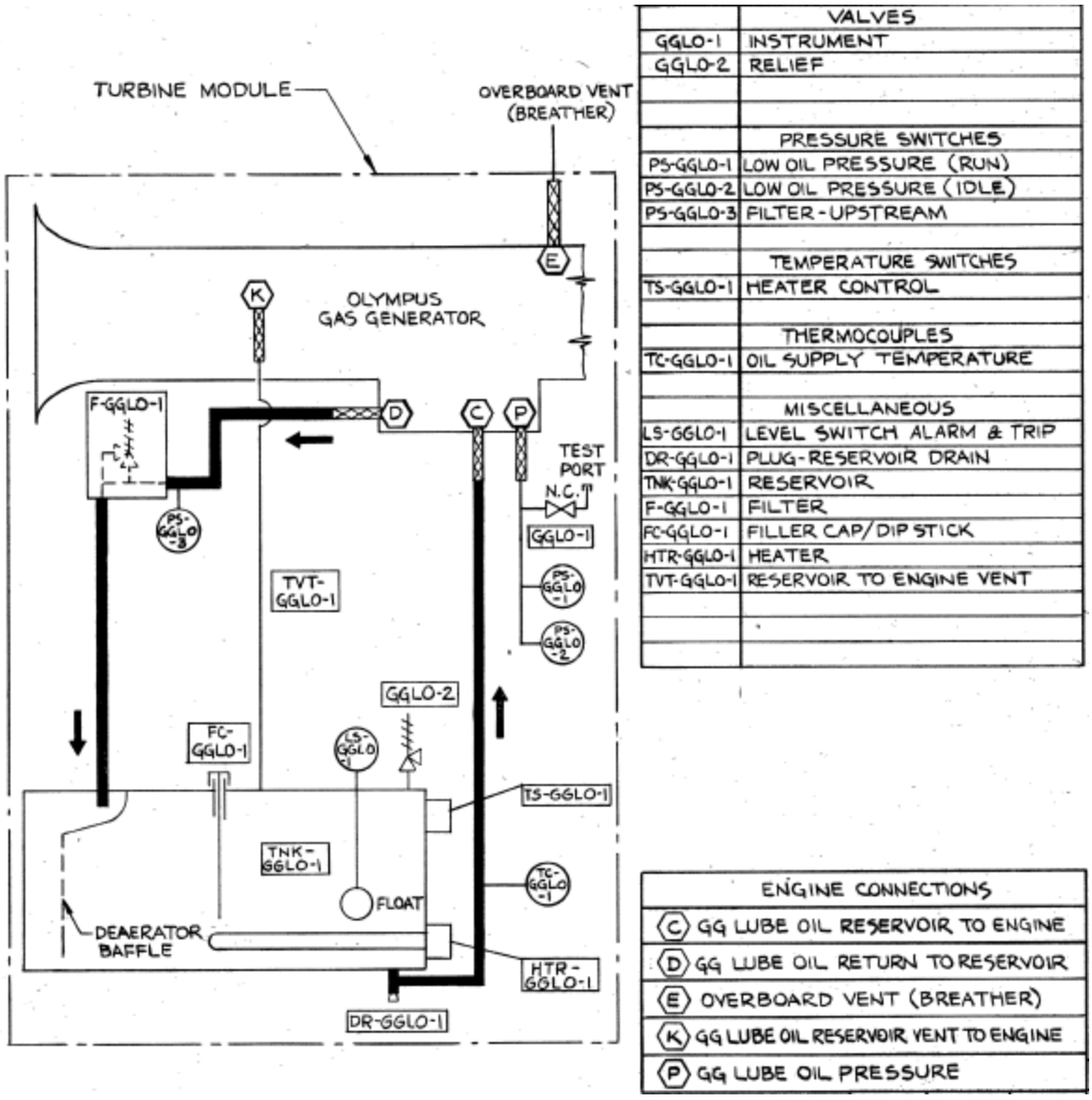



**Fig 20. Curtiss Wright packaged Olympus gas generator lube oil system (GGLO).**

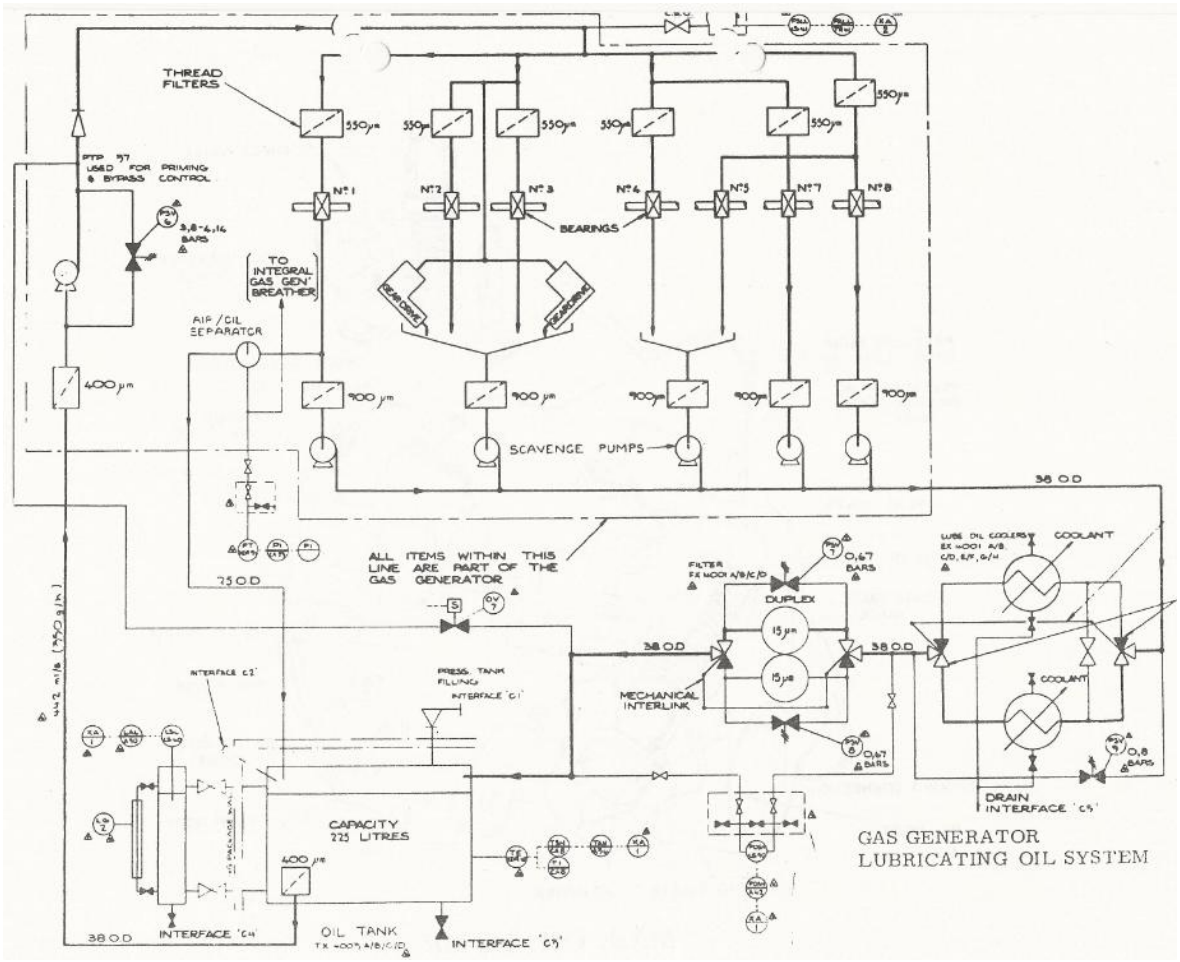



**Fig 21. Rolls-Royce packaged Olympus gas generator lube oil system (GGLO)**

## 11.4 Curtiss Wright LO Tank Arrangement.

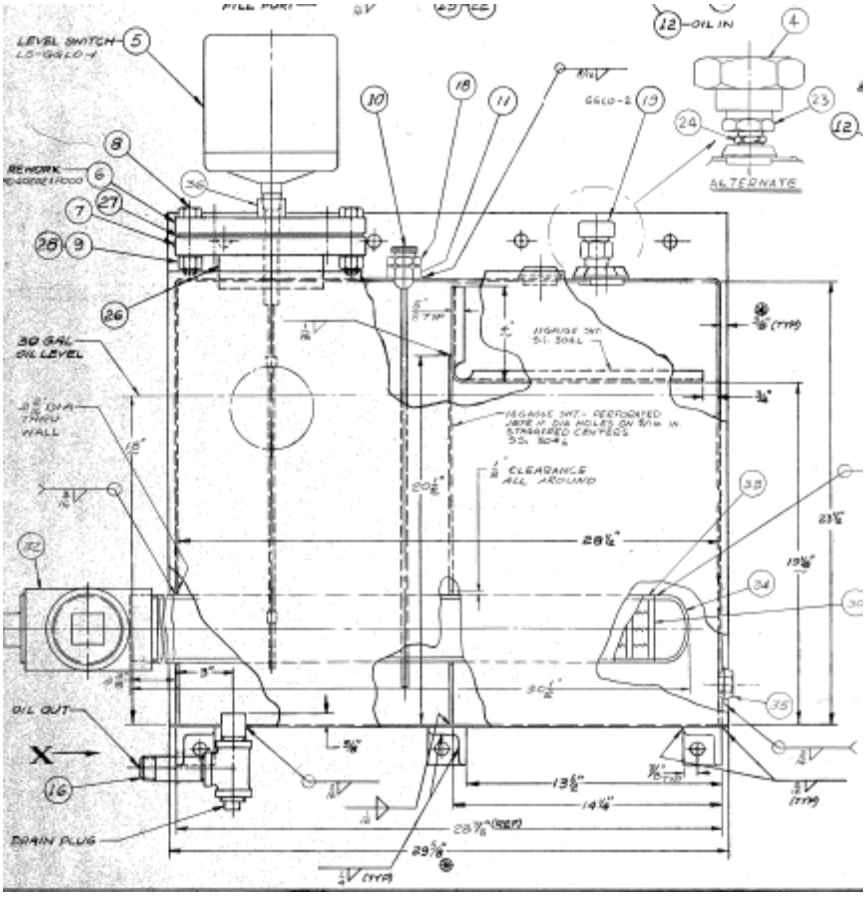



**Fig 22. Extract from LO tank drawing 495033**

The design of the LO tank has weakness in the draw off arrangement, the offtake is common with the drain and has only a 5/8" upstand from the bottom of the tank. In a typical arrangement the draw off would be elevated to prevent bottom sediment and water (BS&W) from being delivered to the engine, and the drain would be at the lowest point in the bottom of the tank to allow BS&W to be removed. The intermittent operation of the engine increases the risk associated with the draw off; if a bottom layer accumulates to the point where it is leaving with the oil being drawn off, then when the engine shuts down the material in suspension will settle and as the layer thickens material will be displaced into draw off pipework below the tank.

When the engine is started that slug of BS&W will be delivered to the engine and may cause damage. A sample point to allow this to be checked could be provided by replacing the drain plug with a plugged valve. A sample of oil could be drawn to allow a visual check and any contaminants to be drawn off, when the machine is to be started after a period of downtime. The possibility of drawing off solids would be reduced if the draw off could be elevated.

It is understood that the oil is being filtered periodically using temporary equipment which provides mitigation whilst the practice continues however eventually deposits should be expected to accumulate.

### 11.5 Scavenge Return Filter

It is recommended that effort is focussed on ensuring the existing fine filter in the scavenge return is effective, improving instrumentation to provide reliable monitoring. This involves installing a differential pressure transmitter measuring the pressure drop across the filter, displaying at the control point and generating high and low DP alarms. The high alarm would be set below the pressure at which the bypass opens, say at 8 psi DP, and the low alarm would be set 10% below the measured DP across a new filter element.

Fine filtration at some point in the lubricating oil system is essential and it must be adequately monitored and maintained. When the bearing failure occurred the filter blocked and the bypass opened allowing debris to circulate, instrumentation was subsequently checked and found to be operating satisfactorily however the configuration and settings of the existing instrumentation, also the maintenance information need attention.

The setpoint of the pressure switch PS-GGLO-3 is 15 psig and the filter bypass opens at 10 psi DP, so if there is less than 5 psi in the LO tank the bypass will open before the alarm annunciates and any variation in the tank pressure offsets the differential pressure across the filter. This is likely to have contributed to the bearing failure in 2015. Differential measurement across the filter with an alarm setpoint less than the setpoint of the bypass valve would eliminate this.

The CW maintenance manual specifies filter changes when the differential reaches 15 psi DP or a minimum of once a year. Rolls Royce specify a maximum of 10 psi DP. 15 psi DP is inappropriate because the bypass opens at 10 psi DP. A maximum differential of 9 psi DP is recommended as an initial figure. The alarm point should be reduced to give maximum sensitivity with a working headroom above the normal operating DP when the system behaviour is known. Setting to 5% (say) above the filter DP after 1 year of service would be satisfactory.

PS-GGLO-3 is a switch, this means any failure will be unrevealed until a test is carried out. If the device was a transmitter with an analogue display the operator would get to know what normal indications look like and whether the current reading looks healthy and live. The output from the transmitter would preferably be displayed at the control room and provided with high and low alarms. In the absence of a transmitter some benefit could be realised by having a local gauge.

A low differential would result if the bypass is stuck open or the element had failed, or is not sealing correctly with the housing. An analogue indication readily visible to the operator with high and low alarms could provide early warning of a failure developing during a run.

Regular filter changes and effective monitoring can do much to prevent build up of particulates in the LO system, however monitoring of filter differential may not give early indication of a developing bearing failure.

The manual magnetic chip detectors should reveal failure developing during the previous run but not whilst the engine is running. An alternative which could provide further early warning would be on-line detection of wear debris.

## 11.6 Proposed Cartridge Filter in LO Feed

It is not recommended to install additional filtration in the LO feed to the engine, but to ensure the cartridge filter in the scavenge return is operational and properly monitored. The recommendation would be different if Alba or any other service company insisted on it as a requirement for the guarantee on the service replacement equipment. Such a condition would be unusual and is understood not to apply here. The paragraphs below discuss the merits and requirements of the feed side filter if it was to be installed.

Additional filtration in the LO feed would bring some advantage in terms of oil quality but would introduce a pressure drop into the pressure pump suction path and the possibility of losing or restricting the oil flow to the engine. It would need to have instrumentation to allow blockage or malfunction to be detected. It would not provide a complete remedy to failure of the scavenge filter which would allow debris to settle in the LO tank.

A Vokes E238L duplex cartridge filter has been recommended by Alba Power, no element selection in terms of capacity or rating in microns is included.

Generally it is good practice to minimise equipment which can generate pressure drop in the suction line to a pump fed from a tank operating near ambient pressure, although often there is a strainer. Sometimes referred to as a "bolt catcher" this has a coarse mesh size and offers little pressure drop. It is unlikely to block progressively with running hours, rather it prevents larger particles and objects such as construction debris from reaching the pump.

The RR design shows a 400µ filter at the tank outlet which would catch much of the contamination eg commissioning debris which might be introduced through the tank. It is not fine enough to catch wear debris. The absence of the tank outlet strainer in the CW arrangement is not seen as problematic because the engine mounted 400µ filter in the suction to the LO pressure pump makes it redundant.

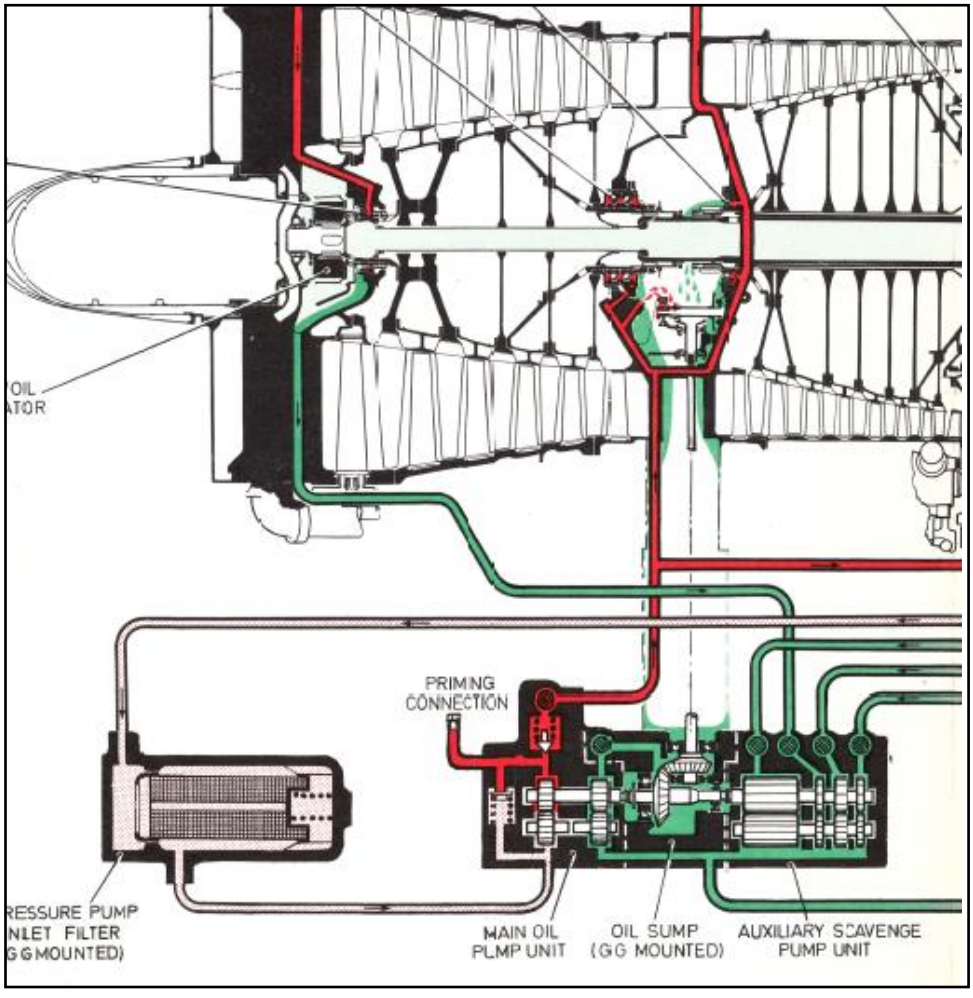



**Fig 23. Extract from the On Engine LO Schematic.**

The pressurisation of the tank and the low vapour pressure of lubricating oils would help to maintain suction head at the pump, nevertheless a fine filter with a significant pressure drop brings the possibility of losing suction pressure to the LO supply pump. The engine should be protected against this by the low LO pressure trips however the new filter would increase the demand on those trips.

The line from the tank to the pump suction is not trace heated or insulated. Assuming this remains the case when the new filter is installed, the effect of cooling to ambient temperature during winter conditions should be considered.

It would be difficult to exceed the maximum tolerable differential pressure across the new filter because of the low driving pressure from the tank, however if a collapse did occur and a slug of debris entered the engine the result could be significant downtime and repair cost.

If the new filter is made permanent, monitoring its condition should be considered. As a minimum a local reading differential pressure gauge is recommended. The correct measurement range is likely to be less than the filter manufacturer's standard. With the LO tank slightly above atmospheric pressure a range greater than 1 bar would be inappropriate, 0.5 bar is likely to be suitable.

The usual arrangement of a LO filter is in the scavenge return (reference RR GGLO diagram in Fig 21), as the original Olympus design, the Vokes filters are likely to be rated based on installation in such an arrangement. The suggested type is available with design capacities of 5, 12 and 18 gpm. For installation on the suction side of the pump rather than on the delivery side of a pump, where the sensitivity to pressure drop is greater it is recommended that the filter is generously sized; such as by selecting the next larger catalogued unit than required for the flow.

The detail of the LO system, selection basis of the new filter and its impact on the pump suction condition was not available. It is recommended that this is reviewed prior to installation.

Apart from any contamination of the oil in the tank, the new filter would be expected to collect relatively little debris. Most of the wear debris from the engine should be collected by the filter in the scavenge return line.

## 11.7 Oil flow and filter element selection

The proposal does not include any information regarding the filter element rating in microns, nor the selection of a suitable filter unit from the options available.

Rolls-Royce Fig 21 notes the oil flow from the tank to the GG pumps to be 350 Imperial gallon / hour. This equates to 5.3 Imperial gallon / min (6.3 US gallon / min).

The quoted Vokes filter figures are in US gallon / min. To select a filter unit capacity, one of the 12 gallon / min elements would be the logical choice being the next available capacity. However, the penalty is a filter DP of 3.5 psi when a new clean element is installed (in practice this would be dependent on flow), a DP which would increase as the filter clogs.

The filters offer an internal bypass function upon a blocked filter raising the DP. This bypass activates at 12 ±2 psi DP. The pump is likely to lose suction placing a demand on the low LO pressure trip to protect the engine before the bypass operates. Given the low pressure in the LO tank, the engine would be likely to lose oil feed before the bypass opens.

## 11.8 LO Sampling and Analysis Results

Sampling analysis results would have been of limited value in predicting the bearing failure, but are more useful for monitoring condition of the oil itself. Data from the CW manuals is less useful than comparison with the specified and measured values for new oil.

Fig 24 compares key LO specifications and sample analysis results

| Item | Iron | Visc | Oxidation | TAN | Water |
|---|---|---|---|---|---|
| | ppm | cSt (40oC) | abs units | MgKOH/g | ppm |
| CW Spec for Shell Oil | - | 34-44 | - | 1.0 increase | <1000 |
| CW Spec for Exxon Oil | - | 24-32 | - | 1.0 increase | <1000 |
| RR Spec for Esso Turbine 2380 | - | 39.1-50.6 | - | 1.0 increase | <1000 |
| Spec for new Mobil Jet II | - | 27.6 | - | 0.03 | - |
| AGAT New Oil | - | 25.8 | 43 | 0.08 | - |
| AGAT No 130090 before failure | 0 | 28.1 | 66 | 0.07 | 189 |
| SKF report. Oil from failed engine | 21 | 24.75 | - | 0.1 | - |
| AGAT No 131037 From system immediately after failure. | 49 | 26.7 | 5 | 0.06 | 344 |
| AGAT No 36459 2 years before failure | | 25.8 | 118 | 1.84 | 109 |
| AGAT No 131030 May 2017 | 1 | 26.3 | 36 | 0.05 | 237 |

**Fig 24. LO Specifications and Analysis Results.**

The data and measurements are scattered but the analysis can give some warning. Increases in iron, oxidation number or TAN are alerts to possible problems. Unusual increase in any of these is a cue to look for other indications of developing problems, also to repeat the sample test for confirmation.

21 ppm of iron was found in the sample taken from the failed engine. This is consistent with the sample taken from the system immediately after failure which indicated 49 ppm. The sample taken before the failure contained none. This is to be expected; the failure will have released iron into the system. Iron in the LO is a strong indicator of trouble and elevated levels should be investigated, however is not possible to conclude that iron in oil analysis is a good measure of a developing failure. Levels may not increase much until the failure, which may occur rapidly, is imminent. Deposits on the magnetic chip detectors are likely to be as good an indicator or a better one.

The oxidation absorbance number given in the AGAT reports and the total acid number (TAN) are measures of oxidation, elevated values are seen in the samples taken before and immediately after the failure. However the TAN in those samples was much lower than the limit of 1.0 mg/g increase between samples indicated in the CW data. AGAT report a TAN of 0.08 mg/g for new oil, more than for sample 130090 taken before the failure, and almost 3 times the figure of 0.03 mg/g given in the manufacturer's spec for Mobil Jet II. All those low numbers are likely to be effectively zero in terms of the sensitivity of the test. The oxidation absorbance number is a guide but not a clear measure. The AGAT report from May 2017 shows an oxidation no of 43 for new oil and a lower value of 36 for the oil sampled that month. The measurement of 66 from the sample taken before the failure is high but not clearly extreme and unlikely to draw attention to trouble.

Sample 36459, 2 years before the failure indicated substantially higher measures of oxidation than those around the time of failure, it also shows elevated levels of combustion products NOx COx and SOx, but was not associated with bearing failure. Such measurements could be the result of contact of oil with combustion gases. Water is a combustion product yet that sample shows 109 ppm, a lower value than other samples on the report, that is consistent with contact between oil and gas at high temperature which would tend to strip out water.

For a similar installation Rolls Royce specify 6 monthly oil changes during which the LO tank is swilled with kerosene. No reference to this was found in the CW manuals. (See Fig 25 below)

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4.8 Oil Tank

The oil tank, filter, drain valve and pipes must be cleaned out every SIX MONTHS and when the gas generator is changed. The tank should be drained whilst the oil is still warm and the interior cleaned using kerosene and sponges - on no account use cotton waste or loose - fibred rags which may become detached. Swill with clean kerosene and thoroughly dry. Fill up with approved lubricating oil, check for leaks and prime the gas generator oil system before starting operations.

**Fig 25. Extract from RR SK 30 Olympus maintenance manual.**

## 11.9 On line Chip Detection

On line lubricant condition and machinery wear monitoring is a developing product area, with a number of devices and technologies on the market and under development with various manufacturers. PI's experience that such systems can give spurious indication however state of the art equipment would be expected to perform better than the earlier types.

PI were recently approached by a vendor, Gastops who produce a sensor system Metalscan 4000 which is designed to detect the type of particles typical of degradation of rolling element bearings. Their system is approved and used by well known gas turbine manufacturers and users. PI contacted a North Sea operator who installed Metalscan on GE LM 2500 gas turbines, they have found the system satisfactory, specifically spurious indications were not a problem. The sensor is a flow cell which is installed to carry the entire lubricant returns flow between the scavenge pump and the cartridge filter, it uses an electromagnetic principle similar to that of a linear variable differential transformer to detect passage of a debris particle by its magnetic effect. The output is as a particle count against which alarms can be set, and the sensitivity is set to detect the metal flakes characteristic of fatigue in rolling element bearings, which have a size around 200µm, these are much larger than the smaller micron sized particles generated by "benign" wear.

The flow through sensor connects to a local base unit, suitably environmentally rated for plant applications including flammable atmospheres. The base unit hands off data via a Modbus serial link to whatever device is used for logging and display. It would be most convenient to provide a display for the operator at the control room via the existing BPCS and HMI, provided a suitable communications card can be installed. Alternatively a standalone PC can be provided.

The above detail was obtained from an approach by Gastops. An Internet source http://www.machinerylubrication.com/Read/521/in-line-wear-debris-detectors, gives a review of nine companies producing lubricant and wear monitoring instrumentation, some offer them more than one technology including Metalscan.

From a brief review the Metalscan product looks to be one of those more suitable for this application. Gastops indicated that a system comprising a single flow through sensor and base unit would cost about USD 20,000 (approx. CAD 26,400) per single channel unit.

A second company, Poseidon market a product using similar technology to Metalscan. The Trident DM 4500 field unit costs about USD 3,150 (approx. CAD 4,260) it contains the detector and processing logic to sort the counts into size categories, there is no additional field mounted base unit. Similar to Metalscan the detector takes the full flow of LO from the scavenge return. The data is handed off via a Modbus serial link to be displayed, logged and used to generate alarms as required. If required the DM 4500 can interface with an Internet gateway, Trident AP 2200 which costs about USD 450, (approx. CAD 590) data is then gathered and processed by Poseidon and accessed via a web portal, avoiding the need to interface with the existing control computer there is a monthly charge of a few dollars for this service. A third option is to use a local PC as the logging and display device.

The Poseidon product is inexpensive and likely to be "state of the art", Poseidon having recently bought two rival companies, Macom and Manor Technology whose IP development has been incorporated into the Poseidon products. Their experience mainly relates to non - gas turbine applications such as wind turbine gearboxes. The maximum temperature rating of 85 $^{o}$C may be limiting. Measured values of LO returns temperature would need to be considered, also unlike the Gastops product aeration and foaming in the returns stream may give false counts. Given the low cost this product could be installed on a trial basis with a view to making permanent or trying the more expensive Gastops product if the results are not satisfactory.

Product information for the Gastops and Poseidon devices is contained in Appendix 2

## 11.10 Conclusions

The cartridge filter in the LO scavenge return should be capable of providing the required micron level filtration. Improvement to that filter arrangement to ensure reliability is preferred to installing a second similar filter in the LO feed to the machine.

On line chip detection could be useful to give early warning of a developing condition. The types featuring electromagnetic particle counting in a full flow sensor are preferred to those which capture particles and give an output based on amount of material captured.

Oil analysis reports are useful for monitoring oil condition and may indicate problems developing, however they are less likely to indicate the onset of a bearing failure.

## 11.11 Recommendations

1. Do not install a new filter in the LO supply line but ensure the filter in the scavenge return is effective:
    a. Install a differential pressure transmitter measuring the differential across the LO filter, display the reading at the control room and provide high and low alarms.
    b. Monitor the filter DP throughout the service life of the cartridge. Install analogue reading device so that high, low and healthy DP can all be confirmed.
    c. Check the setpoints of the filter internal bypass and high pressure/differential alarm against the filter elements being used.
    d. Adjust alarm points based on operational experience to allow adequate headroom over operating conditions with but maximise sensitivity.
    e. Ensure documentation is updated: the CW manual specifies 15 psi DP which is too high.
    f. Carry out regular element changes.

2. Monitor condition of oil by sampling, changes in the following are possible indicators of developing problems:
    a. Iron content.
    b. Oxidation and increased acidity indicate deterioration which may be associated with, or may lead to, bearing failure.
    c. Presence of NOx, COx and SOx is likely to result from contact with combustion gases and is likely to be associated with oxidation of the oil.

3. LO Takeoff and Check LO before machine start
    a. Install a valve on the GG LO tank drain point, eg reduce and use ½" instrument valve.
    b. If practical change the draw off point to elevate it above the tank bottom.
    c. If b above cannot be achieved, when there has been a downtime period of days or more for the turbine, sample oil at the tank drain point to ensure cleanliness.

4. Continue to check chip detectors after each running period.

5. Consider installing on – line chip detection of a type which will detect the type of debris characteristic of rolling element bearings. If the engines are to run for extended periods this could give warning of a developing fault.

# 12 Trip Setpoint Verification

The table Fig 27 compares installed setpoints from copied from the software listing and compares with the values in the CW documentation and a similar RR Olympus installation.

There are differences between the figures; the software is not set according to the listing in the CW manuals. The reasons for the differences are not clear; however the installed figures do not look inappropriate and do not raise any immediate concern. It is worth noting the larger exhaust temperature differential installed 65 °C for HWD and 55 °C for SVL, compared with the CW figure of 37 °C.

| Parameter | Curtiss Wright setting | Direction | RR if applicable | Found in Software | Remarks |
|---|---|---|---|---|---|
| PT (N3) Overspeed | 4140 rpm | High | N/A | 4140 RPM (CLD-017) | OK |
| Main Lube Oil Pressure | 20 psi | Low | N/A | 20 psi (CLD-049)* | OK |
| Power Turbine Main Lube Oil Drain Temperature | 82°C | High | N/A | 85°C on Thrust Drain (CLD-100) | Higher than CW figure, review if possible to lower to 82°C |
| | | | | 85°C on Common Drain (CLD-100) | Higher than CW figure, review if possible to lower to 82°C |
| Fuel Pressure | 5 psi | Low | N/A | Pressure Switch (CLD-61) | Ensure annual testing proves calibration and trip function |
| Exhaust Temperature | 800°C | High | 775°C | 776°C (CLD-092) | OK |
| Exhaust Temperature Differential (Spread) | 37°C *** | High | 60°C For C rated GG | 65°C (CLD-093) | Higher than CW figure, review if possible to lower to RR 60°C |
| GG Lube Oil Pressure PSGGLO1 (Running) | 50 psi | Low | 50 psi | Pressure Switch | Ensure annual testing proves calibration and trip function |
| GG Lube Oil Pressure PSGGLO2 (Idle) | 10 psi | Low | N/A | Pressure Switch | Ensure annual testing proves calibration and trip function |
| Flame Failure Temperature | 190°C | Low | | 204.44°C (CLD-073) | OK |
| GG vibration | 5 mils (=127µm) (Curtiss position) | High | 124 µm | N/A | Displacement N/A |
| | | High | 19mm/s avg. (= 24.2mm/s p-p) (RR position) | 1.2 in/s pp operational (= 30.5mm/s p-p)<br><br>3.6 in/s pp during accel. (= 91.4 mm/s p-p) (CLD-103) | Velocity trip level is close to RR figures, but slightly higher. This may be due to requirements of the particular GG installed and should be in agreement with GG over-hauler. |
| Starter Failure | 1900 rpm N2 | High | N/A | ? | Not Found in Logic, consider implementation. |
| | 265 psi to motor | High | N/A | Pressure Switch (CLD-057)** | Ensure annual testing proves calibration and trip |

| Parameter | Curtiss Wright setting | Direction | RR if applicable | Found in Software | Remarks |
|---|---|---|---|---|---|
| | | | | | function |
| | 100 sec overcrank | High | N/A | N/A | Various other starter watchdogs take place of this 100 sec timer. |
| Enclosure Temperature | 85°C | High | N/A | 70°C (CLD-097) | OK |
| Fuel Pressure | 15 psi | High | N/A | Pressure Switch | Ensure annual testing proves calibration and trip function |

| | | | | | |
|---|---|---|---|---|---|
| GG Lube Oil Temperature | Alarm 74°C | High | Alarm 100°C | Trip 115°C | Curtiss Wright and RR specify different alarm points; unit actually has a trip point, so not a direct comparison. |

**Fig 26. Hardwoods Trip Verification**

| Parameter | Curtiss Wright setting | Direction | RR if applicable | Found in Software | Remarks |
|---|---|---|---|---|---|
| PT (N3) Overspeed | 4140 rpm | High | N/A | 4140rpm (CLD-017) | OK |
| Main Lube Oil Pressure | 20 psi | Low | N/A | 20 psi (CLD-049)* | OK |
| Main Lube Oil Temperature | 82°C | High | N/A | 82°C on Thrust Drain (CLD-100) | OK |
| | | | | 85°C on Common Drain (CLD-100) | High – Review if possible to lower to 82°C |
| Fuel Pressure | 5 psi | Low | N/A | Pressure Switch (CLD-61) | Ensure annual testing proves calibration and trip function |
| Exhaust Temperature | 800°C | High | 775°C | 680°C (CLD-092) | OK |
| Exhaust Temperature Differential (Spread) | 37°C | High | 60°C For C rated GG | 55°C (CLD-093) | Higher than CW figure, but within RR C-rated figure. |
| GG Lube Oil Pressure PSGGLO1 (Running) | 50 psi | Low | 50 psi | Pressure Switch | Ensure annual testing proves calibration and trip function **NOTE:** PLC logic states 40 psi for SVL, but 50 psi for HWD |
| GG Lube Oil Pressure PSGGLO2 (Idle) | 10 psi | Low | N/A | Pressure Switch | Ensure annual testing proves calibration and trip function |
| Flame Failure Temperature | 190°C | Low | | 204.44°C (CLD-73) | OK |
| GG vibration | 5 mils (=127µm) (Curtiss position) | High | 124 µm | N/A | Displacement N/A |
| | | High | 19mm/s avg. (= 24.2mm/s p-p) (RR position) | 1.2 in/s pp operational (= 30.5mm/s p-p)<br><br>3.6 in/s pp during accel. (= 91.4 mm/s p-p) (CLD-103) | Acceleration trip level is close to RR figures, but slightly higher. This may be due to requirements of the particular GG installed and should be in agreement with GG over-hauler. |
| Starter Failure | 1900 rpm N2 | High | N/A | ? | Not Found in Logic, consider implementation. |
| | 265 psi to motor | High | N/A | Pressure Switch (CLD-057)** | Ensure annual testing proves calibration and trip function |
| | 100 sec overcrank | High | N/A | N/A | Various other starter watchdogs take place of this 100 sec timer. |
| Enclosure Temperature | 85°C | High | N/A | 82°C (CLD-097) | OK |
| Fuel Pressure | 15 psi | High | N/A | Pressure Switch | Ensure annual testing proves calibration and trip function |

| | | | | | |
|---|---|---|---|---|---|
| GG Lube Oil Temperature | Alarm 74°C | High | Alarm 100°C | Trip 115°C | Curtiss Wright and RR specify different alarm points; unit actually has a trip point, so not a direct comparison. |

**Fig 27. Stephenville Trip Verification**

Notes:

RR info from SK30 Olympus engine manual 7740, and cross referenced to RR Olympus training notes.

*CLD-049 shows alarms and trips associated with Engine (GG) Lube Oil, but these are observing Main Lube Oil (Power Turbine and generator). This does not pose a protection issue, as GG Lube Oil pressure protection is provided by pressure switches PSGGL01 and PSGGL02, but may be found misleading.

**CLD-057 starter motor high pressure switch PS-CA3 is denoted as STARTER OPERATIONAL-A, whereas in the Starter Air P&ID (183481) is denoted as STARTER OVER PRESSURE. The notation in the software may be found misleading.

*** The CW figure may not refer to the same engine rating as installed.

# APPENDIX 1a: MARKED COPY OF

# HWDGT Operators Daily Checks

HYDRO
THE POWER OF COMMITMENT

GAS TURBINE OPERATORS DAILY CHECKS

| *In CW 4.3.2.33* | | | | | | |
|---|---|---|---|---|---|---|
| **1. CONTROL MODULE** | | | | | | |
| *a. PC* | Pg 53 recording instrument | | | | | |
| *b. MCC* | | | | | | |
| *c. AVR* | | | | | | |
| *d. Check Meters, lights* | | | | | | |
| *e. General Safety Check* | | | | | | |
| *f. Building heating / air conditioning* | | | | | | |
| | | | | | | |
| **2. FUEL FORWARDING MODULE** | | | | | | |
| *a. Forwarding Pumps* | | | | | | |
| *b. Filter/coalescer* | | | | | | |
| *c. Inergen fire system* | | | | | | |
| *d. Lighting, heating, vents, etc…* | | | | | | |
| *e. Sump drains* | | | | | | |
| | | | | | | |
| **3. A&B MODULES** | | | | | | |
| ***GAS GENERATOR 'A'*** | | | | | | |
| *a. Fuel Leaks* | | | | | | |
| *b. Air Leaks* | | | | | | |
| *c. GG Oil* | YES | | | | | |
| *d. Electrical Connections* | | | | | | |
| *e. Sump Drains* | | | | | | |
| *f. Fan Forced Heaters* | | | | | | |
| ***GAS GENERATOR 'B'*** | | | | | | |
| *a. Fuel Leaks* | | | | | | |
| *b. Air Leaks* | | | | | | |
| *c. GG Oil* | YES | | | | | |
| *d. Electrical connections* | | | | | | |
| *e. Sump Drains* | | | | | | |
| *f. Fan Forced Heaters* | | | | | | |
| | | | | | | |
| ***Power Turbine 'A'*** | | | | | | |
| *a. Oil Leaks* | pg 81 | | | | | |
| *b. Blankets & Thermocouple* | | | | | | |
| *c. Bellows Assembly* | pg 81 | | | | | |
| *d. Bearing Supports* | pg 83 | | | | | |
| ***Power Turbine 'B'*** | | | | | | |
| *a. Oil Leaks* | pg 81 | | | | | |
| *b. Blankets & Thermocouple* | | | | | | |
| *c. Bellows Assembly* | pg 81 | | | | | |
| *d. Bearing Supports* | pg 83 | | | | | |

HYDRO
THE POWER OF COMMITMENT

GAS TURBINE OPERATORS DAILY CHECKS

| | In CW 4.3.2.33 | Tue | Wed | Thur | Fri | Expected value/Comments |
|---|---|---|---|---|---|---|
| **4. GENERAL** | | | | | | |
| *a. Lighting* | | | | | | |
| *b. Heaters* | | | | | | |
| *c. Coolant Leaks* | | | | | | |
| | | | | | | |
| **5. FIRE PROTECTION** | | | | | | |
| *a. Verify all Openings* | | | | | | |
| *b. Check Inergen System* | | | | | | |
| | | | | | | |
| **6. ALTERNATOR MODULE** | | | | | | |
| *a. Jacking Pumps* | | | | | | |
| *b. Bearing Supports* | | | | | | |
| *c. Air Filters* | | | | | | |
| *d. Lighting/Heating* | | | | | | |
| *e. Air filters* | | | | | | |
| | | | | | | |
| **7. AUXILIARY MODULE** | | | | | | |
| *a. Pumps* | | | | | | |
| *b. Demister* | | | | | | |
| *c. MLO System* | YES | | | | | |
| *d. Glycol System* | | | | | | |
| *e. Ligh ti ng/Heating* | | | | | | |
| *f. Inergen fire system* | | | | | | |
| | | | | | | |
| **8. COMPRESSED AIR SYSTEM** | | | | | | |
| *a. Air Leaks* | | | | | | |
| *b. Compressor oil* | | | | | | |
| *c. Dryer & receiver Tanks* | | | | | | |
| *d. Confirm Operation of Drains* | | | | | | |
| | | | | | | |
| **9. GLYCOL** | | | | | | |
| *a. Coolant* | | | | | | |
| *b. Heat Exchangers* | | | | | | |
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HYDRO
THE POWER OF COMMITMENT

GAS TURBINE OPERATORS DAILY CHECKS

| | *In CW 4.3.2.33* | *Tue* | *Wed* | *Thur* | *Fri* | *Expected value/Comments* |
|---|---|---|---|---|---|---|
| **10. MISCELLANEOUS** | | | | | | |
| *a. Sump level* | | | | | | |
| *b. Yard fencing* | | | | | | |
| *c. Tank Farm* | | | | | | |
| *d. Security* | | | | | | |
| *e. Check all drums for leaks and ensure secondary containment.* | | | | | | |
| | | | | | | |
| **11. FUEL OFF-LOADING MODULE** | | | | | | |
| *a. Building* | | | | | | |
| *b. Varec Gauge* | | | | | | |
| *c. Check Double Wall Fuel Pipe* | | | | | | |
| | | | | | | |
| **12. MAINTENANCE BUILDING** | | | | | | |
| *a. Building* | | | | | | |
| *b. Water Supply* | | | | | | |
| | | | | | | |
| **13. TERMINAL STATIONS** | | | | | | |
| *a. Building* | | | | | | |
| *b. Recorder* | | | | | | |
| *c. Security* | | | | | | |
| *d. Alarms* | | | | | | |
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| **14. REMARKS** | | | | | | |
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| **Inspection Date:** | | | | | | |
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# GAS TURBINE OPERATOR'S DAILY CHECK GUIDE FOR UNIT & ASSOCIATED EQUIPMENT

| | |
|---|---|
| **1. CONTROL MODULE** | PI COMMENTS |
| a. PC (alarms, printer, paper, etc. | what does etc. comprise? CW manual 4.3.2.33 pg 53 refers to recorder paper and ink. |
| b. MCC's (lights, bkr's, general condition, heaters, SS transformer temp., etc.) | This might benefit from a checklist of specific items identified by tag nos. |
| c. AVR (inverter, charger, batteries, etc.) | As above |
| d. Check kwhr meters, lights, etc. | Do readings need to be recorded and filed? |
| e. General safety check (building lighting, building heating/air conditioning.) | Checklist would ensure consistency and that everything is covered. |
| **2. FUEL FORWARDING MODULE** | |
| a. Forwarding pumps (leaks, pressure, temperature, flow, etc.) | If readings are recorded and filed then trends can be identified. |
| b. Filter/Coalescer (leaks, pressure across filter, etc.) | As above |
| c. Sump drains, etc. | Checklist would ensure consistency and that everything is covered. |
| d. General safety check (building Lighting, heating, vents, etc.) | As above |
| **3. A & B MODULES** | |
| **GAS GENERATOR "A"** | Include checks on inlet plenum. CW Manual 4.3.2.33 pg 51 refers to daily checks on an evaporative cooler. Do the HWD units have this? |
| a. Fuel leaks (lines, fittings, gauges, valves, etc.) | Marked drawing with the lines in question would ensure consistency and completeness |
| b. Air leaks (starter, lines, etc.) | As above, also method statement would be useful for finding leaks. |

| | | |
|---|---|---|
| c. GG Oil (level, leaks, heater, fittings, valves, etc.) | | Include temperature and oil level check (CW Man. 4.3.2.33 pg27). Checklist and method statement would be useful. Eg what exactly are the checks on the heater. |
| d. Electrical connections. | | Checklist would ensure consistency and that everything is covered. |
| e. Sump drains | | As above |
| f. Fan forced heaters. | | As above |
| | | |
| **GAS GENERATOR "B"** | | As GG A |
| | | |
| a. Fuel leaks (lines, fittings, gauges, valves, etc.) | | |
| b. Air leaks (starter, lines, etc.) | | |
| c. GG Oil (level, leaks, heater, fittings, valves, etc.) | | |
| d. Electrical connections. | | |
| e. Sump drains | | |
| f. Fan forced heaters. | | |
| | | |
| **POWER TURBINE "A"** | | |
| | | |
| a. Oil leaks (lines, clutch module, etc.) | | Checklist would ensure consistency and that everything is covered. |
| b. Blankets and thermocouples (burnt indication, etc.) | | As above |
| c. Bearing supports (leaks, wear, etc.) | | As above |
| d. Bellows assembly (security of attachment, cracks in flanges & volute, etc.) | | As above |
| | | |
| | | |
| | | |
| | | |

| | | |
|---|---|---|
| **POWER TURBINE "B"** | | As PT A |
| | | |
| a. Oil leaks (lines, clutch module, etc.) | | |
| b. Blankets and thermocouples (burnt indication, etc.) | | |
| c. Bearing supports (leaks, wear, etc.) | | |
| d. Bellows assembly (security of attachment, cracks in flanges & volute, etc.) | | |
| | | |
| 4. **GENERAL** | | |
| | | |
| a. Lighting. | | Checklist would ensure consistency and that everything is covered. |
| b. Heaters. | | As above |
| c. Coolant leaks. | | As above |
| | | |
| **5. FIRE PROTECTION** | | |
| | | |
| a. Verify all doors and openings are well sealed and auto closers are functioning. | | Checklist would ensure consistency and that everything is covered. |
| b. Check Inergen fire system (fire panel, pressure, etc. | | As above |
| | | |
| **6. ALTERNATOR MODULE** | | |
| | | |
| a. Jacking pumps (leaks, gauges, pressure switches, etc.) | | What are checks on pressure switches and gauges? Are readings from gauges to be recorded Checklist/logsheet/method statement would be useful. |
| b. Bearing supports (leaks, wear, etc.) | | How is wear to be determined? |
| c. Check conditions of air filters. | | What type of check? Method statement. |
| d. Lighting. | | Checklist |
| | | |
| **7. AUXILIARY MODULE** | | |
| | | |
| a. Pumps (leaks, pressure, etc.) | | Checklist and logsheet would ensure consistency and allow trends to be identified. |
| b. Demister & evacuator (leaks, etc.) | | As above |
| c. MLO system (temperature, pressure, leaks, etc.) | | As above. 4.3.2.33 pg 92: check oil level and flow indicators. |
| d. Glycol system (temperature, pressure, leaks, etc.) | | As above |
| e. Lighting. | | Checklist |

| | | |
|---|---|---|
| | | |
| **8. COMPRESSED AIR SYSTEM** | | Drawing 183481. CW manual 4 page 4-9 listss weekly checks. |
| | | |
| a. Air leaks (lines safety valves, unloaders, etc. | | Marked drawing and /or checklist would ensure completeness and consistency. |
| b. Compressor oil (level, color, etc.) | | How is the colour to be assessed? Activity as listed in CW Manual 4.3.2.33 |
| c. Dryer & receiver tanks (leaks, etc.) | | Method? No dryer is shown on dwg 183481 |
| d. Confirm operation of condensate drains. | | As above |
| e. Check oil-water separator for leaks and levels. | | As above. Could not find an oil water separator on dwg.,183481. Does this mean the auto drains which separate oily water from air? Line above mentions condensate drains |
| | | |
| **9. GLYCOL SYSTEM** | | |
| | | |
| a. Coolant (leaks, temperature, etc.) | | |
| b. Heat exchangers (fans, belts, guards, motors, etc.) | | Checklist and method statement. Include checks on ventilation openings in motors and air coolers (4.3.2.32 pg 31) |
| | | |
| **10. MISCELLANEOUS** | | Checklists required. CW Man 4.3.2.33 pg 92 refers to combustible gas related equipment. If *present this will need maintenance and is probably safety critical.* |
| | | |
| a. Sump level | | |
| b. Yard fencing (signs, holes, etc.) | | |
| c. Tank farm (piping, leaks, vegetation, etc.) | | |
| d. Security (check back gate, fence, etc.) | | |
| e. Check all drums for leaks and ensure secondary containment. | | |
| | | |

| | | |
|---|---|---|
| **11. FUEL OFF-LOADING MODULE** | | |
| | | |
| a. Building (fuel leaks, lighting, heating, vents, etc.) | | |
| b. Varec gauge: _____m. Oil temperature: F. | | |
| c. Check double wall fuel pipe vacuum gauge. | | |
| | | |
| **12. MAINTENANCE BUILDING** | | |
| | | |
| a. Building (general condition, lighting, security, etc.) | | |
| b. Water supply (hot/cold water, leaks, etc.) | | |
| c. Check spill-kit is sealed | | |
| | | |
| **13. TERMINAL STATION** | | |
| | | |
| a. Building (lighting, heating, water, etc.) | | |
| b. Recorder - frequency/mw/mvar (check date, time, paper, etc.) | | |
| c. Security (fire door closed, etc.) | | |
| d. Alarms | | SVL has an alarm check. Worthwhile here. |
| **14. REMARKS:** | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

# APPENDIX 1b: MARKED COPY OF

# HWD Semi-annual Maintenance

1

2011-05-10 Rev 04

# SEMI-ANNUAL INSPECTIONS

## HARDWOODS GAS TURBINE

1. Inlet plenum A & B
2. Gas generator A & B
3. Power turbine A & B
4. Exhaust A & B
5. Fuel forwarding and off-loading
6. Jacking pumps
7. Demister
8. Vent fan
9. Glycol system
10. Alternator
11. Sump and dykes
12. Fire protection system
13. 13.8 KV Switchgear Module

**GAS TURBINE**
**UNIT & ASSOCIATED EQUIPEMENT**
**SEMI-ANNUAL INSPECTION**

DATE:_____ INSPECTED BY:_____

**Inlet Plenum A:**

1. Inspect inlet plenum for rocks, dirt, rust, sand, paint chips, or anything else that could cause blade damage or deterioration. Clean and apply coating as required. Ensure that door gaskets seal sufficiently to prevent ingress of dirt into the inlet plenum. Seal until no daylight can be seen. Wear protective covering over boots and place a mat at the entrance. Remarks: _____

**Comment [j1]:** Detail as 4.3.2.33 pg 50

_____

2. Check the inlet temperature thermocouple reading on computer with a digital

thermometer held next to thermocouple probe. Remarks: _____

_____

**Inlet Plenum B.**

1. Inspect inlet plenum for rocks, dirt, rust, sand, paint chips, or anything else that could cause blade damage or deterioration. Clean and apply coating as required. Ensure that door gaskets seal sufficiently to prevent egress of dirt into the inlet plenum. Seal until no daylight can be seen. Wear protective covering over boots and place a mat at the entrance.

Remarks: _____

_____

2. Check the inlet temperature thermocouple reading on computer with a digital thermometer held next to thermocouple probe. Remarks: _____

_____

**Gas Generator A:**

1. Inspect the five chip detectors for metallic deposits (refer to C.W. Manual, Volume (111 7.2.1.2-14) Remarks:
_____
_____

**Comment [j2]:** This refers to the SVL manual only. 4.3.2.33 pg12 it 14

2. Drain and refill the air starter with 150cc.( 5oz.) of clean generator lubricating oil. Remarks: _____

**Comment [j3]:** 4.3.2.33 pg 10 it12

3. Inspect the ignition units and igniter plugs. Check for security of connections And any physical damage. Remarks: _____

**Comment [j4]:** 4.3.2.33 pg 14 it20

4. Inspect combustion chamber outer casing general condition. Inspect the engine to power turbine bellows for dents, distortion, hot spots, etc.
Remarks:_____

5. Check lube oil tank level using the dipstick level indicator. Top up as required.
Remarks:
_____

**Comment [j5]:** 6 monthly is too infrequent unless the duty cycle is very low.

6. Check that the drainage hole is clear and free. Remarks: _____

**Comment [j6]:** Detail reqd.

7. Check forced air heaters, lubricate motors if required.
Remarks:_____

**Gas Generator B**

1. Inspect the five chip detectors for metallic deposits (refer to C.W. Manual, Volume (111 7.2.1.2-14) Remarks:
   _____
   _____

2. Drain and refill the air starter with 150cc.( 5oz.) of clean generator lubricating oil. Remarks: _____

3. Inspect the ignition units and igniter plugs. Check for security of connections And any physical damage. Remarks: _____

4. Inspect combustion chamber outer casing general condition. Inspect the engine to power turbine bellows for dents, distortion, hot spots, etc. Remarks:_____

5. Check lube oil tank level using the dipstick level indicator. Top up as required. Remarks:
   _____

6. Check that the drainage hole is clear and free. Remarks: _____

7. Check forced air heaters, lubricate motors if required. Remarks:_____

**Power Turbine A:**

1. Inspect the inside of the power turbine volute for falling objects, cracks, loose or defective deflector rings, etc.

a) Inspect bolts for evidence of any bolt movement, broken wire or broken tack weld.
b) Remove and discard any bolts showing signs of being dislodged.
c) Clean threaded bolt holes.
d) Clean existing tack weld material.
e) Install new bolts to recommended torque of 90 +/- in-lbs (see attached service bulletin), (use washers only if they were supplied with the bolts when they were purchased)
f) Reinstall all lock wires.
g) Put a small tack weld between the head of each bolt and the ring.
h) Put the tack weld between the deflector ring and the casing.

Remarks:_____
_____

**Power Turbine B**:

1. Inspect the inside of the power turbine volute for falling objects, cracks, loose or defective deflector rings, etc.

a) Inspect bolts for evidence of any bolt movement, broken wire or broken tac weld.
b) Remove and discard any bolts showing signs of being dislodged.
c) Clean threaded bolt holes.
d) Clean existing tack weld material.
e) Install new bolts to recommended torque of 90 +/- in-lbs (see attached service bulletin), (use washers only if they were supplied with the bolts when they were purchased)
f) Reinstall all lock wires.
g) Put a small tack weld between the head of each bolt and the ring.
h) Put the tack weld between the deflector ring and the casing.

Remarks:
_____
_____

**Comment [j7]:** 4.3.2.33 pg 86 item 1, items 2-7 should also be considered.

**Comment [j8]:** Is tack welding the recognized means of locking the bolts? If not the local heating may create problems with the metallurgy.

**Exhaust A:**

1. Check snow doors and cylinders for ease of operation, lubricate as required.
   Check operation of limit switches, wiring, air leaks, etc. Remarks:
_____
_____

**Exhaust B:**

1. Check snow doors and cylinders for ease of operation, lubricate as required.
   Check operation of limit switches, wiring, air leaks, etc. Remarks:
_____
_____

**Fuel forwarding & off-loading:**

1. Check the filter vessels, heater vessel, etc. for fuel leaks. Note: Fuel temperature:_____ and Pressure:_____.
   Remarks_____
2. Check fuel forwarding and off-loading pumps for leaks, etc. grease as required.
   Remarks:_____
3. Check fuel flow meters for leaks, etc.
   Remarks:_____
4. Lubricate all manual valves as required.
   Remarks:_____
5. Check diesel generator tank for leaks, level etc.
   Remarks_____
6. Check turbine oil storage for leaks, etc.
   Remarks:_____

**Comment [j9]:** 4.3.2.33 gives more detail than this. Pg 17 it 2, 3

**Comment [j10]:** More detail in CW manuals. 4.3.2.33 pg 20

7. Check that the drainage hole is free and clear.
Remarks:_____

8. Clean Y-strainers in the fuel system. Remarks:
_____

**Comment [j11]:** 4.3.2.33 pg16 it1 and pg 17 it 1

9. Verify DC pump operation and pressure. Remarks:
_____

**Jacking Pumps:**

1. Check all pumps and fittings for leaks. Remarks:
_____
_____

**Demister:**

1. Inspect mounting hardware, hose and connections. Check for oil leaks, vibration etc. Remarks: _____

_____

2. Clean/change filter as required. Remarks: _____

**Comment [j12]:** How is need to replace determined?

**Glycol System:**

1. Check tightness & condition of belts. Remarks:
_____
_____

**Comment [j13]:** : 4.3.2.33 pg34

2. Lubricate all manual valves, flow control valves, etc. and grease bearings as required. Remarks:
_____
_____

**Comment [j14]:** Checklist reqd.

**Alternator:**

1. Check condition of air filters (front and back ends), alternator cooling system – HWD only. Remarks: _____

2. Check alternator anti-condensation heaters, load readings, etc. Remarks: _____

3. Replace earth fault indication brush, if required. (Exciter room). Remarks_____

**Comment [j15]:** 4.3.2.33 pg31 it 2. Earthing brush also needs inspection. (item 1)

**Sump & Dykes:**

1. Check level of fluid in sump. Operate level switch to get alarm in control room.

Arrange to have sump pumped out if close to level switch. Remarks:_____

_____

2. Check for debris & weeds inside dyke. Remarks: _____

_____

3. Check to make sure no liner in dyke is exposed. Remarks: _____

_____

4. Check varec gauge for freedom of movement, reading compares with fuel dips.

Remarks: _____

5. Check fuel lines, expansion joints, etc., for leaks, rust, etc. Remarks _____

---

**13.8 kv Switchgear Module:**

1. Inspect area around flange and reseal if required to prevent water from getting on 13.8 kV equipment. Remarks:
   _____
   _____

**FIRE PROTECTION SYSTEM**
**SEMI-ANNUAL INSPECTIONS**

The following checks should be performed during an Inergen system inspection:

1. Visually inspect area to verify it has not changed, look for blocked open doors or dampers, new equipment, etc.
2. Check detectors to make certain they are in place, not damaged or coated with dirt grease, paint or any contamination.
3. Check all manual pull stations, make sure they are not blocked from use.
4. Check all alarm devices for damage, dirt or corrosion.
5. Check piping is secure and nozzles are in place and not covered with dirt, etc.
6. Verify all pressure switches are in place and in the non-operated position.
7. Visually verify control panel is functioning properly. Power light on, no alarms.
8. Check each cylinder indicator gauge to determine that the cylinder pressure is in the operable range. (Green) Record pressure.

**Comment [j16]:** 4.3.2.32 pg 47

**Comment [j17]:** Include pressure fo full cylinder and min allowable.

Inergen Fire Systems:
---

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| End A Module | Cylinder Pressure | ____ | ____ | ____ | ____ | ____ | ____ |
| Aux. Module | Cylinder Pressure | ____ | ____ | ____ | ____ | ____ | ____ |
| End B Module | Cylinder Pressure | ____ | ____ | ____ | ____ | ____ | ____ |
| Exciter Module | Cylinder Pressure | | ____ | ____ | | | |
| Control Module | Cylinder Pressure | | ____ | ____ | | | |
| Fuel Forward Module | Cylinder Pressure | | ____ | ____ | ____ | ____ | |
| Fuel Off-loading Module | Cylinder Pressure | | ____ | ____ | ____ | ____ | |

Remarks:_____
_____

NOTES:_____

_____
_____

# APPENDIX 1c: MARKED COPY OF

# HWDGT & SVLGT Annual Inspection

2014-04-11 Rev 04

**GAS TURBINES**
**ANNUAL MAINTENANCE**

1. Take oil samples from GGA, GGB, and MLO. ☐ Completed

**Comment [j1]:** Increased frequency recommended say 3 monthly. Reference what to do with the samples.

2. Complete a tool inventory. (Done on separate PM) ☐ Completed

**Comment [j2]:** Reference list or PM

3. Complete a spill control inventory. (Done on separate PM) ☐ Completed

**Comment [j3]:** Reference list of oil spill equipment. Vol II 2.1.12.1?

4. Check Sump Level Indicators/Switch. ☐ Completed

**Comment [j4]:** Ref Detail (PM?)

5. Check Operation of Fuel Level Switches. (SVL Only) ☐ Completed

**Comment [j5]:** Reference detail (PM?)

6. Inlet Plenum A:

a. Check condition of bird screens, plenum floor, walls, etc. Remarks:
_____
_____

**Comment [j6]:** Need to reference or include detail, especially of "etc." Provide a list or sketch.

b. Check condition of inlet filters: Remarks:
_____
_____

**Comment [j7]:** Is this a visual inspection? List the check points.

c. Check operation of pressure differential switch for inlet filters, check that tubing is not plugged, etc. Remarks:
_____
_____

**Comment [j8]:** Reference detail. Calibration settings, check lines by blowing through? Record as found and as left. (It is important to note items found in a failed state even though repaired before being left.)

d. Check condition of monoclones, fans & ductwork for cracks. (HWD Only)
Remarks:
_____
_____

e. Inspect and check operation of blow-in-doors for freedom of movement and operation of alarm limit switches. Remarks:
_____
_____

**Comment [j9]:** List detail including tag numbers. Record as found and as left.

f. Lubricate blow-in door hinges and limit switches. Remarks:
_____
_____

g. Check louvers and lubricate for freedom of movement, etc, on enclosure fans 1 & 2 GGA. Verify noise free operation of the fans. Remarks:
_____
_____

**Comment [j10]:** Record as found and as left.

h. Inspect all ladders and climbing systems as per fall protection program checklist. Remarks:
_____
_____

**Comment [j11]:** Include detail eg sketch/drawing or checklist.

7. Inlet Plenum B:

**Comment [j12]:** Comments as for A

a. Check condition of bird screens, plenum floor, walls, etc. Remarks:
_____
_____

b. Check condition of inlet filters: Remarks:
_____
_____

c. Check operation of pressure differential switch for inlet filters, check that tubing is not plugged, etc. Remarks:
_____
_____

d. Check condition of monoclones, fans & ductwork for cracks. (HWD Only)
Remarks:
_____
_____

**Comment [j13]:** This is also in SVL procedure

e. Inspect and check operation of blow-in-doors for freedom of movement and operation of alarm limit switches. Remarks:

_____
_____

f. Lubricate blow-in door hinges and limit switches. Remarks:

_____
_____

g. Check louvers and lubricate for freedom of movement, etc, on enclosure fans 1 & 2 GGA. Verify noise free operation of the fans. Remarks:

_____
_____

h. Inspect all ladders and climbing systems as per fall protection program checklist. Remarks:

_____
_____

6. Gas Generator A:

Inlet Area Inspection

a. Check for cracks in nose bullet. Remarks:

_____
_____

b. Wipe/clean entry guide vanes with rag and appropriate solvent; do not use wire brush. Inspect with extension light and mirror. If indication of cracks, investigate using dye penetrate procedure. Also inspect the first stage compressor shrouded stators. If damage is found, complete a secondary inspection of first stage stator blades for impact, erosion, corrosion, fatigue damage. This involves removing LP compressor casings and stator blades for secondary inspection and possibly returning to overhaul facility. Remarks:

_____
_____

c. Check nose cone flange, rubber connector, band clamps, retaining plates and alignment. Remarks:

_____
_____

**Comment [j14]:** Method? Visual, Dye pen?

**Comment [j15]:** CWMan 4.3.2.33 pg 2 it 2

**Comment [j16]:** Reference acceptance criteria. Section 2.1.11.2 of CW manual.

**Comment [j17]:** CWMan 4.3.2.33 pg 2 it 1

Gas Generator General Maintenance

a. Check all fuel, oil and airlines for condition and security of connections. Remarks:

_____
_____

**Comment [j18]:** Checklist 4.3.2.33 pg5 it 6

b. Inspect and lubricate the fuel pressure regulator (LF-4) shaft and check for leaks. Remarks:

_____
_____

**Comment [j19]:** Detail ref? 4 .3.2.33 pg25it 2

c. Inspect liquid fuel valve and actuator for loose bolts, oil leaks, wear, binding and security of mounting. Remarks:

_____
_____

**Comment [j20]:** How do we test for binding?

d. Remove the air system strainer screen (ST-CA-1) Inspect and clean, check the air regulating system components for leaks, cleanliness, etc. Remarks:

_____
_____

e. Inspect and lubricate the fuel fire valve plunger rod to assure freedom of operation. Remarks:

_____
_____

f. Check the security of the supplementary fuel pump/motor assembly. Check the supplementary fuel filter indicator. Clean/change filter if required. Remarks:

_____
_____

**Comment [j21]:** Change only?

g. Check all junction boxes for security of terminals, tidiness, overheating, etc. Remarks:

_____
_____

**Comment [j22]:** checklist

h. Check nozzle strainers (screens) Remarks:

_____
_____

i. Replace two air filters – one on the regulator, and one under the floor grating. Remarks:

_____
_____

j. Clean fuel nozzles in ultrasonic bath (using sodium hydroxide), only if EGT has been problematic. Attempt to clean ourselves first, with factory clean as last resort. Note: we have two styles of fuel injection nozzles- the newer style can not be taken apart on-site for cleaning. Remarks:

_____
_____

**Comment [j23]:** Whatv isa the symptom? Temperature spread?

**Comment [j24]:** Are the two types easily identified?

k. Replace lube oil filters. Note there are 2 GG lube oil system filters – one per each end. Remarks:

_____
_____

**Comment [j25]:** Nered to clarify which there refer to. There are apparently 12 in the gas generator plus the tanlk strainer and duplex filter. Volume 2 3-32 refers to a single pressure filter. The diagram shows individual 550 micron strainers serving each bearing. Need to serviceF-GGLO-1 4.3.2.33 pg26 it 1

Fuel Lines

a. For fuel lines to the nozzles, inspect piping clips (brackets) for security & wear; replace clips if cracked or worn packing. Ensure no metal-to-metal contact between pipe & clip; ensure there are no plastic bands or tape on flex lines. Remarks:

_____
_____

7. Gas Generator B:

**Comment [j26]:** As GG A

Inlet Area Inspection

a. Check for cracks in nose bullet. Remarks:

_____
_____

b. Wipe/clean entry guide vanes with rag and appropriate solvent; do not use wire brush. Inspect with extension light and mirror. If indication of cracks, investigate using dye penetrate procedure. Also inspect the first stage compressor shrouded stators. If damage is found, complete a secondary inspection of first stage stator blades for impact, erosion, corrosion, fatigue damage. This involves removing LP compressor casings and stator blades for secondary inspection and possibly returning to overhaul facility. Remarks:

_____
_____

c. Check nose cone flange, rubber connector, band clamps, retaining plates and alignment. Remarks:

_____
_____

Gas Generator General Maintenance

a. Check all fuel, oil and airlines for condition and security of connections. Remarks:

_____
_____

b. Inspect and lubricate the fuel pressure regulator (LF-4) shaft and check for leaks. Remarks:

_____
_____

c. Inspect liquid fuel valve and actuator for loose bolts, oil leaks, wear, binding and security of mounting. Remarks:

_____
_____

d. Remove the air system strainer screen (ST-CA-1) Inspect and clean, check the air regulating system components for leaks, cleanliness, etc. Remarks:

_____
_____

e. Inspect and lubricate the fuel fire valve plunger rod to assure freedom of operation. Remarks:

_____
_____

f. Check the security of the supplementary fuel pump/motor assembly. Check the supplementary fuel filter indicator. Clean/change filter if required. Remarks:

_____
_____

g. Check all junction boxes for security of terminals, tidiness, overheating, etc. Remarks:

_____
_____

h. Check nozzle strainers (screens) Remarks:

_____
_____

i. Replace two air filters – one on the regulator, and one under the floor grating. Remarks:

_____
_____

j. Clean fuel nozzles in ultrasonic bath (using sodium hydroxide), only if EGT has been problematic. Attempt to clean ourselves first, with factory clean as last resort. Note: we have two styles of fuel injection nozzles- the newer style can not be taken apart on-site for cleaning. Remarks:

_____
_____

Fuel Lines

a. For fuel lines to the nozzles, inspect piping clips (brackets) for security & wear; replace clips if cracked or worn packing. Ensure no metal-to-metal contact between pipe & clip; ensure there are no plastic bands or tape on flex lines. Remarks:

_____
_____

**Power Turbine A:**

1. Check the security of thermocouple terminations, etc. Remarks:

**Comment [j27]:** Checklist

_____
_____

2. Inspect the power turbine cover blankets for general condition. Remarks:

_____
_____

3. Check vibration detectors security of pickup and connections. Remarks:

**Comment [j28]:** Checklist

_____
_____

4. Inspect the front and rear bearing supports for oil seepage at covers. Check all hold down bolts, etc. Remarks:

_____
_____

5. Inspect the exhaust volute general condition, mount supports and load reference

indication (refer to C.W. Operation & Maintenance Manual, Section 2.2.2.2)
Remarks:
_____
_____

6. Check security of power turbine fasteners at inter-turbine duct to stator casing, stator casing to bellows, and bellows exhaust volute, as per Rolls Royce Service Bulletin 423. Remarks:
_____
_____

**Comment [j29]:** OK

**Power Turbine B**:

**Comment [j30]:** As power Turbine A

1. Check the security of thermocouple terminations, etc.
Remarks:
_____
_____

2. Inspect the power turbine cover blankets for general condition. Remarks:
_____
_____

3. Check vibration detectors security of pickup and connections. Remarks:
_____
_____

**Comment [j31]:** No calibration check

4. Inspect the front and rear bearing supports for oil seepage at covers. Check all hold down bolts, etc. Remarks:
_____
_____

5. Inspect the exhaust volute general condition, mount supports and load reference indication (refer to C.W. Operation & Maintenance Manual, Section 2.2.2.2)
Remarks:
_____
_____

6. Check security of power turbine fasteners at inter-turbine duct to stator casing, stator casing to bellows, and bellows exhaust volute, as per Rolls Royce Service Bulletin 423.

Remarks:_____
_____

**Clutch A:**

1. Check the clutch box base hold down bolts. Inspect grounding brush.
Remarks:
_____
_____

**Clutch B:**

1. Check the clutch box base hold down bolts. Inspect grounding brush.
Remarks:
_____
_____

**Exhaust A:**

1. Check the exhaust stack inside wall panels for security of insulation, plates, etc.
Remarks:_____
_____

**Exhaust B:**

1. Check the exhaust stack inside wall panels for security of insulation, plates, etc.
Remarks:_____
_____

**Vent Fan:**

1. Check mounting bolts, fan, fan coupling, louver free to move, etc… verify operation. Remarks:
_____
_____

**Alternator:**

AVR / Exciter

1. Internal inspection of exciter. Remove covers and check tightness of bolts, fuse clips, brackets, etc… test diodes. Review interval of this after each inspection.
Remarks:
_____
_____

**Comment [j32]:** How?

**Comment [j33]:** This has general applicability. A method of recording, comparing and reviewing failures is needed.

**Fuel:**

**Comment [j34]:** Drawing ref 183511

1. Verify fuel servo stroke characteristic. Remarks:
_____
_____

**Comment [j35]:** How?

2. Clean Y-strainers in the fuel system. Remarks:
_____
_____

**Comment [j36]:** Same tag used for more than 1 eg ST-LF-1

3. Replace last chance fuel filter and supplementary fuel pump filter. Also clean out the bottom of the housings at the time of filter replacement. Remarks:
_____
_____

**Comment [j37]:** Identify on drawings.

**Comment [j38]:** CW Manual 4.3.2.33 pg 25 it1

**Fuel Storage**

**Comment [j39]:** Reference drawing 183511? Filters and coalescers on fuel skid. CW Man 4.3.2.33 p 20 it2,4

1. Check drain valve main tank for water & dirt contamination.
Remarks:_____
_____
_____

2. Check tank sides, roof, and associated piping for excessive rust, etc…
Remarks:
_____
_____

3. Check and grease all fuel valve stems and associated equipment.

Remarks:
_____
_____

## Lube Oil

Comment [j40]: PT & Alt LO system. CR Manual 4.1 page 4-1

1. Replace actuator filter and clean out the bottom of the housing. Remarks:
   _____
   _____

2. **Jacking Pumps:** Check motor brushes; Check operation pressures and shaft lift (both ends) with dial indicator Note: The following motors must be on prior to performing this test Evacuator, Demister, MLO pump & Jacking Pump.
   Check hold down bolts and grease motor bearing if required. Remarks:
   _____
   _____

Comment [j41]: Tags PJO1 and PJO2 on the alternator in drawing 183482 listed as 3 monthly and other in 4.3.2.33 pg39

3. **Main Lube Pumps:** Check general condition. Grease bearings as required; Check brushes on DC motors. Remarks:
   _____
   _____

Comment [j42]: Main LO filters F-LO-1 should be changed annually. 4.3.2.33 pg 36 as 1 and 3 monthly.

4. **Main Lube Oil Tank:** Drain condensation from main tank. Use valve at bottom of tank; Check level of oil in tank (dipstick), add as required. Remarks:
   _____
   _____

Comment [j43]: This should be done more frequently than annually. 4.3.2.33 pg 35 it1

5. **GG Lube Oil Filter:** Replace filters annually. There are 2 filters required, one on each end. Remarks:
   _____
   _____

Comment [j44]: This has already been mentioned above. This section is (or appears to be) the PT & Alt LO system.

Comment [j45]: Which filters does this refer to? It's the cartridge filter in the return line F-GGLO-1that's critical.

Comment [j46]: When arePSVs tested general question but eg LO.2 on dwg 183482

## Cooling

Comment [j47]: Specify alternator air cooling. There is also a glycol cooling loop associated with the LO system.

Note: Both items below are for HWD only.

1. Check filter block switch, (check hose is not let go or pinched) Remarks:
_____
_____

2. Check Alternator Dampers:

2(a) Alternator stopped. (Work permit in effect Inverter Panel Breaker #5 OFF).

2(b) Discharge dampers and re-circ dampers closed.

2(c) Check linkages and lubricate.

2(d) Restore 120 volt AC (Inverter Panel Breaker #5 ON).

2(e) Jumper in control module points 21222 and 21223.

2(f) Discharge dampers OPEN.

2(g) Check linkages and lubricate.

2(h) Adjust thermostat above ambient temperature. (Thermostat located in air inlet after filters on B side. Extension ladder to access door)

2(i) Re-circ dampers OPEN.

2(j) Discharge dampers CLOSE.

2(k) Check linkages and lubricate.

2(l) Return thermostat to 5 degrees Celsius.

2(m) Re-circ dampers CLOSE (ambient temperature above 5 degrees Celsius).

2(n) Discharge dampers OPEN.

2(o) Remove jumpers on points 21222 and 21223.

2(p) Discharge dampers CLOSE.

Remarks:
_____
_____
_____
_____

**Comment [j48]:** Dwg, tag, check calibration.

**Comment [j49]:** Emg damper test 4.3.2.33 pg 77

**Comment [j50]:** This is the first reference to PTW, isolation etc. Need policy to include or exclude it in the maintenance procedures.

**Comment [j51]:** Drawing ref

**Comment [j52]:** detail

**Comment [j53]:** explain purpose, drawing ref. In which panel. Is this to open the discharge dampers?

**Comment [j54]:** Need policy re including equipment. Possibly include sections in a standard template.

_____
_____

**Glycol System:**

1. Check cooling fans pitch angle settings & general condition of blades.
Remarks:_____
_____

2. Check for leaks, and check expansion tank glycol level. Make note of tank level. Check low level alarm switch. Remarks:
_____
_____

3. Drain off some glycol and check contamination content and protection level.
Remarks:
_____
_____

4. Check heat exchanger cooling tubes and vanes for leaks, rust, etc. Remarks:
_____
_____

5. Check the condition and operation of the three-way thermostat. (Lubricate all moving parts) Remarks:
_____
_____

6. Clean the Y-strainers in the glycol systems. Remarks:
_____
_____

**Comment [j55]:** This is the cooling circuit serving the LO. Dwg 183517

**Comment [j56]:** What are correct settings?

**Comment [j57]:** Top up? With what?

**Comment [j58]:** Detail.

**Comment [j59]:** Detail or cross reference.

**Comment [j60]:** Identify on drawings.

**Buildings and Properties:**

1. Check forced air heaters, lubricate motors if required.
   Remarks:_____
   _____
   _____

2. Check mounting bolts, fan, fan coupling, louver free to move, etc… verify operation. Remarks:
   _____
   _____
   _____

3. Check lighting at tank farm (operate photocell for lighting) Remarks:
   _____
   _____

4. Check steps and handrail on tank and over dyke for security. Remarks:
   _____
   _____

5. Test the 3 fire alarm pull station and associated alarm devices. Remarks:
   _____
   _____
   _____

6. Inspect all ladders & climbing systems per fall protection checklist, available in Lotus Notes. Remarks:
   _____
   _____
   .

Completed by:_____

Date: _____

**Comment [j61]:** How does the user decide…should we just lubricate?

**Comment [j62]:** Do these need toi be marked on a layout?

**Comment [j63]:** And these

**Comment [j64]:** Still? Can we include it here?

**Comment [j65]:** There are systems missing from this procedure, eg air start, fire detection.., governor,

# APPENDIX 1d: MARKED COPY OF

# HVYGT Operators 5 Year Check

newfoundland labrador hydro
a nalcor energy company

HVY GT 5 YEAR INSPECTION

| Completed by: | | Date: |
|---|---|---|
| Work Order: | | |

| | ✓ / ✗ | ✓ Expected value / ✗ Comments |
|---|---|---|
| **TURBINE/GENERATOR** | | |
| a. Monitor and Record Noise Level | | |
| b. Verify Pressure Gauge Operation | | |
| c. Instrumentation Sensors | | |
| d. Verify IRD Equipment | | |
| e. Air System | | |
| f. Oil Filters | | |
| g. Fuel Filters | | |
| h. Air Filters | | |
| i. DC Oil Pumps GG _____Amps PT_____Amps | | |
| j. Clean/Inspect Bus Duct | | |
| k. Doble Bus Duct | | |
| l. Megger Stator 1 min_____ 10 min_____ PI _____ | | |
| m. Megger Rotor 1 min _____ 10 min_____ PI _____ | | |
| n. Megger Exciter 1 min _____ 10 min_____ PI _____ | | |
| o. Doble Stator | | |
| p. Megger S/S Transformer 1 min _____10 min PI_____ | | |
| q. S/S Transformer A_____ B_____ C_____ Amps | | |
| r. SF6 Breaker P.M. | | |
| s. Metering | | |
| | | |
| **FIRE PROTECTION** | | |
| a. Test / Recertify Fire System | | |
| b. Fire System Piping | | |
| c. System Integrity | | |
| | | |

**NOTES:**

**SUPERVISOR:** _____ **DATE:** _____

# GAS TURBINE OPERATOR'S
# 5 YEAR CHECK GUIDE
# FOR UNIT & ASSOCIATED EQUIPMENT

| | | |
|---|---|---|
| **TURBINE:** | | |
| a. Obtain a building layout plan and measure noise levels at predetermined areas inside the building, keeping in mind the same areas will be measured and compared infuture. Attach the drawing to the workorder for scanning | | |
| b. Calibrate all pressure gauges associated with unit Air, Oil, Fuel, Coolant, noting each gauge calibrated workorder | | |
| c. Calibrate all RTD's, Pressure Switches,Temperature Switches,Transducers,etc. associated with unit Air, Oil, Fuel, Coolant, recording each with the calibrated value separately on the workorder. | | This procedure references work orders. These should provide the deatail method statement and a record for |
| d. Calibrate all IRD sensors and monitoring equipment on Turbine, Generator, Alternator, etc. | | does this include CW Man 34.3.2.33pg14 it 21? |
| e. Clean/Inspect and lubricate Air System components, valves, sensors, et. | | does this include CW Man 4.3.2.33 pg 11 it 13? |
| f. Replace all lube oil filters on unit | | checklist reqd. CW Man 4.3.2.33 pg 13 it 15.16.17 |
| g. Replace all fuel filters, clean on board mesh fuel filters & clean filter housings | | |
| h. Replace inside air filters, wash/replace outside air filters | | |

| | | |
|---|---|---|
| i. Lubricate GG & PT Dc pumps and record amperage of each | | list tag nos, wo nos etc. Which pumps does this referto? |
| j. Clean and inspect bus duct | | |
| k. Perform doble test on bus duct | | |
| l. Perform megger tests on stator. Record 1 minute and 10 minute test, calculate and record polarization index. | | |
| m. Perform megger tests on rotor. Record 1 minute and 10 minute test, calculate and record polarization index. | | |
| n. Perform megger tests on exciter. Record 1 minute and 10 minute test, calculate and record polarization index. | | |
| o. Perform doble test on stator | | |
| p. Perform megger tests on station service transformer. Record 1 minute and 10 minute test, calculate and record polarization index. | | |
| q. Clean, check connections, on station service transformer and associated equipment, i.e. disconnects, panels, etc. Measure station service load during after service run up | | |
| r. Perform SF6 breaker p.m. as per terminals maintenance manual procedure | | |
| s. Calibrate statistical and plant metering | | |
| | | |
| **FIRE SYSTEM** | | |
| a. Have contractor test and recertify fire system and hoses. | | |
| b. Perform pressure test on fire system piping | | |
| c. Check room integrity, door seals, vents, louvers, etc. as per NFPA 2001 | | |
| | | |
| | | |
| **REMARKS:** | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

# APPENDIX 1e: MARKED COPY OF

# HVYGT P & C 6 Year Check

newfoundland labrador hydro
a nalcor energy company

HVY GT PROTECTION CONTROL 6 YEAR INSPECTION

| Completed by: | | Date: |
|---|---|---|
| Work Order: | | |

| | ✓ / ✗ | ✓ *Expected value* / ✗ *Comments* |
|---|---|---|
| | | |
| a. Relay Trip 86 and 94 Relays | | *PI: Checked against CW Manual 4.3.2.33 Items covered in this and 5 yearly indicated with lilac circles.* |
| b. Relay Protection Timers, Elect/Mech | | |
| c. Relay Protection Timers, Electronic | | |
| d. Electronic Protection Relays | | |
| e. Elect/Mech C/V Solenoid Type Protection Relays | | |
| f. Elect/Mech C/V Induction Type Protection Relays | | |
| g. Transducers | | |
| h. Panel Metering | | |
| i. Panel Transformers | | |
| j. AVR | | |
| | | |
| **BREAKER / METAL CLAD SWITCHGEAR** | | |
| All checks & tests to be completed with Breaker racked out | | |
| | | |
| k. Counter Before Operating _____ | | |
| l. Ductor(100 A (micro ohm): A _____B_____C_____ | | |
| m. Timing Close A _____B_____C_____ | | |
| n. Timing Trip A _____B_____C_____ | | |
| o. Doble Test | | |
| p. Inspect Arcing Chamber | | |
| q. Command Current Close _____ Trip_____ | | |
| r. Control Coil (ohms) Close_____ Trip_____ | | |
| s. Megger (5Kv bkr. open) A_____B_____C_____ | | |
| t. Counter After Operating _____ | | |
| u. Lubricate Control Block | | |
| v. Check Primary Connections | | |
| w. Check / Lubricate Latching Pawl | | |
| x. Check Erosion Indicator, Wipes and Gaps | | |
| y. Perform Vacuum Interrupter Integrity Test | | |
| | | |
| | | |

**NOTES:**

**SUPERVISOR:**_____ **DATE:**_____

# APPENDIX 1f: MARKED COPY OF

# Maintenance Gas Turbine Insp & Maint. Curtiss Wright 4.3.2.33

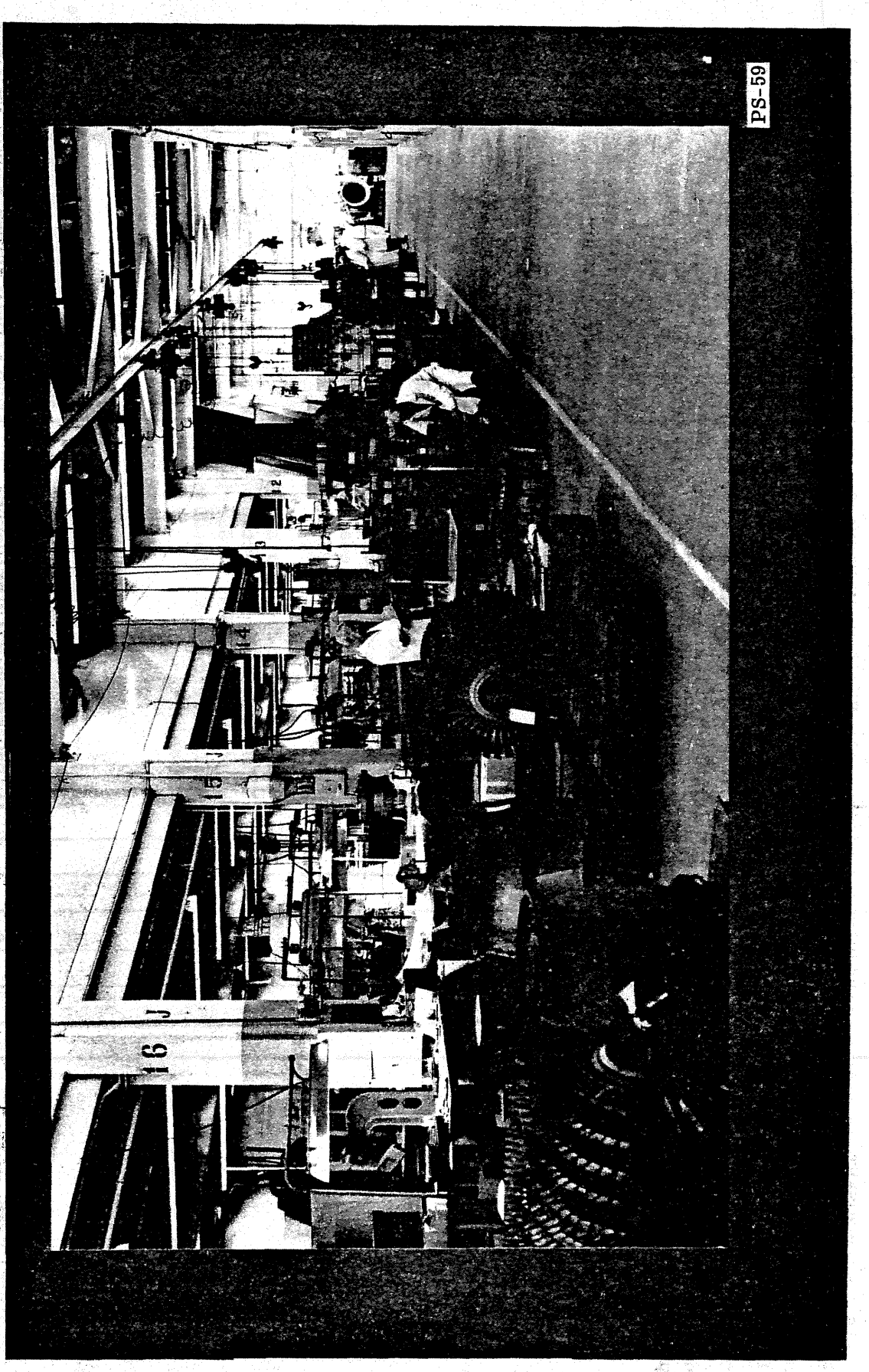



Figure 4-9
4-13

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| SYSTEM INSPECTION AND MAINTENANCE | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Gas Generator, Olympus "B" and "C" Type | | | | | | | | | |
| NOTE: These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with inspection and maintenance. Should further information be desired the matter should be referred to the Vendor Manual. | | | | | | | | | |
| Functional Checks | | | | | | | | | |
| 1. General | | | | | | | X | Refer to general instructions for routine servicing and repair by replacement for gas generator and associated systems provided in Section 2 of Operation and Maintenance Manual. | |
| 2. Gas Path | | | | | | | X | Refer to Hot Section and Major Field periodic inspection criteria provided in Section 2 of Operation and Maintenance Manual. | |
| Hardware and Systems | | | | | | | | | |
| 1. Nose Bullet | | | | X | | | | Inspect for cracks. | Report any cracks to C-W. Replace assembly. |
| 2. Entry Guide Vanes | | | | X | | | | Clean vanes with kerosene. Visually inspect vanes with a flashlight and mirror. | Crack indications should be thoroughly investigated using the dye penetrant inspection procedure; Inform C-W of damage found during |

NOT FOUND IN HYDRO

IN HWD DAILY

IN HWD SEMI ANNUAL

IN HWD ANNUAL

IN HWD 5 YEARLY

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 2. Entry Guide Vanes (Continued) | | | | | | | | | inspection; For identification purposes the vanes must be numbered anti-clockwise viewed from the front of the gas generator; i.e. No. 1 at top dead center; Compare damage with Limits of Acceptance C-W Bulletin #3. |
| 3. Compressor | | | | | | | X | Visually inspect Compressor blades and vanes for signs of foreign object damage, cracks and distortions; As necessary, remove and replace compressor cases in accordance with Section 2. | (Same as item 2) Minor nicks and dents may be blended. Contact C-W for permissible blending limits. |
| | | | | | | | | (When Required) (Co-Incident with Entry Guide Vane Inspection - Item 2) Inspect the First Stage Compressor Shrouded Stators as follows:<br>1. Remove bolts retaining inlet plenum septum door, open doors.<br>2. Clean 1st stage shrouded stator vane segments with solvent.<br>3. Visually inspect airfoil to shroud joints of each stator vane for cracking of the fillet braze. | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Compressor (Cont'd) | | | | | | | | 4. If a suspect crack is found, apply pressure to the shroud and attempt to open crack. (It is likely that any crack may merely be cracking of the rockhard lacquer) | |
| CONDITIONAL ON CRACK BEING OBSERVED | X | | X | | | | | 5. If the crack does not open record position, length, hours run, and refer to SIB No. 14, Figure 1 illustration. | |
| | | | | | | | | 6. If gaping crack is found, segment (P/N BDA 9766) should be changed; If necessary, remove affected L.P. stator housing half in accordance with SIB No. 14 and Section 2 of Operations and Maintenance Manual. | |
| 4. Compressor Wash | (When Required) | | | | | | X | Clean Compressor per Handbook Instructions provided with optional C-W wash skid P/N 928041 and in accordance with Section 2 Operation Procedures. | |
| 5. Anti-Icing System | X | | | | | | | Check condition and security of piping, clamps, electrical binding cables and clips. | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Anti-Icing System (Cont'd) | | | | | | | | Visually inspect actuator and valve as follows:<br><br>1. Remove actuator and valve by releasing the king clamps for and aft of the anti-icing valve.<br><br>2. Check that the valve is in the closed position and carry out a functional check to ensure that the actuator and valve operate correctly.<br><br>3. Replace unit, if necessary. | |
| 6. Cooling and Lubrication System | | | X | | | | | Inspect actuator and valve.<br><br>Check pipe for condition and security of connection (Refer to Section 2 of Operations and Maintenance Manual). | |
| 7. Fuel System | (When Required) | | | | | | X | Check filter element. Bleed fuel system valves and lines as necessary. | Service filter element and valves in accordance with the periodic conditions specified and procedures provided in Section 2 Operation and Maintenance Manual. |
| 8. Exhaust Annulus | (After 1000 Hrs. and 2000 Hrs.) | | | | | | X | Examine for cracks.<br>Inspect the bellows joint and | Minor cracks are acceptable, however frequency of Inspection must |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Exhaust Annulus (Cont'd) | | | | | | | | inter-turbine duct for failure indicated by fuel, oil or gas leakage. | be increased or exhaust annulus repaired. |
| 9. Combustion Chambers | (In accordance with criteria for Hot Section Inspection Note in Section 2 of Operation and Maintenance Manual) | | | | | | | 1. Visually inspect the two chutes for cracking of the attachment welds and the center support web. | One crack on each surface up to 0.5 inches long is acceptable. All cracks beyond acceptable limits are to be repair welded. |
| | | | | | | | X | 2. Inspect all tapped holes for thread damage. Clean up all tapped holes prior to reinstalling snouts. | Reject any with broken bolts which cannot be extracted. |
| | | | | | | | | 3. Inspect snout pilot surfaces for wear and cracking. | Reject any with cracks longer than 0.5 inches or where the flame spray plate has worn through to the parent material. |
| Combustion Chamber Assembly | | | | | | | X | 1. Inspect swirler for cracks.<br>a. Cracks not to exceed 0.9 inches in length in four vanes and the remainder not to exceed 0.6 inches. | Only one crack per vane is permitted. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Combustion Chamber Assembly (Cont'd) | | | | | | | | b. Cracks in the swirler inner ring must not exceed 0.375 inches in length.<br><br>2. Inspect swirler assembly for alignment by placing a straight edge across the front face of the combustion chamber and measuring the gap which is not to exceed 0.025 inches.<br><br>3. Inspect flares for cracking, burning and distortion.<br><br>a. Cracks exceeding 0.25 inches are not acceptable.<br><br>b. No burning of the flare edges more than 10% of the material thickness is acceptable.<br><br>c. No discernable distortion of the flare gap is permissible. Gap should be 0.125 inches nominal. | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Combustion Chamber Assembly (Cont'd) | | | | | | | | 4. Inspect the inner connectors for wear and cracking. Cracks in interconnector cuff welds exceeding 0.25 inches are not acceptable. Cracks exceeding the limit stated should be repair welded.<br><br>5. Inspection of combustion chamber barrel assembly.<br><br>a. Local bulging up to one inch diameter is acceptable provided no cracking is apparent and the bulging is not within 0.325 inches of an adjacent hole.<br><br>b. Cracking between the 0.125 inches diameter holes downstream of the male interconnector is acceptable provided that not more than three (3) holes are connected. Cracks exceeding this limit must be repair welded. | Where fretting has reduced the metal thickness to below 0.020 inches blend back using appropriate hand grinder.<br><br>Closure of the gap between the cuff and the combustion chamber barrel is acceptable. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Combustion Chamber Assembly (Cont'd) | | | | | | | | c. Cracking of the rivet tack welds is not acceptable.<br><br>d. Cooling skirts are to be dye penetrant inspected. No cracks in the cooling skirts is acceptable. Cracks in tack welds adjacent to the interconnectors should be rewelded.<br><br>6. Gaps for the first three cooling rings should measure 0.125 inches and 0.080-0.090 inches for the rear support ring.<br><br>7. Erosion or burning of the cooling rings up to ten percent of the material thickness is allowable.<br><br>8. Inspect combustion chamber (ignitor position) for fretting up to a depth of 0.050 inches at bushing. If fretting has occured inspect igniters for integrity. | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Combustion Chamber Assembly (Cont'd) | | | | | | | | 9. Inspect combustion chamber rear support locating area for wear. Wear at this area is acceptable providing that the hard face has not worn through to the parent metal as indicated by change in color from silver to gold.<br><br>10. All skin cracks in the barrel surface area should be weld repaired. | |
| 10. Combustion Chamber Outer Casing | | | | X | | | | Inspection - Inspect for cracks, dents, distortion and hot spots. | |
| 11. Turbine Entry Duct | | | | | | | X (In accordance with criteria for Hot Section Inspection noted in Section 2 of Operations and Maintenance Manual) | Inspect for broken welds, cracks, excessive wear on mating lugs, and foreign object damage. | Any part defect or damage beyond acceptable limits will have to be repaired or replaced by heavy maintenance procedure or overhaul. |
| 12. Air Starter | | | | | | | X (Every 250 starts, or 250 running hours or every 4 months). | Drain and refill with 150 cc of clean Gas Generator lubricating oil per C-W Service Bulletin #11. | Refer to Section 2 Operation and Maintenance Manual for Fitting the Air starter. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 13. Phonic Wheels<br><br>Frequency of test required depends on purpose of signal . may be included in item d of the 5 year checks. If used for overspeed protection it, must be tested to achieve specified reliability. | | | | | X | | | 1. Check insulation and security of terminals.<br><br>2. Check and calibrate the magnetic pickups on test rig. | Equipment Required:<br><br>1. Variable speed drive with flex coupling 500 - 4000 RPM 1/2 HP.<br><br>2. One 1.5 OHM ± 5% resistor.<br><br>3. AC voltmeter 0 - 10V 20K OHM/V.<br><br>4. Digital frequency meter 0-4K Hz.<br><br>Procedure:<br><br>1. Remove phonic wheel assemblies.<br><br>2. Remove covers and check for 0.007 in. air gap.<br><br>3. Lube bearings. Ensure wheels are free to turn.<br><br>4. Verify output voltage at 2500 Hz to be between 2.8 V-4.0 V (RMS).<br><br>5. If voltage reading is low - reduce air gap to a min. of 0.005 in. and recheck output. If voltage reading is high - increase air gap to 0.010 in. Recheck.<br><br>6. Reinstall on gas generator. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 14. Magnetic Chip Detectors | | | X | | | | | Inspection of (5) chip detectors for metallic deposits. | Whenever metal is found remove housing and screen and analyze the plug deposits as follows:<br><br>1. Remove the detector plugs by pushing the knurled end inward and turn anti-clockwise to release the bayonet type fitting.<br><br>2. Use a magnifying glass to determine type of deposit described in Metal Deposit Chart provided in Section 2 of Operation and Maintenance Manual.<br><br>3. Replace detector as necessary after fitting new seals.<br><br>NOTE:<br><br>If the gas generator is rejected, the deposits from detector and filter should be placed in a suitable container, labeled, and returned with the gas generator for examination and analysis.<br><br>If any doubt exists in establishing the source of any deposit and before rejecting the gas generator, consult Curtiss-Wright Corporation, Wood-Ridge, New Jersey. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 15. Pressure Pump Suction Oil Filter | | | | X | | | | Inspect and clean filter with clean kerosene. Reinstall in accordance with Section 2, Servicing. | If contaminated with metal particles contact C-W prior to further operation of gas generator. |
| 16. Sump Oil Pressure Filter | | | | X | | | | Remove, inspect and clean - reinstall as noted above. | |
| 17. Oil Scavenge Filters | | | | | | | X | Inspect and clean filters with clean kerosene. Reinstall as noted above. | 1. Same as item 14.<br>2. Inspect after the first run of a newly installed engine and at following periods:<br>a. Base Load Continuous Duty- At installation and after every 300 hours running.<br>b. Mixed Rating - at installation and after every 200 hours running.<br>c. Peak Lopping - at installation and after every 100 hours running. |
| 18. Turbine Blades | (Same as Item 14) | | | | | | X | Inspect turbine blades and vanes for signs of foreign object damage, cracks, or distortion. | (Same as Item 14).<br>WARNING: BEFORE INSPECTION, ENSURE THAT THE LOW TENSION LEAD IS DISCONNECTED FROM THE HIGH ENERGY IGNITION UNIT. ALLOW TWO MINUTES TO ELAPSE BEFORE CHECKING ANY COMPONENT AFTER DISCONNECTION. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 19. Ignition Unit and Igniter Plugs | | | | X | | | | 1. Check for security of connections.<br>2. Inspect for physical damage in accordance with Section 2 of Operation and Maintenance Manual.<br>3. Isolate one unit at a time and check (audibly) at the gas generator for proper igniter plug firing. | WARNING: EXERCISE CARE DUE TO HIGH VOLTAGE AND FUEL VAPOR BUILD UP. |
| 20. Junction Box (Port Side of Intermediate Casing) | | | | | X | | | Check all electrical wiring and cables for secure connections and any signs of damage and overheating. | |
| 21. Vibration Detector<br>may be included in 5 yr checks, item d. Function checks need to be more frequent for critical items. | | | | X (or engine change) | | | | Check calibration of detector (frequency range 20-400cps) and use a spare calibration pickup; Fit the Vibration Pickup in accordance with Section 2 Operation and Maintenance Manual. | A vibration table, power amplifier, oscillator and image microscope will be required if recalibration is required. |
| 22. Gas Temperature Control | | | | X (or engine change) | | | | 1. Check security of terminals.<br>2. Check circuit resistance and insulation of thermocouple harness. | Use a resistance bridge and "megger". |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 22. Gas Temperature Control (Continued) | | | | | | | | 3. Calibrate the temperature indicator and check control and trip setting of gas temperature control unit. | Use millivolt injection equipment. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| LIQUID FUEL SUPPLY SYSTEM | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Fuel Off Loading Skid | | | | | | | | | |
| 1. "Y" Strainer, Mobile and Field Supply Inlet (1/8" Perforated Screen) | | | | | | | X | Flush through blow-off valve. | Periodically open "Y" strainer blow-off valve to flush out accumulated foreign matter. Frequency of servicing requirement should be established consistent with individual site operating experience. |
| 2. "Y" Strainer, Off Loading Pump Discharge | | | | | | | X | Flush through blow-off valve. | Same as Item 1, above. |
| 3. Pump, Off Loading | | | | | | | X | Inspection of pump shaft seal. | Monitor leakage and adequacy of lubrication at pump shaft seal (packing box). Mechanical seals or packing are interchangeable in the same box. Inspection and service requirements differ depending upon configuration. Service in accordance with Component Vendor Instruction, Ingersoll-Rand, Form SPAD-14C. |
| 4. Motor, Off Loading Pump | | | | | | | X | Lubrication. | All ball bearing motors that have grease fittings and plugs near the bearings are to be lubricated in accordance with motor manufacturer's instruction. Refer to affected component vendor instruction for specific service recommendation. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 4. Motor, Off Loading Pump (Cont'd) | | | | | | | X | Check motor bearing temperature. | Periodically check motor bearing temperature. Temperature above 88°C is indicative of an abnormal condition warranting investigative action. |
| 5. System Piping and Sealing<br>semi annual maintenance includes leak checks for rest of system. Piping not specifically mentioned. | | | | | | | X | Check for leakage. | Monitor to ensure sealing integrity of all pipe connections, sealing surfaces gland fittings, etc. This should be accomplished on a continuing routine basis. |
| Fuel Forwarding Pumps Skid Assembly | | | | | | | | | |
| 1. "Y" Strainer, Inlet (1/16" Perforated Screen) | | | | | | | X | Flush through blow-off port. | Periodically, open "Y" strainer blow-off ports to flush out accumulated foreign matter. Close ports. Ensure proper positioning of butterfly valves. Frequency of servicing requirement should be established consistent with individual site operating experience. |
| 2. Pump (2), AC Fuel Forwarding | | | | | | | X | Inspection of pump shaft seal. | Monitor leakage and adequacy of lubrication at pump shaft seal (stuffing box). Mechanical seals or packing are interchangeable in the same box. Inspection and service requirements differ depending upon configuration. Service in accordance with Component Vendor Instruction. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 3. Motor (2), AC Fuel Forwarding Pump | | | | | | | X | Lubrication. | All ball bearing motors that have grease fittings and plugs near the bearings are to lubricated in accordance with motor manufacturer's instructions. Refer to affected component vendor instruction for specific service recommendation. |
| | | | | | | | X | Check motor bearing temperature | Periodically check motor bearing temperature. Temperature above 88°C is indicative of an abnormal condition warranting investigative action. |
| 4. Pump, DC Fuel Forwarding | | | | | | | X | Bearing lubrication. | Lubricate bearings in accordance with Component Vendor, Gould, Maintenance Instructions, Section III, consistent with type bearing lubrication provided. Pump may incorporate externally oiled bearings, grease lubricated bearings or sealed bearings. |
| | | | | | | | X | Inspection of pump shaft seal. | Monitor leakage and adequacy of lubrication at pump shaft seal (stuffing box). Mechanical seals or packing are interchangeable in the same box. Inspection and service requirements differ depending upon configuration. Service in accordance with Component Vendor. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 4. Pump, DC Fuel Forwarding (Cont'd) | | | | | | | X | Check pump bearing temperature | Periodically check pump bearing temperature. Temperature above 82°C is indicative of an abnormal condition warranting investigative action. Refer to Component Vendor Maintenance Instructions. |
| 5. Motor, DC Fuel Pump Forwarding | | | | | | | X | Lubrication. | All ball bearing motors that have grease fittings and plugs near the bearings are to be lubricated in accordance with motor manufacturer instructions. Refer to affected component vendor instruction for specific service recommendation. |
| 6. System Piping and Sealing | | | | | | | X | Leak check all fittings, lines and components. | Monitor to ensure sealing integrity of all pipe connections, sealing surfaces, gland fittings, etc. This should be accomplished on a continuing routine basis. |
| Fuel Conditioning Skid | | | | | | | | | |
| 1. Filter, Fuel | | | | | | X | X | Replace filter elements. | Replace filter elements when pressure differential across the filter reaches 15 psig or once a year whichever occurs first. Refer to vendor instruction for removal and replacement of component elements and to Section 2 of Operation and Maintenance Manual for preliminary procedures to removal of component. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 1. Filter, Fuel (Cont'd) | | | | | | | | Clean interior of sediment and replace filter element. (GG4C) | Drain fuel from filter by removing drain plug on bottom and bleed plug on top. Remove cover by turning the cover nut handle CCW, jacking the cover off the case. Remove the element, clean interior and replace element with AC-8330F-EE1Z. Reinstall drain and bleed nut. |
| 2. Filter, Fuel Oil (Coalescer) | | | | | | X | X | Replace filter elements. | Same as Item 1, above. |
| 3. Filter, Gas Fuel (F-GF-1) no gas fuel | | | | | | X | X | Inspect gaskets and O-rings for signs of damage. Replace filter elements. | Same as Item 1, above. |
| 4. Liquid Fuel Meter, Totalizing (FM-LF-1) | | | | | | X | X | Adjust and clean flow meter; Check the gearshafts and bushings for excessive wear and oil rings for wear and nicks; clean all parts in kerosene. | Replace doubtful or defective parts; Refer to vendor instructions for adjustment and disassembly and assembly procedures. |
| Water Injection System (GG4C-1DF) | | | | | | | | No reference to water injection found in other documents. Does it exist on these engines? | |
| 1. Regulated "Water-In" Components | | | | | | | | | |
| a. Inlet Valve, Piping Fittings, Couplings, Elbows, etc. | X | | | | | | | Visually check all components for leakage, dirt, corrosion, etc. and security of connections. | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| b. Water Pump (Sundyne LMV) | | X (After initial 24 hours of operation.) | | | | | | Visually check gearbox oil level. | Maintain the fluid level within the block circle in the sight glass, even when pump is in operation. |
| | (4000 Hrs or) | | | | X | | | Change gearbox oil. | |
| | (8000 Hrs or) | | | | | X | | Change gearbox oil filter. | |
| | | X | | | | | | Check for Seal drain leakage, Replace Seals if leakage suddenly increases. | Check port numbers for seal drain on Seal Port Identification Plate. |
| | | X | | | | | | Inspect gearbox heat exchanger for leakage. | |
| | | X | | | | | | Check for leakage through heat exchanger into cooling fluid. | Pressure test heat exchanger and replace if required in accordance with Vendor Instructions. |
| | | | | | | | X | Replace Radial Ball Bearings on gearbox idler and low speed shafts every 3 years. | |
| | | | | | | | X | Inspect and service Driver in accordance with Vendors Instructions. | |
| | | | | | | | X | When Driver is removed for normal maintenance, lubricate the interconnection shaft splines. | Remove all grease from female splines, then apply 5cc of anti-fretting compound (Sundstrand, P/N 688272-1) to spline at each end of shaft. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| b. Water Pump (Sundyne LMV) (Cont'd) | | | | | | | X | If flexible coupling is used, service in accordance with Vendors Instructions. | Refer to Sundyne Instruction Manual for replacement parts which are required as a result of removal of Pump Mechanical Seal, Gearbox High Speed Shaft Mechanical Seal, Impeller, Inducer or Diffuser, Gearbox Low Speed Shaft Seal or for gearbox internal repair. |
| 2. Water Conditioning Skid | | | | | | | | To be supplied. | |
| 3. Fuel Distribution Block | | | | | | | | Refer to Liquid Fuel Supply GG4C-1DF Fuel Control components. | |
| 4. Air Supply Skid (Water Injection and Nozzle Purge Air Supply) | | | | | | | | | |
| a. Tubing, Elbows, Ties, Nipples, Sleeves, Shut-Off Valves, etc. | | X | | | | | | Check all piping and association parts for leaks and proper and tight connections. Retighten parts as necessary. | |
| b. Solenoid Valve (Automatic Switch Co.) | | | X | | | | | Check for sluggish valve operation or excessive leakage when voltage is applied to coil. If the valve indicates any of the above conditions, check for damage and clogging. | If valve fails to operate, cut off line pressure and energize the solenoid. A metallic click is heard if the solenoid is operating. If a distinct hum is in evidence the valve is not operating fully. |
| | | | | | | | | Clean valve by removing accumulations of foreign matter. | The pressure must not exceed that stamped on the nameplate. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| b. Solenoid Valve (Automatic Switch Co.) (Cont'd) | | | X | | | | | Replace worn or damaged parts. Check pressure at the solenoid valve. | |
| c. Air Safety Valve (Lonergan) | | X | | | | | | Check that inlet connection to valve is clean. | |
| | | | | | | | X | Dismantle the valve for inspection and repair and charge set pressure in accordance with manufacturer's instructions. | During reassembly, make sure the flange bolts are tightened evenly to exert uniform pressure. |
| d. High Pressure Regulation Valve (Fisher 1301F) | | X | | | | | | Check springcase vent openings to see that they are not plugged. | The set pressure of relief valve should not be adjusted over a range greater than ± 10% of the original set pressure of the valve. |
| | | | | | | | X | Inspect regulator periodically for damage or after any overpressure or unusual condition. | WARNING: TO AVOID PERSONAL INJURY AND EQUIPMENT DAMAGE, ISOLATE THE REGULATOR FROM ALL PRESSURE. CONTINUOUSLY RELEASE PRESSURE FROM REGULATOR BEFORE ATTEMPTING DISASSEMBLY. DISASSEMBLE VALVE IN ACCORDANCE WITH VENDOR INSTRUCTIONS. |
| | | | | | X | | | Check that the range of allowable pressure settings is as shown on nameplate. | Change regulator spring if pressure setting is beyond nameplate ranges required; use a pressure gauge to monitor pressure when making adjustments. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| d. High Pressure Regulation Valve (Fisher 1301F) (Cont'd) | | | | | | | X | Check the valve disc, diaphragm, body gasket, diaphragm head gasket and seat ring; replace parts as necessary. The frequency of inspection and replacement depends upon the severity of service conditions or the requirements of state and federal laws. | Normal wear of the valve disc and seat ring is accelerated by high pressure drops and when large amounts of impurities exist in the flow stream. External sources may also cause damage to the regulator. |
| 5. Compressed Air-Filter Dryer (Filter Eng. Co., A38) | | X | | | | | | Check for excessive hydrocarbon, sulphur residue and pipe scale. | Clean and disassemble air-filter dryer in accordance with vendor. |
| | | | | | | | | Check the filter element, screen and gasket for proper functioning. | |
| | | | | X | | | | Change filter element as required. | |
| | | | | | | | | Check "O" rings and seals, and for pit marks on metal surfaces. | |
| | | | | | | | | Check separator and dryer for proper functioning. | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| **Fire Valve** | | | | | | | | | |
| 1. Valve, Fire (5) LF-8 | | | | X | | | | Lubricate engaging bolt and latch. | Apply a slight amount of silicone grease to surface of engaging bolt latch. |
| 2. System Piping and Sealing | | | | | | | X | Check for leakage. | Monitor to ensure sealing integrity of all pipe connections, sealing surfaces, gland fittings, etc. This should be accomplished on a continuing routine basis. |
| **Turbine Enclosure Components** | | | | | | | | | |
| 1. Filter, Final Fuel | | | | | | X | X | Replace filter elements. | Replace filter elements when pressure differential across filter reaches 15 psig or once a year whichever occurs first. |
| 2. Regulator, Fuel Pressure | | | | | | | X | Lubricate packing box. | Keep lubricator filled with specified lubricant. Refer to Component Vendor, Masoneilan, Instructions. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| GAS GENERATOR LUBE OIL SUPPLY (External to Gas Generator) | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 1. Filter, Oil (F-GGLO-1) | | | | | | X | X | Inspect and/or replace. | Replace filter element once a year or when pressure differential across filter reaches 15 psid. |
| 2. Lube Oil Sample Check | | | X | | | | | Qualitative oil sample check. | Perform sample check of lube oil on a monthly basis. Apply following criteria for acceptability:<br>a. Kinematic Viscosity – C.S. @ 100°F 34.0 minimum, 44.0 maximum<br>b. Total Acid No. – 1.0 mgm KOH/gm increase<br>c. Water Content, % Vol. – 0.1<br>d. Saponfication Value – 155.0 Min. KOH/gal<br>e. Flash Point C.O.C. – 420°F<br>f. Insoluble Material – 0.21<br>Failure to satisfy sample check requirement warrants complete cleaning of system oil and filter.<br>If automatic drain trap is not used drain at least weekly or more often if necessary. |

15 psi looks high.

important diagnostic. OIl samples need to be correctly assessed, the list of points in the remarks column is unlikely to be sufficient.

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 3. Lube Oil Tank | X | | | | | | | Check oil level using the dipstick level indicator. | Replenish reservoir with approved lube oil. |
| 4. Pressure and Level Switches, Sensors | | | | | | | | | Refer to Control Sequencer. |
| 5. Lube Oil System Components | X | | | | | | | Visually inspect lines, connections, security of mounting, valves, etc. | Maintain and repair as necessary. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| AIR START SYSTEM | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 1. Air Compressors | | X | | | | | | Inspect and fill oil level; drain traps. | If automatic drain trap is not used drain at least weekly or more often if necessary. |
| | | | | X | | | X | Drain and change oil. | Every 300 hours or every 3 months whichever occurs first. Use lubricating oil type and viscosity recommended in Vendor Component Manual, (Worthington).<br>SAE 20 if in heated building or 40 if ambient temperature is 100°F or higher.<br>SAE 10 if unit is subjected to freezing temperature. |
| | | | X | | | | | Clean equipment. | Clean cylinders and intercooling fins with compressed air. |
| | | X | | | | | | Clean air filter, clean compressor valve, clean motor, check belt tension. | Clean with compressed air or replace if necessary. Inlet and discharge valves should be inspected and any dirt or carbon removed from seats. Blow off motor windings with dry compressed air. Check for accumulation of foreign matter. |
| | | | | X | | X | | Motor lubrication and service. | Sleeve bearing motors should be oiled with SAE 10 oil. Ball bearings should be repacked yearly with a grease about the same consistency as vaseline, or stiffer. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 1. Air Compressors (Cont'd) | | | | | | | | | Do not oil commutator. Inspect motor brushes and replace if necessary. Shape brushes to fit contour of commutator. |
| | | | | | | | X | Tighten all bolts. | For torque valve refer to vendor's (Ingersoll-Rand) literature on air compressors. |
| 2. Strainer, Starting Air "Y" Type, Muessco No. 762 | | | | | | X | X | Clean strainer. | Periodically open strainer blow-out port to remove collected foreign matter. Inspect strainer element and clean or replace annually. |
| 3. Air Dryer<br>No dryer found on HWD drwawings. | | | X | | | | | Inspect air dryer/filter element. | Inspection and Maintenance of air start system required before scheduling if:<br>1. Operational lags indicate pressure trend toward abnormal.<br>2. Pressure alarm has been annunciated. |
| 4. Control Valve | | | | X | | | | Inspect starter control valve and regulators for leakage. Check security of starter control valve loading turbine. | |
| 5. Air Starter | | | | | | | | Refer to Gas Generator Hardware. | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| ALTERNATOR | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Mechanical Components | | | | | | | | | |
| 1. Bearings | | | | | | | X | If a rise in bearing temperature is observed, check oil supply pressure at bearing and condition of oil filters. | Bearings are normally trouble free providing they are supplied with clean oil at the correct temperature and pressure. |
| 2. Pilot Exciter | | | | | X | | | Check vibration levels on the pilot excitor, if levels are exceeded, check<br>a. Alignment of the pilot excitor.<br>b. The coupling sleeve wear.<br>c. The pilot excitor bearings for wear. | The flexible coupling is in the form of a nylon sleeve with internal gear teeth connecting two gear wheels, one on the main shaft and one on the pilot exciter shaft.<br>Replace deteriorated components. |
| | | | | | | | X | Check exciter bearings at 5 year intervals; Replace bearings with grease every 10,000 operating hours as specified in Section 2 Operation and Maintenance Manual. | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 3. Air Cooled Heat Exchange Unit (Perfex Inc.) (CLR-GL-1, HE-GA-2 and -3) | | | | | | | X | Check fan, V belt, motor and bearings. | |
| For Drive Assembly | | | | | X | | | Check the fan blade angle. | All blades should be set at same location, that is, if the first blade was set at a position of 12 o'clock in the fan ring all subsequent blades should be similiarly positioned as the fan is rotated. |
| | | | | | | | X | Check that there is no less than 1/2" clearance between tip of the longest blade and the inside surface of the fan ring. | |
| | | | | | X | | | Check V belts for evidence of loosening. Retighten if necessary. | Refer to manufacturers instructions for tensioning the belts. |
| does this need to be done daily in the HWD/SVL environment? | X | | | | | | | Check that ventilation openings of motor are clear of dust, dirt or other debris. | |
| | | | | | | | X | Check the fan motor bearings for wear and lubricate the motor in accordance with the instruction plate on the unit and Vendor Instructions. | |
| Heat Exchanger Tube Bundles | | | | | | | X | Check the tube bundles for serviceability and damage. | Refer to Vendor Instruction Manual. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Electrical Components | | | | | | | | | |
| 1. Shaft Earthing Brush | | | | | X | | X | Brush inspection. | WARNING: THE MACHINE SHOULD BE STOPPED AND ISOLATED FROM ALL SUPPLIES BEFORE ANY PART OF IT IS TOUCHED.<br><br>NOTE<br><br>Refer to Section 2 Operation and Maintenance Manual for special care and inspection required for the component systems after an extended period of idleness.<br><br>Examine brush every 6 months or 2500 hours. Replace on condition, if wear exceeds two-thirds or if any deterioration is evident. |
| included as semi annual check | | | | | | | | | |
| 2. Rotor Earth Fault Slip Ring Brush | | | | X | | | X | Brush inspection. | Examine brush every 3 months or 1000 hours. Replace on condition, if wear is excessive or if any deterioration is evident. |
| 3. Rectifier Assembly | | | | | | | X | External cleaning. | Remove dirt and foreign material from external surface of rectifier every 5000 hours or sooner if excessive accumulation is apparent. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 4. Alternator Stator End Windings | | | | | | | X | Inspection and external cleaning. | Remove surface deposits of dust and/or oil from stator end windings by wiping with Inhibited III Trichloroethane, i.e. "Genklene" (I.C.I.) or equivalent. If the recommended solution is not available, clean windings with a rag lightly dampened with white spirit. Particular care must be taken not to wash the contamination further into the windings as such treatment can cause a serious breakdown. Perform every 10,000 hours or sooner if excessive accumulation is apparent. Exercise caution to ensure foreign matter is removed, and not introduced further into windings. |
| 5. Automatic Synchronizer | | | | X | | | | Clean and inspect. | The PRS-210 requires no periodic maintenance. Inspection should be made to ensure unit is kept clean and free from dirt and moisture. Accumulation of dust should be removed from the unit with a soft bristle brush or with clean compressed air. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| MAIN LUBE OIL SYSTEM | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Air Cooled Heat Exchanger (Ecodyne) | | | | | | | | | |
| 1. Cooler (CLR-GL-1 + CLR-LO-1) | | X | | | | | | Inspect and clean exterior surfaces of cooler core. Clean as necessary with compressed air or warm water jet. | When necessary remove side panels on module to gain access to cooler headers on each side for tube repair or plugging. |
| 2. V-Belt | | | | | X | | | Check V-belt for alignment and tensioning. Retighten if necessary. replace if necessary. | Refer to Vendor Manual for tensioning V-belts. |
| | | | | | | | X | Clean V-belt when necessary using a cloth moistened with alcohol, benzene or gasoline. | |
| 3. Motor and Shaft Bearings | | (60 days) | | | | | | Check the motor and shaft bearings for wear and lubricate as determined by good practice. Use only high grade recommended lubricants. | |
| | | | | | | | X | Inspect the shielded bearings for wear at 2 or 3 year intervals. | |
| | | X | | | | | | Check motor and bearing temperatures. | |

glycol system only is covered in hydro manual.

unusual to clean the belt.

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 4. Fan Blades<br>should not need to check monthly. | | | X | | | | | Check the pitch angle settings of the fan blades. | Blade angles on all units are referred to the horizontal or plane of the fan wheel. As specified in the Vendors Manual, class 2000 and 7000 angles are measured across the blade at a point of three hub diameters. Class 5000 angles are measured on the edge of the clevis. |
| | | | | | | | X | Check that there is clearance between the tips of the fan blades and fan rings. | Check with Vendor Manual for clearance between the tip of blades and the inside surface of the fan ring. |
| 5. Cooler Tank | | X | | | | | | Check coolant quantity and service as required. | Refer to Section 3.0 for coolants/Water ratio. |
| Main Oil System Components | | | | | | | | | |
| 1. Main Oil Tanks TNK-LO-1 and TNK-LO-2 | | X | | | | | | Check oil quantity and service to usable capacity. | Service using the following lube oils:<br>1. Teresso 32 (formerly 43)<br>2. Mobile D.T.E. Light<br>3. Shell Tellus Oil No. 25<br>4. Shell Turbo Oil No. 25 (formerly 27)<br>5. Texaco Regal A R/O<br>Add quantity as shown by dipsticks level indicator which is attached to the reservoir screen assembly. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| | | | | | X | | | Drain condensation from system. | Utilize tank drain at bottom rear, left side of large tank. Drain approximately ten (10) gallons of liquid to ensure removal of accumulated water. Accomplish after system has been inoperative at least 8 hours. |
| 2. Main Lube Pump Motors Aux. DC Pump (2) Motor, P-LO-2 & -3 | | | X | | | | | Inspect and clean. | Remove commutator access covers. Blow out with dry compressed air (50 psi max.) to remove accumulated dust and foreign matter. Inspect brushes for proper bedding and freedom of movement in their holders. |
| | | | X | | | | | Check brush lengths. | Replace brushes if worn below 3/4" (19 mm). Refer to Vendor Component Bulletin. |
| | | | | X | | | | Check bearing lubrication. | Relubricate per bulletin utilizing grease specified on motor data plate. |
| Main AC Pump Motor P-LO-1 | | | | X | | | | Check bearing lubrication. | Relubricate as necessary per Vendor Component Instructions. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 3. Main Lube Oil Filter F-LO-1<br>included in 5 yrly checks item f (?) | | | | | | X | X | Replacement of cartridge elements. | NOTE<br>When a pump is installed for the first time, either as new or after removal for maintenance, the thrust bearing is dry and could be damaged in the first few seconds until the oil reaches the screw elements. It is therefore advisable to check the priming of the pump when first put into service on site, so that the situation where a pump is removed during installation and tipped over is guarded against.<br><br>(Pump priming is necessary for both AC and DC motor driven units.)<br><br>Gear type pumps are normally self priming, but on an initial start hand priming is recommended.<br><br>To service filters, replace cartridges yearly or when pressure differential is 20 psi (whichever occurs first) using the following procedure:<br><br>1. Shut off gate valves LO-10 and LO-11 and open drain valve LO-12 or LO-31 to drain oil from filter housing. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| | | | | | | | | | 2. Loosen bolts retaining the cover assembly.<br><br>3. Lift off cover using overhead monorail and suitable hoist and remove individual seal plate assemblies from the top of each stack.<br><br>4. Lift off top cartridges and lift out cartridge posts to remove remaining cartridges in the stacks. Cartridge posts can be removed by twisting them slightly in either direction and pulling them upward to free them from the pedestals.<br><br>5. The center posts should be cleaned. Do not attempt to remove cartridge pedestals. When cleaning around the cartridge pedestals, be careful not to allow contaminant to pass down through the pedestals into the filtered fluid chamber.<br><br>6. Check condition of the cover gasket and replace if necessary.<br><br>7. Reassemble replacement cartridges and the filter assembly in reverse order. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 4. Oil Jacking Pump Motor P-JO-1 | | | | | X | | | Check bearing lubrication. | Remove bearing caps and examine grease for consistency and sufficiency. Apply bearing lubrication as necessary. Refer to Vendor Component Maintenance Instructions. Recommended grease is Shell Alvania 2. |
| | | | | | | | X | Bearing grease renewal. | Bearings should be completely re-serviced with grease every 2 years. Shell Alvania 2. |
| | | | | X | | | | Inspect brushes for wear. | Periodically, not to exceed three month intervals, inspect brushes for excessive or abnormal wear. Check brush pressure against the commutator and freedom of brushes in their holders. Refer to Vendor Component Maintenance Instructions. |
| 5. Three-way Thermostatic Control Valve | | | | | | X | | Disassembly inspection and cleaning. | Disassemble valve, inspect and clean per Vendor Component Maintenance Instructions. Valve body need not be removed from pipework to perform this inspection. |
| 6. Oil Supply and Drain Piping | X | | | | | | | Inspect for leakage. | Surveillance for leakage should be a continuing process. Ensure sealing integrity by visual observation of all fluid connecting |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| | | | | | | | | | junctions; sealing flanges, valve gland packings, filter housing covers, tanks, etc. Correct any leakage condition observed. |
| 7. Pressure Switches, Sensors, Level Switches, etc. | | | | | | | O | Refer to Control Sequencer. | Check and calibrate as required. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| FIRE SYSTEM | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| | | | | | | | | | CAUTION: AS A SAFETY PRECAUTION, BEFORE ANY MAINTENANCE IS CONDUCTED ON THE UNIT, LOCK OUT THE UNIT AND SWITCH OFF THE FIRE PROTECTION CIRCUIT TO DISARM THE HALON SYSTEM TO PROTECT PERSONNEL WORKING INSIDE THE MODULES FROM ACCIDENTAL DISCHARGE OF THIS SYSTEM. |
| Halon Systems (Safety First Products and/or Fenwall) | | | | | | | | | |
| 1. General Systems | | | | X | | | | Normal system check. | Check pressure gauges of each storage container. If the pressure is less than 325 psig at 70°F the container should be removed by qualified personnel, inspected and reconditioned as necessary. Check all components supporting hardware and tighten and repair as required. Visually check all components for security and evidence of damage. Refer to Vendor Manual for removal, resetting and reinstalling of system components and to Section 4 Operation and Maintenance Manual for Pressure and Actuation Checks. |
| 2. Control Units | | | | X | | | | Control unit function. | Depress the "Alarm Test" button at the top on the inside panel of the control unit. The alarm lite and |

now replaced with Inergen? checks in semi-annual maintenance.

Further checks in 5 yearly maintenance. Exact content is unclear.

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| | | | | | | | | | other connected alarm devices must function. Supplementary devices operating on a fire condition must respond. |
| 3. Detectors and Initiators (Fenwall and/or Scott)<br><br>WARNING: THE INITIATOR ASSEMBLY IS A CLASS "C" EXPLOSIVE. HANDLE AND STORE IN ACCORDANCE WITH APPROPRIATE REGULATIONS. WEAR SAFETY GLASSES OR A FACE SHIELD WHILE HANDLING. | | | | X | | | | Inspect, clean, and test (Fenwall) | Detector lenses to be cleaned as follows: Shut off system. Clean lens with lens tissue. If covered with oil or other material impervious to ultraviolet rays, clean with tissue soaked in solvent supplied. Do not damage gasket and detector paint. Spray lens with an anti-static solution such as Anti-Stat No. 6 available from Brown Laboratories, Philadelphia, Pa., or equivalent. Turn system on. |
| | | | | | | X | | Inspect, clean and test. | Clean product of combustion detectors by blowing clean dry air through the opening between collector plate and well where radium sensor is located; remove foreign material with a swab saturated with alcohol. |
| | | X | | | | | | Inspect, clean and test the 800 series gas monitor (Scott).<br><br>Check instrument zero settings. Adjust instrument in excess of 5% of full scale. | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 3. Detectors and Initiators (Cont'd) | | | X | | | | | Check outer diffusion guard for clogging of element. Inspect filament current, span and alarm setting.<br><br>Clean element as required by immersion in commercial solvents and then blowing out with air. | Test for clogging if element in accordance with Vendor's Manual and as follows:<br><br>Connect a 0-5 LPM rotameter to an air source and to the calibration inlet fitting on the sensing head. Provide a tee at the calibration inlet fitting and connect to one side of a water monometer. A water manometer may be constructed using clear plastic tubing and a scale with 1 inch maximum scale divisions. Adjust air flow to 5 LPM; manometer readings should not exceed 5 inches of water. |
| | | | | | | X | | Replace filament in accordance with Vendor's Manual and procedure provided in remarks column. | Replace filaments as follows:<br><br>1. Remove condulet housing cover.<br><br>NOTE: Instrument should be off before cover is removed.<br><br>2. Remove sensor lead wires from terminal strip.<br><br>3. Unscrew sensor base from condulet.<br><br>4. Unscrew outer diffusion element from sensor base. |

are these instructions still relevant? They look to be for maintenance of detector types or styles which are now obsolete.

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| | | | | | | | | | 5. Unscrew inner diffusion element from sensor base.<br><br>6. Clip wire lugs from sensor leads.<br><br>7. Unscrew active and reference filaments from sensor base.<br><br>8. Screw reference filament until it bottoms in sensor base.<br><br>NOTE: If filament wire is touched by hand, contamination and filament poisoning may occur. Extreme care should be taken to prevent this occurrence.<br><br>9. Feed filament leads from active filaments through port in sensor base and screw active element until it bottoms in sensor base. |
| | | | | | | X | | Test thermal detectors. | Test combustion detectors as follows:<br><br>1. Perform the functional tests provided in the Vendor's (Fenwall) Manual, or as follows: |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 3. Detectors and Initiators (Cont'd) | | | | | | | | | 2. Check Fenwall Detectors, used on GG4 engines, as required, and when exposed to a temperature exceeding 550°F (288°C) as follows:<br><br>a. Disconnect DC power to the system.<br><br>b. Remove the detectors from the junction boxes.<br><br>c. Connect an ohmmeter across the wire leads and insert into a controlled heat bath of oil or other fluid.<br><br>d. Thermal detectors used to activate the fire suppresion system should close at 450°F ± 20°F. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| | | | | | | X | | Test initiators. | The initiators are destroyed by its operation and must be replaced after system activation. Because of its explosive nature the assembly should be checked and tested in accordance with the Vendor Instructions as follows: Disconnect initiators at each agent storage container and install jumper wires at the connector in place of the initiators. Connect a 24 VDC test lamp in series with the initiator loop and connect to initiator terminals at control unit. Install a temporary jumper across actuating terminals of a detector unit and turn system on. The test lite, trouble lite and alarm should function. As jumpers are removed from each initiator cable, the test lite should go out. If system is equipped with a secondary or reverse supply, turn system off; switch to secondary supply and repeat test procedure. Disconnect all temporary test wiring, remove test devices, reconnect all system components and activate system. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| | | | | | | | X | Replace initiators. | The initiators should be replaced every two (2) years by qualified personnel. Dispose old initiators in accordance with local safety codes. |
| 4. Storage Containers | | | | | X | | | Remove, inspect and weigh. | Qualified personnel are to remove and weigh agent storage containers Losses in weight of agent must not exceed 5 percent of design weight indicated on system drawing and actual weight marked on container tag. Refer to Vendor Component Manual and Operations and Maintenance Manual for nominal weights and recharging of Halon 1301 system. |
| 5. Halon Nozzles and Piping | | | | | X | | | Inspect and clean. | Inspect nozzles for tightness (in high vibration environments), tighten 1/2 to 3/4 turn beyond hand tight.<br><br>Clean nozzles with compressed air. Blow air or nitrogen through piping to check for obstruction or clogging of nozzles or piping. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| **Carbon Dioxide ($CO_2$) Extinguishing System (Walter Kidde)** | | | | | | | | | |
| General System<br>is this system now replaced with Inergen extinguishant? Is it necessary to weigh the bottles? | | | | | X | | | Normal System Inspection.<br><br>Perform the following procedure as required or when $CO_2$ has been discharged:<br><br>1. Remove cylinder for check weighing. If cylinder registers less than 90% FULL it is to be recharged to FULL capacity.<br><br>2. When cylinder is disconnected:<br><br>a. Check operation of mechanical trip.<br><br>b. Remove glass from pull box and operate handle to ensure cable has freedom of movement within its conduit replace glass.<br><br>c. Reset the mechanical release trip, pressure switch, fusible links and pull box. | Refer to Vendor (Walter Kidde) Manual for removal, resetting and reinstalling of system components. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| General System (Cont'd) | | | | | | | | d. Check contents of premix vessel through the sight glass level indicator. Top up as required.<br><br>e. Operate 3 in. gate valve to ensure freedom of movement. | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| ENCLOSURES<br>Inlet Plenum | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 1. Inlet Area<br>In semi annual maintenance. | X | | | | | | | All inlet areas to be free of loose objects and foreign material. | Required after every entry prior to start and/or after corrective maintenance has been performed. After a thorough inspection has been made of the inlet plenum, close and securely fasten the inlet doors and access panels. Insure all bolts or nuts used to fasten doors or panels are accounted for after closing up the inlet plenum. |
| 2. Engine Inlet Sensor<br>In semi annual maintenance. | | | | X | | | | Check the accuracy of the inlet temperature thermocouple (TC-CIT) reading by comparing the indicator reading to a mercury thermometer held next to thermocouple probe in the inlet plenum. | If readings vary by more than ±2°F, check the indicator reading by applying a millivolt signal to the thermocouple leads and check to the indicator reading against the signal for iron constantan material. If calibrator test checks out, replace thermocouple. |
| 3. Blow-in Doors | | | | | X | | | Inspect and check operation of blow-in doors, as required and when filter elements are changed, for freedom of movement and operation of alarm limit switches. | Inspection of blow-in door assembly also required when control room alarm sounds. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 4. Inlet Silencer | | | | | X | | | Inspect accessible silencer baffles for cracks and security of attached components. | Single cracks of less than 3" may be stopped drilled, unless cracks are running toward each other which would result in eventual breaking away of material. These later types of cracks should be weld repaired and excess material and slag carefully removed from plenum area. |
| 5. Drainage | | | | X | | | | Check level of drainage tank and pump out if necessary. | |
| 6. Evaporative Cooler Assembly (Burgess Industries) | X | | | | | | | Check water level to tanks, water supply pressure to nozzles and any nozzles for clogging. | |
| | | X | | | | | | Check tank water for cleanliness and any sludge collection on tank bottom. If dirty, drain hose down and refill with clean water; recheck setting of float valve. | |
| | | X | | | | | | Inspect condition of cooler interiors, plenum and tanks. | |

Is this installed on the Hydro plant. No reference to it has been found elsewhere.

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| No reference to spray cooling found in other CW manuals. Is this section relevant? | | | | | | X | | Clean tank thoroughly. | Scrape or wire brush all areas of corrosion and touch up with zinc rich paint. |
| | | | | | | X | | Inspect spray nozzles. Remove and replace any with badly eroded orifices. | Note some erosion will not affect cooler performance materially, but obviously bad ones should be replaced. |
| | | | | | | X | | Inspect all spray drain piping for any leaks at seals or joints. The pump should be lubricated and inspected. | Refer to performance criteria provided in Section 1 Operation and Maintenance Manual illustration with title: "Intake Air evaporative Cooler Curve." |
| | | | | | | X | | Check eliminator blades if water carry-over is apparent in the plenum area. | |
| | | | | | | X | | Check condition of implosion door hardware. Check and oil if necessary and make sure hinges and latches operate freely. Recheck release point and limit switch operation. | |
| | | | | | | X | | Remove and replace polyurethane foam cell filters. | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| **Control Building** | | | | | | | | | |
| 1. AC/DC Motor Control Centers | | | | | X | X | | General; Inspect, clean and service. | Refer to Motor Control Centers |
| 2. Sequence Timers | | | | | | | X | Check timer settings, mounting and terminal connections. | Refer to Control Sequencer. |
| 3. Recording Instrument | X | | | | | | | Inspect ink supply paper supply and instrument zero setting. | |
| | | | X | | | | | Flush and clean inkwell. Clean pen capillary tube and tip. | Use water or alcohol. Use pen cleaning wire to clean pen tip. Flush with water. |
| | | | | X | | | | Clean and lubricate motor chart drive bearings and reroll drive mechanism. | Bearings may be removed for cleaning by taking out three machine screws which secure mechanism side plates. Clean bearings by brushing out with naptha. Dry and lubricate bearings with Westinghouse Clock Oil Style No. 935736 or equivalent. |
| 4. Watthour Meters | | | | | | | X | Replace. | Refer to Vendor Component Manual. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 5. Circuit Breakers | | | | | X | X | | General, inspect for cleanliness, inspect contacts, inspect for loose parts, lubricate. | Initial inspection and lubrication is after 6 months of service or number of operations.<br><br>Refer to Vendor Component Manual for instructions to disassemble, contact adjustment, cleaning and lubrication. (Special lubricant is required in a few places and must be applied with care).<br><br>WARNING: IN THE OPERATION OF THE BATTERIES, GASES ARE FORMED WHICH MAY BE EXPLOSIVE IF IGNITED. NEVER BRING ANY BURNING MATERIAL SUCH AS LIGHTED MATCHES, CIGARETTES, AND THE LIKE, OR SPARKS OF ANY KIND IN THE BATTERY ROOM. |
| 6. Batteries | | X | | | | | | Check battery fluid level and hydrometer reading of pilot cell. | Immediately after installation, check and record voltage across each cell and specific gravity of each cell. During this check, the cell with the lowest voltage and specific gravity will be determined and may be used as a pilot cell for periodic checks. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Limited electrical checks found in 5 yearly. | | | X | | | | | Check and record battery cell voltage. | Add distilled water to each cell as often as necessary to maintain fluid level. |
| | | | | X | | | | Check and record hydrometer readings of each cell and temperature of each fifth (5th) cell. Compare readings with previous readings for signs of deterioration. | |
| 7. Inverter | | | X | | | | | Check for cleanliness and record output voltage and frequency. | Check inspection readings with previous data. |
| 8. Battery Charger | | | X | | | | | Check for cleanliness, and record output voltage and amperage. | Check inspection readings with previous data. |
| 9. Annunciator | | | | | | | X | Relamp as necessary. | Remove front bezel and window assembly, replace bulb, then replace bezel and window assembly. |
| | | | | | | | X | Annunciator Card replacement. | Remove window and bezel assembly; grasp light box at the edges and pull sharply. To replace the module align the new module in place and start into the socket; then finish with a sharp push. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 10. Fire Control System | | | | X | | | | For normal system check and control unit function, refer to Halon Fire Protection of System Inspection and Maintenance chart. | |
| Control Sequencer Instrumentation | | | | | | | | | Refer to Operations & Maintenance Manual, for listing of test equipment required to inspect, calibrate and maintain control sequence instrumentation. |
| 1. Level Switches (As applicable) | | | | | X | | | Inspect float mechanisms for freedom of movement. Check electrical wiring for security. | Calibrate level switches by varying the liquid level in the related tanks or measure level above tank in dry condition. Refer to Vendor literature for details. |
| 2. Thermal Switches Temperature Switches | | | | | | X | | Inspect all temperature switches for proper voltage and evidence of filling fluid on external parts and freedom of plungers and conical springs. | Refer to temperature switch bulletins in Vendor Component Manuals for check and calibration procedures. |

Generic statements are included in 5 yearly checks. It is unclear which are specifically addressed. There may be lists in associated work orders.

checklists with tag numbers are needed to ensure all devices are checked. Safety critical ones need to be proof tested and results recorded.

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| | | | | | | | | Check fire thermal switches and calibrate. | Disconnect the heat actuator device from the system. (Refer to Vendor Manual for precautionary measures during system maintenance) Connect a 24V DC test lamp, a power source and the detector in series. Heat the detector with a heat lamp on other convenient source.<br><br>When the test lamp lights, remove the heat source and allow detector to cool. The test lamp should go out and the detector contacts should be open. Contact closure temperatures are given in Operations and Maintenance Manual. |
| 3. Relays - Voltage (DC) | | | | | X | | X | Inspect, clean, test. | The maintenance period for various types of relays vary from 6 months to the maximum of 24 months. Testing and cleaning of relays and contacts are generally in accordance with procedures used for the Motor Control Center and instructions for testing the individual type of relays are given in the Vendor Instruction Manuals. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 4. Limit Switches | | | | | X | | | Inspect for tightness and test. | Check for connector tightness. Actuate switches manually in circuit or with test instrument to determine switch closing and opening. Calibrate by adjusting mounting, etc. to actuate switch lever and roller at desired position. Check switch contacts position with test light or other indicating test instrument. |
| 5. Pressure Switches & Transmitters | | | | X | | | | Inspect switch and transmitter for leaks, shorts and security of mounting. | |
| | | | | | | X | | Inspect and calibrate<br>5 yearly checks item c (?) | Calibrate or check pressure switches using easily adjusted pressure source capable of producing a pressure equal to the proof pressure of the switch. Use accurate pressure gage connected to pressure source and low voltage indicator light for contact checks. Check alarm and trip settings using gage and lite for reference. Refer to Vendor Component Manuals for test and adjustment instructions for particular switch. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 6. Vibration Monitors | X | | | | | | | System test. | When the test button is depressed a signal is applied to the input of the channel selected and the DC output of this channel is shown on the meter provided the channel select switch is indicating the channel tested. The test signal provides full scale deflection. During this operation a relay lockout is provided to desensitize the alarm and shutdown relays, but the indicator lamps will be energized.<br><br>This procedure checks the overall gain of the system, the reaction of the comparators and the amount of time delay. There is a delay of 1.0 seconds between the time when the test button is released and the time when the monitoring function is resumed. The test signal is applied to the channel whose test button is pushed even when the channel select switch is indicating a different channel. The meter will not respond, but the monitoring function of the tested channel will be interrupted and the indicator lamps will light. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 6. Vibration Monitors (Cont'd)<br><br>included in 5 year checks, item d (?) | | | | | X | | | Step 1. Turn off AC power to meter and adjust mechanical zero on front of meter to a pointer position of zero. Turn AC power back on.<br><br>Step 2. Disconnect pickup input leads to Channel No. 1. Connect the sine wave output of the oscillator to the input terminals of Channel No. 1. Connect the DVM to the oscillator output. Connect the square wave output of the oscillator to the frequency counter. Remove Channel No. 1 card and reinstall with the extender card. Disconnect circuit attenuation on Term 10.<br><br>Step 3. Set oscillator to 100 Hz at 24 MV. Adjust R28 for 1 mil on the monitor meter. CW to raise.<br><br>Step 4. Set oscillator to 100 Hz at 248 MV. Adjust R5 to set 10 mils. If R5 has no effect, adjust R1 until R5 adjustments do have an effect, i.e. if you are trying to raise R5 with no effect, raise with R1 slightly more than 9 mils then set 9 mils with R5. CCW on R5 to raise. CW on R1 to raise.<br><br>Step 5. Repeat steps 3 and 4 until no further adjustments of R1, R5 and R28 is required. | Maintenance & Service for detail test, calibration and trouble-shooting procedures.<br><br>To calibrate monitor installed in panel, proceed as follows: |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 6. Vibration Monitors (Cont'd) | | | | | | | | Step 6. Press test button on front of channel card and adjust R26 to near full scale. Ensure R26 is still in control at the maximum attainable meter reading nearest 10 mils.<br><br>Step 7. Repeat steps 5 and 6 until no further adjustments are required.<br><br>Step 8. Set the recommended input (MV) (at 100 Hz) and check the meter readings:<br><br>1 mil<br>2 mil<br>3 mil<br>4 mil<br>5 mil<br>6 mil<br>7 mil<br>8 mil<br>9 mil<br><br>NOTE: $\pm$ 0.05 is acceptable at 2 through 5 mils.<br>$\pm$ 0.1 is acceptable at 6 through 8 mils.<br><br>Step 9. Disconnect test equipment at back of Channel No. 1 and reconnect leads removed in Step 2. Remove extender card and reinstall channel card.<br><br>Step 10. Push alarm button and adjust alarm to 5 mils, release button. Push shutdown button and adjust shutdown to 10 mils.<br><br>Step 11. Repeat Steps 2 through 10 for the remaining channels. | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 6. Vibration Monitors (Cont'd) | | X | | | | | | Inspect transducer wiring for chafing or other damage. Inspect transducer mount for security. | Check setting of N3 overspeed switches (AD10 and AD11) by applying oscillator signal of 1000 Hz to terminal 5 and 6 of speed switch. Open reset contact between Terminals 7 and 8. Connect ohmeter between shutdown switch terminals 3 and 4, (should read closed). Increase oscillator frequency until ohmmeter on terminals 3 and 4 indicate open. Frequency should be 4140 Hz. Reduce oscillator frequency to about 1000 Hz. Terminals 3 and 4 should read open until speed switch is reset by momentarily closing contacts 7 and 8. |
| | | | | | X | | | Check switch settings. | Check frequency (RPM) at which the N3 speed relays operate by increasing or decreasing oscillator frequency and monitoring relays:<br><br>114T10X1 - de-energize - 1000 HZ<br>214T10X1 (increase)<br><br>114T32X1 - energize - 3200 HZ<br>214T32X1 (increase) |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 6. Vibration Monitors (Cont'd) | | | | | X | | | Calibrate N4 speed monitor for meter readout and set points. | Use N4 speed conversion below. Set points at which relays operate are as follows:<br>14N4RX - energize - 50 RPM (decrease)<br>14G10X1 - de-energize -1000 RPM (increase)<br>14G32X1 - energize - 3200 RPM (increase)<br>14G36X1 - energize - 3600 RPM (increase) |
| 7. Speed Circuits Woodward Control | | X | | | | | | Inspect transducer wiring for chafing or other damage. Inspect transducer mount for security. | NOTE: Woodward governor has overspeed switches which will be set during the governor calibration.<br>N1 (Hz) x 2.3622 = RPM<br>N2 (Hz) x 2.8680 = RPM<br>N3 (Hz) x 1.111 = RPM<br>N4 (Hz) x 1.1538 = RPM |
| | | | | | X | | | Inspect and test calibrate speed circuits. | Check N1, N2 and N3 speed transducers and cables for continuity, resistances and shorts to ground. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 7. Speed Circuits Woodward Control (Cont'd) | | | | | | | X | Routine cleaning. | Testing and performance checks of the N1, N2 and N3 speed circuits related to the Woodward Governor should be accomplished in accordance with procedures outlined in Vendor Component literature, Woodward Manual 43027 and associated bulletins. Reference Control Schematics or Sequencer Wiring Diagrams (Governor Signal Inputs and Unit Speed Points) for transducer input connections and frequency/speed conversions.<br><br>Clean internal parts by removing dust and foreign matter by brushing, wiping with clean dry cloth. Compressed air at low pressure may be used to blow dust from hard to reach areas.<br><br>CAUTION: INTERNAL PARTS SHOULD ONLY BE CLEANED WHEN POWER IS REMOVED FROM THE 43027 RACK CABINET. |
| 8. Speed Circuits Hamilton Standard Control<br><br>are these relevant? Other manuals refer to a Woodward governor. | 8000 Hrs. | | | | | | X | Perform a basic check of Hamilton Standard SPC 2H. Refer to Hamilton Standard Fuel Control Manual Checkout and specified operating characteristics of SPC 2H. | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 8. Speed Circuits Hamilton Standard Control (Cont'd)<br><br>SPC2H Overspeed<br><br>Overspeed shutdown sensors are safety critical. | | | | | | | 400 Hrs. | Check SPC2H Overspeed. Use high impediance 4-digit frequency counter. Accuracy ± 2 Hz. | NOTE: If SPC2H is equipped with dual N3 (NF) feature, activate the high Max. N3 switch in sequencer cabinet before starting the unit.<br><br>1. Deactivate any other overspeed switch supplied.<br><br>2. Start in Manual Mode.<br><br>3. Use governor switch and increase N3 speed slowly to shutdown. Do not exceed *N3 RPM.<br><br>* Curtiss-Wright to set this value<br><br>4. Shutoff valves should close at *N3 RPM.<br><br>5. If necessary, adjust as follows:<br><br>a. Remove fuel control cover and locate R-141 on N3 card.<br><br>b. If shutdown occurred below specified RPM, adjust R-141 clockwise to increase shutdown RPM. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 8. Speed Circuits Hamilton Standard Control (Cont'd) | | | | | | | | | c. Repeat steps 1 thru 3.<br><br>d. If shutdown did not occur by *N3 RPM, use governor switch to set *N3 RPM, and then adjust R-141 counter-clockwise until shutdown occurs.<br><br>e. Repeat Steps 1 thru 3 for check.<br><br>NOTE: If SPC2H is equipped with dual N3 (NF) feature, deactivate high Max. N3 switch after shut-down.<br><br>*Curtiss-Wright to set this value. |
| Droop Resistor | | | | | X | | | Check voltage drop across Droop Resistor. Adjust as required. | 1. Determine the 100% power output for the Peak Load Schedule, adjusted for ambient temperature and station elevation.<br><br>2. Using Kilowatt Hour Meter method, determine actual power output for peak Load Schedule. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 8. Speed Circuits Hamilton Standard Control (Cont'd) | | | | | | | | | 3. If actual power output is equal to 100% of the adjusted value determined in Step 1, above, the Droop Resistor setting at 80°F should be 300 Mullivolts (RMS) measured at the fuel control terminals using an ungrounded 11 megohm input impedance.<br><br>4. If conditions prevent 100% power output, the Droop Resistor voltage drop should be in direct proportion to the percentage of power output:<br><br>Droop Millivolts (RMS) = (% Power Output) x 3<br><br>NOTE: While checking and setting the droop voltage, the fuel control droop setting must be 4% and the VAR's must be at unity power factor. |
| N1, N2, N3 Sensors | | | X | | | | | Check Speed Sensors N1 and N2 for security of mounting and wiring integrity.<br><br>Check Speed Sensors N2, N3 signal voltage. | 1. Measure N3 signal voltage across SPC2H terminals 1-2.<br>2. Measure N2 signal voltage across SPC2H terminals 4-5.<br>3. The acceptable range of either N2 or N3 signal voltage is from 3 to 5 VAC.<br>4. Voltage is adjusted by adding or removing transducer shims. |
| | | | | | | X | | | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 8. Speed Circuits Hamilton Standard Control (Cont'd) | | | | | | | | | NOTE: No more than .009 total shim thickness may be added to or removed from the original installed shim settings. Minimal meter sensitivity should be at least 1,000 ohms/volt AC. |
| 9. RTD Recorder and Circuit | | | X | | | | | Inspect wiring and connections for tightness and security of mounting. | |
| | | | | | | X | | Test and calibrate RTD Stator circuits and recorder. | Refer to Operation and Maintenance Manual, Section 3, for test setup and resistance values vs temperature conversion chart. Refer to Control Schematics, for RTD input connections. Calibrate by substituting resistance values representing temperature for the RTD in the circuit as close to the alternator as possible. Refer to Vendor Component Manual for basic calibration procedures. |
| | | | | | | | X | RTD Circuit Checks. | Prior to calibration or malfunction of system. Check for shorts and proper resistance values per Section 3 of Operation & Maintenance Manual. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 9. RTD Recorder and Circuit (Cont'd)<br>is this still current? | | | X | | X | | X | Shafts and print mechanisms. | Routine maintenance is outlined in Vendor Component Manual. Belts should be replaced every 7 months. Clean print mechanism carriage and shafts with clean, low pressure blast of compressed air every month. Lubricate print mechanism carriage shaft every six months by applying light oil with clean cloth.<br><br>Clean pinion shaft every six months using brush. (Do not lubricate pinion shaft).<br><br>Lubricate points per Vendor Component Manual. Use good grade, medium weight, non-detergent oil. (L&N Part No. Std. 763). |
| | | | | | | | X | Relays, input selector and control commutator. | Clean contacts every 10 years. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 10. I/C Thermocouple Circuit (26R Recorder)<br>is this still current? | | | X | | | | X | Cleaning and lubrication (Normal Conditions). Check thermocouple wiring, connectors. | (Refer to Vendor Component Manual for service periods and instructions). Once a month clean per carriage or print wheel carriage shaft and carriage guide rod with a small quantity of oil on a clean cloth. Place 2 or 3 drops of oil on the pinion and gears and smaller gears as noted.<br><br>Every 2 months oil parts as designated in manual. Clean measuring and control slidewires with cloth moistened with benzine. (Use carbon tetrachloride if use of benzine is prohibited). Clean all other slide wires with a clean cloth lightly coated with a thin film of vaseline. Every 4 months oil all parts indicated by manual.<br><br>Every 8 months lubricate and clean as previous and clean commutator contacts.<br>NOTE: Use L&N lubricants, Part No. Std. 763. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 10. I/C Thermocouple Circuit (Cont'd) | | | | | | X | X | Motor Bearing Inspection and replacement. | Sealed bearings cannot be serviced with lubricant. Noisy and/or rough bearings should be replaced. Refer to Vendor Component Manual. |
| is this still current? unusual to | | | X | | | X | X | Cleaning and Lubrication (Unusual Conditions). | Refer to Vendor Component Manual, for service periods and instructions. |
| | | | | | | X | | Calibrate recorder. | Disconnect sensor input leads and test each thermocouple circuit for continuity check. (Refer to Control Schematics, Temperature Recording and Monitoring, for terminal connections). Check calibration of 26R recorder by manually operating point advance and slidewire mechanisms while monitoring scale readings at which switch contacts operate. Inject millivolt signals (I/C) corresponding to specific temperature values to verify trip and alarm settings. |
| 11. C/A Thermocouple Circuit (26EM/R Recorder) | | | X | | | | X | Cleaning and lubrication (Normal Conditions). | See Vendor Component Manual. |
| is this still current? | | | | | | X | X | Motor Bearing inspection and replacement. | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 11. C/A Thermocouple Circuit (26EM/R Recorder) Cont'd. | | | | | | X | | Calibrate recorder. | See Item 9 except use C/A thermocouple input. Refer to Control Schematics, Temperature Recording and Monitoring, for C/A exhaust temperature thermocouple connections to switch and recorder. Calibrate the C/A exhaust gas temperature settings during the Woodward control calibration. Refer to Control Schematics, Gov. Sequencing Inputs, for governor terminal connections. Calibration of governor should be accomplished during compliance with Item 8, using Woodward Manual 43027 and associated bulletins. |
| 12. Sequence Logic Timers | | | | | | | X | Check time settings, mounting and terminal connections. | When required due to logic change or timer replacement. Refer to Control Schematics associated with the following circuits for the various settings:<br>1. End and Unit Hourmeters Anti-Ice Control<br>2. End Starting, Master Start To Run Transition and Horn Control<br>3. End Auxiliaries and Unit Fuel Control<br>4. Unit Delayed Trips (Class 7) Electrical Trip<br>5. End A Sequence Control<br>6. End B Sequence Control<br>7. Main Lube & Fuel System Control<br>8. Unit Gov. Auto Synchronizing and Breaker, Closure Control |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 12. Sequence Logic Timers (Cont'd) | | | | | | | | | 9. Sequence Watchdog Timers. Also refer to Vendor Component Manual for particular time bulletins for installation and operating instructions. |
| | | | | | | | | Anti-Ice Valve Failure<br>102AIF, Control Schematic (Circuit 1) | |
| | | | | | | | | Start Warning Horn<br>2H, Control Schematic (Circuit 2) | |
| | | | | | | | | Black Start Transfer<br>2/27 BS, Control Schematic (Circuit 3) | |
| | | | | | | | | Non-Urgent Trip Delay<br>2-86 DT, Control Schematic (Circuit 4) | |
| | | | | | | | | Anti-Ice Minimum Cycle<br>2AIS, Control Schematic (Circuit 1) | |
| | | | | | | | | Starter Over Crank<br>2-120 ST, Control Schematic (Circuit 5) | |
| | | | | | | | | Demister Cutoff<br>2-30A, Control Schematic (Circuit 7) | |
| | | | | | | | | Fuel Recirculation Anti-Cycle<br>2-3 FR, Control Schematic (Circuit 3) | |
| | | | | | | | | Enclosure Fan Cutoff (Unit A)<br>2-103 EF, Control Schematic (Circuit 3) | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 12. Sequence Logic Timers | | | | | | | | Breaker Close and Anti-Cycle<br>2-4 BC, Control Schematic (Circuit 8)<br><br>Governor Auto Loading Pulse<br>2-66I, Control Schematic (Circuit 8)<br><br>Governor Auto Loading Pulse<br>2-66P, Control Schematic (Circuit 8)<br><br>Starter Watchdog<br>102 S, Control Schematic (Circuit 9)<br><br>Purge Timer<br>102 P, Control Schematic (Circuit 9)<br><br>Lightoff Verification Watchdog<br>102 LV, Control Schematic (Circuit 9)<br><br>Turbine/Gen. Auxiliaries Watchdog<br>2A, Control Schematic (Circuit 9)<br><br>Post Lube Timer No. 1<br>62 PL1, Control Schematic (Circuit 9)<br><br>First Acceleration Watchdog<br>102 AT1, Control Schematics (Circuit 9)<br><br>Sec. Acceleration Watchdog<br>102 AT2, Control Schematics (Circuit 9)<br><br>Turb. Breakaway Watchdog<br>102 TB, Control Schematic (Circuit 9) | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 12. Sequence Logic Timers (Cont'd) | | | | | | | | Overall Auto Seq. Watchdog 34 S, Control Schematic (Circuit 9)<br><br>Post Lube No. 2 62 PL2, Control Schematic (Circuit 9)<br><br>Breaker Closure 2-3BC, Control Schematic (Circuit 4) | |
| 13. Relays (Generator Protective) | | | | | X | | X | Inspect, clean contacts | The maintenance period for the various types of generator protective relays cover from 6 months to 24 month periods. |
| | | | | | | X | | Test. | In general, voltage operated relays should be tested to ensure satisfactory operation at 50% to 120% normal volts for DC operation, or 80% to 120% normal volts for AC operation. Contact maintenance and gap settings, relay tests and test set-ups, calibration and assembly information is contained in the Vendor Component Manuals for the particular type of relay. |
| 14. Dynalco Monitors Series TC 2000 | | | | | | X | X | Calibrate. | No specific inspection or maintenance required. Unit replacement necessary if malfunction occurs. Calibration is required if control |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 14. Dynalco Monitors Series TC 2000 (Cont'd) | | | | | | | | | systems settings are changed. Refer to Vendor Component Manual, Dynalco, TC 2000 for calibration instructions. |
| Turbine Module | | | | | | | | | |
| 1. Switches, pressure temperature, speed and level | | | | | | | | Inspect and calibrate. | Refer to Control Sequencer Instrumentation. |
| 2. Fire Protection | | | | | | | | Inspect and calibrate. | Refer to Fire Protection System. |
| 3. Fuel, Lube, Air and Hydraulic | | | | | | | | Inspect and calibrate. | Refer to Gas Generator, Hardware and Systems. |
| 4. Secondary Air Fans | | | | X | X | | X | Motor and fan bearings lubrication. | Direct drive fans - Add 1/3 cubic inch of grease per bearing cavity every 6 months.<br><br>Belt driven fans - Lubricate every 1000 hours or 2 months, add 1/3 cubic inch of grease per bearing cavity.<br><br>All 1750 RPM motors to be inspected every 6 years. All 3450 RPM motors to be inspected every 3 years. Inspection requires motor to be removed from fan casing and dismantle. Refer to Vendor Component Manual for motor regreasing instructions. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 4. Secondary Air Fans (Cont'd) | | | | | | | | | Recommended lubricants are: Gulf Crown EP2, Esso MP Grease H Alvania Grease 2, Sun Prestige 42 Grease, Regal AFB No. 2. |
| Alternator Module | | | | | | | | | |
| 1. Switches, Pressure Temperature, Speed and Level | | | | | | | | Inspect and calibrate. | Refer to Control Sequencer Instrumentation. |
| 2. Fire Protection | | | | | | | | Inspect and calibrate. | Pipes and nozzles in each end canopy are fitted for use with "Halon Gas" or Carbon Dioxide ($CD_2$) fire extinguishing equipment. Manufacturer's recommended safety precautions must be carefully observed. Refer to Fire Protection System. |
| 3. Doors | | | | | X | | | Apply one drop of fine machine oil to the locks, door hinges and bulkhead door catches. | |
| 4. Louvers and Driving Linkage | (400 hours) | | | | | | | Apply drops of fine oil to ensure proper operation. | All bearings on the emergency shutters (modutrol motor linkage dampers) are nylon brushes (bearings). |
| 5. Emergency Shutters | | | X | | | | | Release shutters to ensure they close by gravity. Reset to the open position by lifting the reset lever until the latch box engages. | Access to the latch box on the emergency exhaust shutters is from the air intake compartment. The reset lever hangs down in the same place. Access to the two latch |

calibration may be included in 5 yearly checks item c

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 5. Emergency Shutters (Continued) | | | | | | | | | boxes for emergency inlet shutters is from the generator compartment by removing two cover plates at the outer edges of the bulkhead between the generator and the air filter compartment. The reset levers are in the air filter compartment. |
| 6. Main Lube Oil System | | | | | | | | Inspect and service. | Refer to Main Lube Oil System. |
| 7. Electrical System Components | | | | | | | | Inspect and service. | Refer to Alternator Electrical. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| GOVERNOR | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| General Control Rack | | | | X | | | | Clean and inspect internal parts of all modules. | CAUTION: INTERNAL PARTS SHOULD ONLY BE CLEANED WHEN POWER IS REMOVED FROM THE 43027 RACK CABINET.<br><br>Remove dust and foreign matter by brushing with a clean dry brush. Large surfaces should be wiped with a clean, dry lint-free cloth. Compressed air at low pressure should be used to blow dust from hard to reach places.<br><br>Inspect generally for evidence of loose components and discoloration.<br><br>When modules are replaced, calibrate in accordance with Vendor Component Manual (Woodward). |
| EG-3P Actuator | | | | | X | | | Inspect actuator for loose bolts, oil leaks and security of mounting. Inspect linkage for wear and binding. | Refer to Vendor Component Manual, Woodward Bulletin 82560C. |
| Liquid Fuel Valve | | | | | X | | | Inspect for loose bolts, leaks and rough bearings. | |
| | | | | | | | X | Inspection of all parts when disassembly is required. | Visual inspection of all parts for damage or wear. Refer to Vendor Component Manual, Bulletin 45002A for disassembly and inspection instructions. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Liquid Fuel Valve (Continued) | | | | | | | | | At time of reassembly lubricate parts liberally with No. 10 lubricating oil (MIL-L-7808, Grade 1010). Lubricate all O-rings with petrolatum (Federal Spec. VV-P-236). |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| CT-2 POWER TURBINE | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Operating Records | X | | | | | | | Review operating log sheets for trends:<br><br>Auxiliary oil pressure and Filter Drop<br><br>Main Lube oil filter differential pressures<br><br>Front and Rear Thrust Bearing Oil Temperatures<br><br>Front and Rear radial bearing oil temperatures<br><br>Vibration (Vertical)<br><br>Rundown time (Power Turbine) Overspeed Trips | |
| Oil and Air Systems | X | | | | | | | Visual inspection of lines, connections, fittings, instrumentation, junction boxes, thermocouples, vibration and speed pickups, etc. | Check for security of mounting chafing, leaks, etc. |
| Major Assemblies | | | | | | | | | |
| 1. Bellows Assembly | X | | | | | | | Check for security of attaching flanges; check for cracks | "Dye check" suspected areas. Confirmed cracks should be repair welded. Cracks in excess of 1-1 1/2" (38.1 mm) found in the convoluted area of the bellows requires replacement of the assem- |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 1. Bellows Assembly (Cont'd) | | | | | | | | | bly. Cracks in the attaching flange may be welded. |
| | | | | | | X | | Check the Bellows Inlet Housing Air Seal | Visually inspect fore and aft flange to bellows weldment for cracks or pulled seams. Conform to applicable method provided above. |
| 2. Inlet Housing | | | | | X | | | Visual inspection of welds. Inspect cooling air elbows and tube. | Check front and rear flanges, struts and condition of inlet housing cover assembly. |
| 3. Stator & Rotor Assembly | | | | | | X | | Inspect condition of first and second stage clearance gages, first and second stage rotor blades and stator vanes. | 1. Check general condition of gages indication of rubbing. If contact is indicated measure the distance from the mounting flange surface to tip of the indicator and record. Measure thickness of shim if installed and record. Identify all measurements relative to its location in the stator housing assembly.<br>2. Disassembly and reassemble stator and rotor assembly, as necessary in accordance with Operation and Maintenance Manual Section 2.<br>Remove boroscope inspection port plugs to check first and second stage turbine rotor blades and |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 3. Stator & Rotor Assembly (Continued) | | | | | | | | | stator vanes; check first stage stator leading edges and vane surfaces through the inlet duct housing. Check the second stage stator vanes trailing edge and surfaces by entering the exhaust volute through the viewing port.<br><br>If a discrepancy is evident requiring further checking and disassembly, check first and second stage stator vanes and labyrinth seals for condition. Minor damage may be repairable per Curtiss-Wright Engineering Instruction. |
| 4. Exhaust Volute | X | | | | | | | Check security and condition of base support and attachment of seal to exhaust system; check condition of insulation blankets for tears and security of attachments. Repair as required. | |
| | | | | | | X | | Inspect exhaust volute general conditions, mount supports and load reference indication in accordance with Operation and Maintenance Manual, Section 2. | |
| 5. Thrust Bearing | X | | | | | | | Inspect Bearing Supports. | Check for oil seepage at bearing support cover surfaces. If seepage is evident, check for security of attachment, porous or failed |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 5. Thrust Bearing (Cont'd) | | | | | | | | | welds. If no weld failure is evident or after weld repair is performed, apply sealant compound RTV-732 to all mating surfaces and torque bolts |
| | | | | | | X | | Inspect bearing surfaces, ring assemblies, upper and lower leveling plates and shoes, and measure axial clearances in accordance with Operation and Maintenance Manual, Vol. 1, Section 2. | Remove and inspect 3 shoes from forward assembly and 2 shoes from rear assembly for wear and condition. If wear is apparent, replace if required. Install bearing cap. |
| 6. Instrumentation | | | | | | | | Check resistance readings of Power Turbine components at Junction Box. | Measure resistance of following components:<br>1. Front and Rear Journal Bearing Thermocouple<br>2. Front and Rear Thrust Bearing Pad Resistance Temperature Elements<br>3. Thrust Bearing Oil-Out Thermocouple<br>4. Bearing Support Vibration Pick-ups<br>5. Turbine Disc Cooling Air Thermocouple<br>6. Gas Entry Thermocouples |
| 7. Front & Rear Radial Bearings | | | | | | X | | Inspect bearing supports. | Check for oil seepage at bearing support cover surfaces. If seepage is evident, check for security of attachment, porous or failed welds. If no weld failure is |
| | | | | | | X | | Inspect bearing surfaces and caps and measure diametrical clearances in accordance with | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 7. Front & Rear Radial Bearings (Continued) | | | | | | | | Operation and Maintenance Manual, Vol. I, Section 2. | evident or after weld repair is performed, apply sealant compound RTV-732 to all mating surfaces and torque bolts. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| EXHAUST STACK | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| General | | | | | 2000 hrs or | X | | | |
| 1. Power Turbine Exhaust Volute | | | | | | | | Inspect the inside of Power Turbine Exhaust Volute for falling objects and cracks. | Exhaust Stack inspection can be carried through inspection holes in Stack and in Power Turbine Exhaust Volute. A thorough inspection can be carried through climbing inside the Stack and/or using a bucket crane and ladders to inspect the top section of the Stack. |
| 2. Diffuser Section | | | | | | | | Inspect Diffuser Section for inside cracks. | Stop crack propagation by drilling a relief hole at end of crack. Fill crack with welding rod. Choose welding rod material that is compatible with the parts being welded. |
| 3. Splitter Sections | | | | | | | | Inspect Splitter Sections for the following:<br>1. Cracks in boxes<br>2. Splitter's Supports integrity<br>3. Splitter's guides integrity<br>4. Splitter's perforated Plates and Sides<br>5. Insulation Material inside Splitters | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 4. Expansion Joint | | | | | | | | Check Expansion Joint integrity of Insulation Material and Outside Cover. | |
| 5. Flanges | | | | | | | | Check that bolts on all flanges are tight. | |
| 6. Stack Skin (Outside) | | | | | | | | Check Stack outside skin for integrity. | |
| 7. Screen Section | | | | | | | | Inspect Screen Section for collected objects, if any. | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| S.S.S. CLUTCH | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| General | | | | | | | | The only items likely to require maintenance are the primary and secondary pawls and insulation. When gas turbine alternator set has been dismantled disassemble clutch completely and inspect detail parts described in Section 3.0 of Operations and Maintenance Manual. | During replacement of parts, check all sliding assemblies for freedom of movement and lightly oil parts as necessary. |
| 1. Insulation | (200 Hours initially) | | | | | X | | Check insulation between alternator clutch and alternator Shaft Input Shaft. | Replace insulation as necessary in conformance with requirements of Alternator manufacturer. |
| 2. Primary and Secondary Pawls | (1000-1200 starts or as required due to operating failure) | | | | | | X | Check pawls for excessive wear on the nose, profile and bearing surfaces.<br><br>Inspect the pawl bearing bores in the relay helical sliding component and the pawl retaining ring.<br><br>Inspect the primary pawl springs; check that a radial load of 3-1/2 ozs. applied at the top of the pawl nose will just move the pawl into contact with the stop pin. | Replace pawls at maximum starts limit regardless of their apparent condition;<br><br>Ensure that pawls are facing the correct direction and that primary pawl springs give the correct loading. Check their operation as described in Vendor Literature. |
| 3. Ratchet and Relay Clutch Teeth | | | | | | | X | Check for signs of excessive wear and chipping of the flanks and end of components. | |

no maintenance listed for the clutch. Some insulation tests included in 5 yearly checks items l,m,n,p but no specific mention of the clutch.

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| FLEXIBLE COUPLINGS | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Coupling (Bendix) | | | | X | | | | Inspect drive shaft couplings for loose bolts, nuts, keys or hubs. | NOTE<br>Identification of coupling model should be confirmed to assure applicable inspection and maintenance procedures are adhered to. The required inspections listed refer to standard Bendix coupling models and part numbers as follows:<br>a. 67E322A-1717<br>b. 67E416-1796<br>c. 67E410-1797<br>d. 67E308-1798<br>e. 67E322A-1666 |
| | | | | | | X | | Disassemble, remove oil lubricant piping. Inspect coupling contact surfaces for wear. Inspect gear type couplings for excessive backlash. Inspect diaphragm for rust and/or corrosion. Perform alignment check. | |
| Coupling (Sier Bath) | | | | X | | | | Check the drive shaft couplings for loose nuts and bolts. | |
| | | | | | | | X | Check the weight balance of coupling bolt and nut sets. Inspect coupling contact surfaces for wear. Inspect the two half circle gaskets on both ends. Inspect the cover split line gaskets. Check surface to surface runout. (Power Turbine to Electric Generator) | Replace with weight equivalent parts (within 0.1 gram) |

no maintenance listed for couplings.

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| HIGH VOLTAGE SWITCHGEAR | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Switchgear Cubicles | | | | | | | X | Check switchgear cubicles periodically for proper operation of the anti-condensate heaters, cleanliness and general condition of connections and exposed wiring. | WARNING<br>HIGH VOLTAGE IS PRESENT IN MANY AREAS OF SWITCHGEAR ENCLOSURE. THE BREAKER MUST BE RACKED OUT AND LINE SIDE DISCONNECTS OPENED PRIOR TO PERFORMING WORK NEAR HIGH VOLTAGE EQUIPMENT. |
| Auxiliary Transformer | | | | | X | | | Inspect and clean transformer. Check windings for accumulations of dirt on insulating surfaces, loose connections, signs of overheating and voltage creepage over insulating surfaces as evidences by tracking or carbonization. Check all current carrying parts such as wires, cables and buss bars for signs of overheating due to poor connections. | |
| | | | | | | | | Inspect condition of tap changers or terminal boards. Clean windings with a vacuum cleaner, compressed air or a nitrogen source (less than 25 psig). | Dry transformer, if required, by applying heated air (not to exceed 110°C) and check by insulation resistance measurement. |
| Main Power Transformer (RTE-ASEA Corp.) | | | | | | | | | |
| 1. Transformer Oil | | X | | | | | X | Check oil levels. | Levels should never be below the markings of the oil level indicators. The oil levels in the tank and mechanism compartment should be |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 1. Transformer Oil (Continued) | | | | | | | | | checked at two week intervals during the first month of operation and annually or when required after that. |
| | | | | | | | | | Change oil in the transformer when it is warm and viscosity of oil is low in accordance with instructions in Vendor Component Manual. |
| | | | | | | | X | Test Oil Samples | Sample oil from the bottom of transformer tank and not from oil stored in the sampling pipe. A glass receptacle is desirable so that if air or water is present it may be readily observed. If air is present, allow the sample to stand until the oil is clear of air bubbles. If water is not present in sufficient quantity to settle out, the oil may still contain considerable moisture in a suspended state. Test oil sample for dielectric strength and for specified property values presented in vendor literature in accordance with ASTM specification #877. Perform test prior to breaking of any seals or removing any cover openings. |
| | | | | | | | X | Check acidity and flashpoint (Pensky Martens Test) if oil is in accordance with Vendor Manual. | |
| | X | | | | | | X | Inspect and replace oil conservation system Silica Gel | Replace gel when its ability to absorb moisture begins to diminish. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 1. Transformer Oil (Continued) | | | | | | | | Breather and if necessary the Pressure Vacuum Regulator in the sealed tank system. | Refer to vendor instruction for renewal and regeneration of the gel. |
| 2. Oil Level and Flow Indicators; Oil Pumps with Motors | X | | | | | | X | Inspect and clean per vendor instructions. As necessary perform an Operating Test, Megger Test and general test of electrical circuits. | |
| 3. External Circuits and Control Equipment | (30 days after installation) | | | | | X | | Check the following:<br>1. Control circuit voltage<br>2. Excess heating of parts evidenced by discoloration of metal parts, charred insulation, or odor.<br>3. Freedom of moving parts (no binding or sticking)<br>4. Excessive noise in relay coils<br>5. Excessive arcing in opening circuits<br>6. Proper functioning of timing devices, sequencing of devices, relief device alarm contacts, and thermometer contacts.<br>7. Evidence of water or liquids in control cabinets | Power factor tests on the unit must be made whenever the unit is de-energized for long periods (1 month or more) or the unit is opened for any reason. In addition, power factor tests should be performed annually. |
| 4. Combustible Gas Level Nitrogen Equipment Gas Operated Relay | X | | | | | | X | Visually inspect and clean as necessary.<br>Perform an Operating Test, | Nitrogen Gas Equipment, if supplied, should be checked to determine that the regulator is opera- |

some of the check points look odd. Noise in relay coils, arcing of contacts.

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 4. Combustible Gas Level (Continued) | | | | | | | | Megger Test and General Test of electrical circuits as required.<br>Perform a Combustible Gas Test for combustible gases weekly during the first month of operation. After the first month until the end of the first year make this test monthly. After one year in operation run the test on a quarterly basis. | ting properly. Refer to Vendor Manual Accessory Section Operating Instructions.<br>Always observe the rate of rise of the combustible gas level. If the combustible gas level reaches 0.3% at any time, weekly tests should be made to determine if the level is constant or increasing. If after four weeks the level remains constant, resume the normal test schedule as above. If the level continues to rise, an attempt should be made to locate the cause. However, this attempt should be made whenever a 0.5% level is detected. If at any time a 1.0% combustible gas level is detected, de-energize the unit until the source of the gas is determined. |
| 5. Transformer Temperature | (As required) | | | | | | X | Check temperature indicator (Thermometers and Thermostats) during abnormal temperature rise; as necessary perform in Operating Test, Megger Test and General Test of the electrical circuits. | For transformers furnished with thermometers for oil and winding temperatures, the setting values of the signaling contacts may be set as required by customer standards, or the following recommendations:<br><br>Naturally cooled and forced air cooled — Oil Temp. 80° — Winding Temp. 95°C<br><br>Thermometer contacts, used for starting of oil-pumps and fans on |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 5. Transformer Temp. (Cont'd) | | | | | | | | | transformers cooled by forced circulation, are generally set for 60°C if thermometer is actuated by the oil temperature and for 75°C if actuated by the winding temperature. In both cases the decision has to be done for each separately. |
| | | | | | | | | Check windings and core of the transformer for sludge deposits and overload conditions of bushings, tap changes, etc. Refer to ANSI Loading Guide and Vendor Manual for cleaning and maintenance instructions. | When a transformer filled with oil to the correct level has been opened to the atmosphere for inspection of bushings, etc., it should be pressurized in accordance with one of the procedures provided in the Vendors Manual. |
| 6. Cooling System | | | | | | | | | |
| a. Fan and Motor | | | | | | | X | When required perform an Operating Test, Megger Test and General Test of electrical circuits. Clean in accordance with Vendor Manual. | Fan motors use prelubricated sealed ball bearings that do not require lubrication maintenance. During extended periods of reduced capacity not requiring fan operation, it is suggested that the fans be run periodically (quarterly) to ensure satisfactory operation when required. Make sure that the proper drain holes on the motor are open. Motors on vertically mounted fans must have the drain screw in the bell end removed and the two drain holes in the motor housing plugged. If the fan is mounted for horizontal blowing the two drain |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| a. Fan and Motor (Continued) | | | | | | | | | screws in the body of the motor must be removed and the hole in the bell end plugged. |
| b. Air Cooled Oil Coolers and Radiators | (When required | | | | | X | | In general there is no need to keep cooling surfaces clean. Check oil for sludge formation. | If formation of sludge in the oil has set in, the sludge may deposit in horizontal surfaces in radiators and coolers. In such a case, the radiators and the coolers should be rinsed in connection with the changing of oil. If the sludge does not loosen by flushing with oil, use benzine, trichlorethylene, etc., and afterwards flush with oil<br><br>If it becomes necessary to remove a radiator, first close the valves, top and bottom, and bolt them in the closed position. Next, drain the oil from the radiator by removing the 3/4 inch drain plug from the bottom header and the 3/4 inch vent plug from the top. After draining the oil, remove the radiator. If the radiator, is to be off for any length of time, the transformer valves should be gasketed and covered with covers. This also applies to the radiator header openings. |
| 7. Valves | | | | | | | X | As required, examine and clean all breathers and small openings in pressure relief valves and pressure vacuum bleeders. | |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 8. External Tank, Cover, Gaskets | | | | | | | X | Check tanks for oil leaks. Repair tank, if defective, by welding or with Epoxylite in accordance with Vendor Manual procedures. Any replacement or adjustment required should be accomplished as soon as possible. Nitrile rubber gaskets around doors, manholes, covers, etc. may be re-used if in good condition. | Use an oil solvent to thoroughly remove all oil that appears on the outside of the tank or on the gaskets. This oil, later showing up on the painted surface, often gives the false impression of a leak. |
| 9. Bushings | | | | | | X | | Inspect and clean bushings. | Inspect and clean the mounting gasket surfaces on the bushing. Clean the bushing well using a rag dampened with a fast drying solvent such as denatured alcohol. All surfaces should be wiped clean and dry to prevent contamination of the oil in the transformer. |
| 10. Insulation | | | | | | | X | Check insulation of Transformer for moisture and serviceability. | If moisture is present, use one of the appropriate methods (a. By internal heat, b. By external heat or c. By heating and applying vacuum) for drying out insulation as provided in the Vendors Manual.<br><br>A series of diagnostic tests are recommended to evaluate the condition of the insulation and to insure proper internal connections prior to energization. Never perform electrical tests of any kind |

5 yr checks items i,m,n,p are insulation tests on components of the alternator and service transformer.

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 10. Insulation (Continued) | | | | | | | | | on a unit under vacuum. Flashovers can occur at voltages as low as 250 volts. Before applying any voltage on the transformer make sure that all bushing current transformers are shorted out. Refer to Vendors Manual. |
| Main Power Transformer (Hawker Siddeley) | | | | | | | | | |
| 1. Transformer Oil | | X | | | | | | Check oil levels. | Levels should never be below the markings of oil gauges, of the expansion vessel and below the tap changes diverter switch compartment. |
| | | | | X | | | X | Test oil samples (See B.S.C.P. 1009 for frequency) | Sample taken from main tank while oil is warm. Oil sample taken from sample valve after a few pints should be run off before sample is collected in a chemically clean, dry container. Sample should be stored for 15 min. to permit any air bubbles to surface. Oil tests should be carried out in accordance with British Standard Code of Practice C.P. 1009, Electrical Series for the Maintenance of Insulating Oil. |
| | | | | | | | | | Replacement of oil used must be in accordance with B.S. 148 (1959) and instructions in Vendor Component Man. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 1. Transformer Oil (Cont'd) | | | | | | | | | At the same time the condition of the oil in the conservator sump should be examined. A pet-cock is provided for this purpose. The acidity of the oil should also be checked. |
| 2. Silica-Gel Breather Sizes W & S | | | X | | | | X | Inspect and replace | When charge becomes 2/3 saturated it should be replaced. When the charge is active and dry the color is blue. When the charge is saturated the color changes to pale pink. To reactivate, the container should be heated in an oven to a temperature of approximately 280°F (140°C) for a sufficient length of time to ensure that the whole of the mass of gel attains the specific temperature and the blue color is restored. |
| 3. Gas & Oil Operated Relay | | | | | X | | | Test electrical circuits | Check operation of the gas and oil operated relay alarm and trip contacts by injection of air to the test pet cocks. |
| | | X | | | | | | General, inspect for oil leaks, security of mounting | Refer to Vendor Component Manual Section AA0/3/1 for testing and adjustment instructions. |
| 4. Temperature Controller | | | | | | | X | Adjustment and/or replacement of switches. Reset maximum pointer. | Only if adjustments are greater than ± 1% of dial ranges. Refer to Vendor Component Manual for adjustment instructions. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 5. Cooling System | | | | | | | | | |
| a. Controller | | | | | | | X | Adjustment | |
| b. Fan & Motor | | X | | | | | | Inspect for security of mounting. | |
| | | | | | X | X | X | Lubricate motor bearings (Ball type) | The motor bearings are lubricated at the factory. Unless otherwise stated on the nameplate, the correct grade of grease and re-lubrication period are as follows:<br><br>Shell Alvania-every 2 yrs-up to 40°C<br>R.A. or every 1 yr-41°C-60°C<br>Shell Alvania 2 every 6 months 61°C-80°C<br>(Applies to fans running continuously. For intermittent operation to 40 hrs/week, relubrication period X4. For operation up to 80 hrs/week, relubrication period X2.) |
| | | | | | X | | | Lubricate motor bearings (Sleeve type) | Lubricate through lubricators with good quality light machine oil. |
| c. Motor Protection Relay | | | X | | | | | Inspect connections, heater mounting screws, and fuses for security of mounting. | |
| d. Motor Contactors | | | | | | X | | Clean actuator housing. | Housing is removed complete with magnet and coil by removing the 2 |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| d. Motor Contactors (Cont'd) | | | | | | | | | captive screws. Blow out all dust with low pressure air. Do not polish, file or grease contact faces.<br><br>Remove coil and clean magnet faces with a cloth containing sufficient light machine oil to leave a thin film on the pole faces. Refer to Vendor Component Manual Section CAW/-/3 for detailed instructions. |
| 6. Pressure Relief Valve | | | | | | | X | Assure protective coating of paint is intact. | Valve requires re-setting only if semaphore indicates the unit has functioned. |
| 7. Tap Changer | | | | | | X | | Inspect flange joints for oil leaks or tightness. | Tighten each bolt slightly, moving around the flange until the complete joint has been made leak-proof. |
| a. Gear Train | | | | | | | X | Lubricate | Lubricate all surfaces with molybdenum di-sulphide paste only if original lubrication has been inadvertently wiped away during inspection. A film of this lubricant should be maintained on all bright ferrous parts to obviate rusting. |
| | | | | | | | X | Adjustment, brake | Pre-set. Should for any reason the brake requires adjustment, refer to Vendor Component Manual, Section AB/1/1 for procedures. |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| 7. Tap Changer (Cont'd) | | | | | | | | | |
| b. Step by step auxiliary switches | | | | | X | | | Inspect and clean | Clean foreign material from switch contacts. Use lint free cloth moistened with carbon tetrachloride. |
| 8. Dust Filters | | | | X | | | | Inspect filter | Frequency of inspection may vary according to site conditions. Checks should be made to assess the condition of the filter to establish a frequency of inspection. Filters are to be replaced when required. |
| Circuit Breaker | (2000 Hours) | | | | | | | Actual inspection and maintenance will depend upon individual application conditions. Some atmospheric conditions such as extremes of dust and moisture or corrosive gases might indicate inspection and maintenance at more frequent intervals. | |
| 1. Contacts | | | | | | | | Check for contact overlap. Check that movable contact blades fit snugly against lower contact block. | Clean and adjust or replace the component in accordance with Vendor Manual (Westinghouse Instructions for Parcel-Line Type DH-P Circuit Breakers). |

5 Yearly checks include unspecified maintenance on an SF6 breaker.

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| LOW VOLTAGE SWITCHGEAR | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Switchgear Cubicles | | | | | | | X | Refer to Switchgear Cubicles | |
| Auxiliary Transformer | | | | | X | | | Refer to Auxiliary Transformer | |
| Circuit Breaker (Westinghouse NB30800) | | | | | | X | | Inspect for cleanliness and serviceability. Refer to Vendor Component Manual. | |
| Gas Boost Compressor System Switchgear | | | | | | | | | |
| 1. Vacuum Circuit Breakers | | | | | | | X | Routine check at 2 year period | Inspect mechanism and linkages, lubricate with SAE 20 oil. (Permit oil-mist spray from above within the mechanism side plates if in use). |
| 2. Fittings | | | | | | | X | Fittings and contacts | Inspect fittings for tightness. Check breaker contact wear. (Refer to Section 7, Vendor Component Manual, Brush Switchgear Ltd. No. 55/3019). |
| 3. Contacts | | | | | | | X | Auxiliary contacts 2 year inspection. | Inspect and clean if necessary, apply thin film of vaseline. Check deflection as indicated in Vendor Component Manual. |
| 4. Transformers | | | | | | | X | 2 year inspect and lubrciate | Inspect shutter linkage and lubridate with SAE 20 oil. Replace fuses if necessary. |

6 Yearly checks include varioustests on unspecified electrical equipment including circuit breakers.

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Gas Boost Compressor System Switchgear (Cont'd) | | | | | | | | | |
| 5. Electrical | | | | | | | X | 2 year inspection. | Check circuits during routine inspection. Examine coils to ensure insulation and connections are sound. Ensure tripping batteries are free from faults and are charged. |
| 6. Relays | | | | | | X | | Inspect, clean and lubricate. | Tripping control relays, auxiliary and indicating and measuring relays. Remove dust filters, wash in water and detergent or some other suitable solvent. Rinse, dry and coat with thin film of light machine oil and replace. |
| | | | | | | X | | Contacts | Inspect contacts and if necessary clean with burnishing tool. |
| | | | | | | X | | Operation | Test voltage operated relays for 50% to 120% normal volts DC or 80% to 120% normal volts AC. (Refer to Vendor Component Manual, English Electric Relay Instruction MS/5608 for test circuit information, relay contact gaps and pressures.) |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Wattmeter, Recording (Westinghouse Type KF-44) | X | | | | | | | Inspect ink supply, paper supply and instrument zero setting. | |
| | | | X | | | | | Flush and clean inkwell. Clean pen capillary tube and tip. | Use water or alcohol. Use pen cleaning wire to clean pen tip. Flush with water. |
| | | | | X | | | | Clean and lubricate motor chart drive bearings and reroll drive mechanism. | Bearings may be removed for cleaning by taking out three machine screws which secure mechanism side plates. Clean bearings by brushing out with naptha. Dry and lubricate bearings with Westinghouse Clock Oil Style No. 935736 or equivalent. Refer to Vendor Component Manual, Westinghouse I.L. 43-440J. |
| Meter, Watthour (Westinghouse Types D4B-2F, -8F) | | | | | | | X | Replace. | Refer to Vendor Component Manual, Westinghouse I.L. 42-227. |
| Meter, Varhour (Westinghouse Type D4B-2F) | | | | | | | X | Replace. | Same as above. |

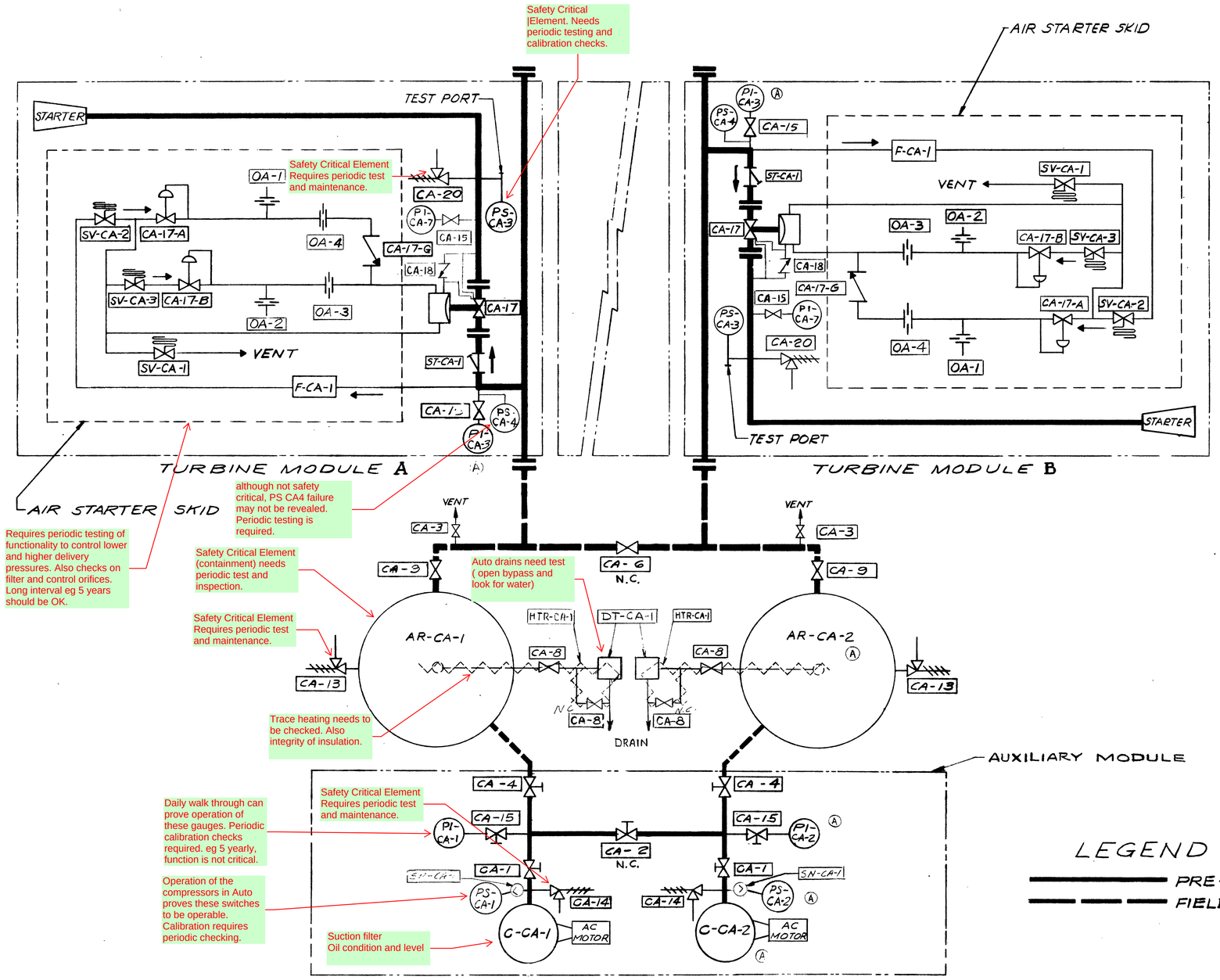
5 Yearly checks include unspecified checks on metering. Item s

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| Circuit Breakers (Westinghouse Types DS206, DS416, DS532) | | | | | | | | General, inspect for cleanliness, inspect contacts, adjust contacts, inspect for loose parts, lubricate. | Initial inspection and lubrication is after 6 months of service or number of operations:<br><br>Type DS206 - 1750 Operations<br>Type DS416 - 500 Operations<br>Type DS532 - 250 Operations<br><br>Refer to Vendor Component Manual, Westinghouse I.B. 33-790-B for instructions to disassemble, contact adjustment, cleaning and lubrication. (Special lubricant is required in a few places and must be applied with care. Refer to Paragraph 9.3 of above manual). |

| SYSTEM/COMPONENT | FREQUENCY | | | | | | | REQUIRED INSPECTION/MAINTENANCE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| AC/DC MOTOR CONTROL CENTERS | DAILY | WEEKLY | 1 MO. | 3 MOS. | 6 MOS. | YEARLY | OTHER | | |
| General Hardware<br><br>Bus Hardware, Circuit Breaker and Switch Terminals Contactor and Relay Terminals, Terminal Blocks<br><br>5 yearly checks item j and k are tests on the bus duct. | | | | | X | | | Check for tight connections. Clean relay contacts. | Badly worn or pitted contacts should be replaced. Do not use lubricant, emery paper, sandpaper or file to clean or dress up any portion of the electrical equipment. Replace silver cadmium contact points of line starters rather than cleaning or sanding. Use aluminum oxide paper for other sanding operation.<br><br>WARNING: ALL CIRCUITS SHOULD BE DE-ENERGIZED AND DISCONNECT DEVICES LOCKED OPEN WHEN WORKING ON UNIT EQUIPMENT. |
| | | | | | | X | | Check operation of equipment under energized conditions using precautionary measures. | CAUTION: ONLY AUTHORIZED PERSONNEL MAY OPEN UNIT DOORS WHILE STARTER UNIT IS ENERGIZED.<br><br>When servicing electrical equipment refer to specific instruction bulletins contained in the Vendor Component Manual. |

APPENDIX 1g: MARKED COPY OF

Drawing No: 183481: Air Start System




| CODED ITEM | DESCRIPTION |
|---|---|
| | **VALVES** |
| CA-1 | COMPRESSOR ISOLATION |
| CA-2 | CROSS-OVER, COMPRESSOR |
| CA-3 | VENT |
| CA-4 | TANK INLET |
| CA-6 | CROSS-OVER, AIR RECEIVER OUTLET |
| CA-8 | CONDENSATE DRAIN ISOLATION |
| CA-9 | OUTLET, AIR RECEIVER |
| CA-13 | RELIEF, AIR RECEIVER |
| CA-14 | RELIEF, AIR COMPRESSOR |
| CA-15 | INSTRUMENT |
| CA-17 | STARTER CONTROL |
| CA-17-A | AIR REGULATOR |
| CA-17-B | AIR REGULATOR |
| CA-17-G | CHECK |
| CA-18 | CHECK |
| CA-20 | RELIEF |
| SV-CA-1 | SOLENOID, 2 WAY - N.O. |
| SV-CA-2 | SOLENOID, 2 WAY - N.C. |
| SV-CA-3 | SOLENOID, 2 WAY - N.C. |
| | **PRESSURE GAUGES** |
| PI-CA-1 | AIR STORAGE WITH SNUBBER |
| (A) PI-CA-2 | AIR STORAGE WITH SNUBBER |
| (A) PI-CA-3 | PRESS UPSTREAM CONTROL |
| PI-CA-7 | PRESS, DOWNSTREAM CONTROL |
| | **PRESSURE SWITCHES** |
| PS-CA-1 | COMPRESSOR START/STOP |
| (A) PS-CA-2 | COMPRESSOR START/STOP |
| PS-CA-3 | STARTER - OVER PRESSURE |
| PS-CA-4 | GAS GENERATOR PERMISSIVE START |
| | **MISCELLANEOUS** |
| C-CA-1 | AIR COMPRESSOR AC MOTOR |
| (A) C-CA-2 | AIR COMPRESSOR AC MOTOR |
| F-CA-1 | CONTROL AIR DRYER |
| SN-CA-1 | SNUBBER |
| AR-CA-1 | AIR RECEIVER |
| DT-CA-1 | CONDENSATE DRAIN TRAP, AUTOMATIC |
| ST-CA-1 | STRAINER |
| HTR-CA-1 | HEATING CABLE (TRACE PIPE & EQPT) |
| OA-1 | ORIFICE, BLEED |
| OA-2 | ORIFICE, BLEED |
| OA-3 | ORIFICE, METERING |
| OA-4 | ORIFICE, METERING |
| AR-CA-2 | AIR RECEIVER |

| REVISIONS | | | |
|---|---|---|---|
| ENGRG ORDER NUMBER | CHG. LTR. DATE | DESCRIPTION | APPR. |
| 36852 K | A | IN SCHEMATIC C-CA-2 WAS C-CA-1, PS-CA-2 WAS PS-CA-1, PI-CA-2 WAS PI-CA-1, AR-CA-2 WAS AR-CA-1 & PI-CA-3 WAS PI-CA-2 (2 LOC) IN DESCRIPTION TABLE ADDED C-CA-2, PS-CA-2, PI-CA-3 & AR-CA-2 PI-CA-2 DESCRIPTION WAS PRESS. UPSTREAM CONTROL | 11-6-75 T |

183481
SHEET A

| | | |
|---|---|---|
| DTR. | R.T./W.H.S. | 5-8-75 |
| CKR. | | |
| SUPV. | | |
| MET. | | |
| MFG. | | |
| ENGR. | T. | 6-20-75 |
| ENGR. | | 6/20/75 |
| ENGR. | | 6/20/75 |



**POWER SYSTEMS**
CURTISS-WRIGHT CORP., WOOD-RIDGE, NEW JERSEY, U.S.A.

SCHEMATIC, AIR STARTER SYSTEM (OLYMPUS "C" GAS GENERATOR)
NEWFOUNDLAND & LABRADOR POWER CORP.
HARDWOODS TERMINAL STATION

| CODE IDENT. NO. | SIZE | |
|---|---|---|
| 66640 | D | 183481 |
| SCALE — | UNIT WT. | SHEET |

# APPENDIX 2a: BROCHURE FOR

# Gastops Metalscan MS 4000

MetalSCAN
ONLY BY GASTOPS

gastops
LONG LIVE EQUIPMENT

ON-LINE OIL DEBRIS MONITOR

# MS4000

## Real-time detection of damage - anytime, anywhere.

MetalSCAN MS4000 oil debris sensor monitors metal particles generated from rotating equipment due to bearing and gear damage. Assess how much time you have to schedule maintenance before equipment failure occurs.

## Requirement

The energy, marine, and aerospace industries require condition monitoring that is capable of detecting bearing and gear damage at the earliest stage of progression, and provide insight into the extent of the damage and its impact on the remaining life of the equipment.

It is understood that condition monitoring cannot be used to avoid damage occurring to the equipment, however, the right technique is used to effectively limit the damage and avoid outright failure of the equipment, where failure is defined as damage sufficient so that the equipment can no longer operate. Managing the risk from the context of the equipment operator is based upon planning the maintenance actions, thus achieving:

- Reduction of lost revenue – the equipment can be scheduled to be out of service for the shortest possible time, where the replacement equipment parts, equipment, and maintenance crews are on site at the time of shutdown.
- Reduction of repair costs - reduced equipment damage such that the extent of the repair is much less than if the equipment was to operate to failure.

An additional benefit of effective risk management is the potential for improved coverage from the insurers, which is delivered in terms of reduced premiums, reduced deductibles and/or reduced depreciation.

### FEATURES

- **100% Detection of Fe and NFe metal particles**
- **Easy to install**
- **Easy to interpret**
- **Rugged, solid-state with no moving parts**
- **Full function continuous built-in test (BIT)**
- **Proven reliability in harsh machinery environments**
- **Proven reliability in high temperature environments**
- **Proven reliability in hazardous environments**

### BENEFITS

- ✓ **Earliest reliable detection of component damage**
- ✓ **Monitor damage progression and estimate remaining life**
- ✓ **Avoid unplanned outages**
- ✓ **Avoid equipment secondary damage**



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# MS4000 SYSTEM

## Description

MetalSCAN is an on-line debris monitoring system designed to detect the passage of metallic particles in fluid lines. The system, which can be used in any pipe flow situation, is particularly suited to equipment applications where it detects metallic debris in a lubrication oil system and provides early indication of component damage.

The MetalSCAN MS4000 system consists of the following major components:

- A non-intrusive through flow Sensor which is fitted to the fluid line to be monitored.
- A custom low noise Sensor Cable which connects the sensor to the electronics.
- A Control Unit which processes the raw signal from the sensor and extracts information about the size and type (ferromagnetic or non-ferromagnetic) of the metallic debris detected.
- A host monitoring system which displays the current counts data, trend data, computes equipment health indices and announces warning/alarm exceedances. This function can be performed by an existing monitoring system host or by a dedicated standalone PC.

MS4000 is available in two basic configurations defined by the Control Unit option:

1) Multi-Sensor System - which includes from 1 to 6 Sensors and Sensor Cables, each connected to a multi-sensor Control Unit.
2) Single Sensor System - which includes one Sensor, one Sensor Cable, and a single-sensor Control Unit.


## SPECIFICATIONS

| System | Single-sensor | Multi-sensor |
|---|---|---|
| **Power Requirement** | 24 VDC | 24 VDC |
| **Rated Current:** | 0.3A | 0.8A |
| **Communication Interface** | RS485 Modbus | RS485 Modbus |
| **Cabling Distance** | up to 4000ft / 1200m | up to 4000ft / 1200m |

## COMPLIANCE

**LC Listed (USA & Canada)**

- Class I, Div 2, Groups A to D Hazardous Locations
- NEMA 250 (Type 4)[1]
- FCC part 15
- Conforms to ASTM D7685

**CE Marking**

- IP 66

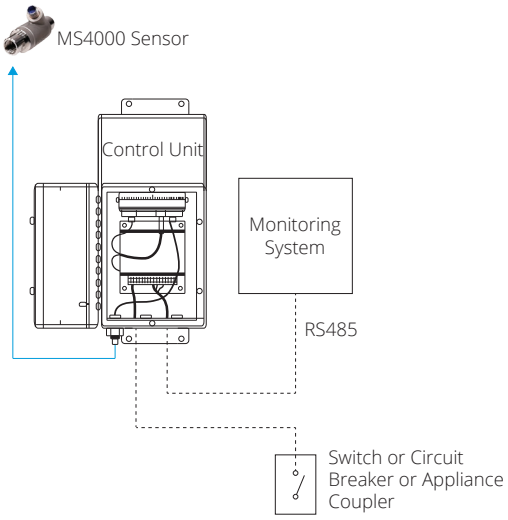
ATEX: CE Ex II 3G
IECEx: Ex nA IIB T4 GC

**Pressure Equipment**

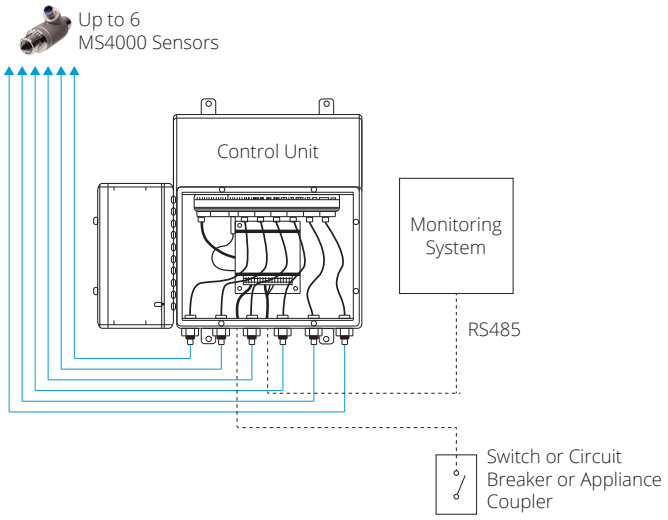
- ASME B31.3B (Process Piping Standard)

**Note 1**

- NEMA 4 - Standard Enclosure
- NEMA 4x - Stainless Steel Enclosure




SINGLE-SENSOR SYSTEM




MULTI-SENSOR SYSTEM



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ON-LINE OIL DEBRIS MONITOR

# MS4000 SENSOR

## Description

The MS4000 Sensors are welded stainless steel assemblies designed to be installed directly into the fluid line with fluid flowing in either direction. The sensors are designed to operate in severe industrial and/or hazardous environments with large temperature extremes and high vibration levels. They are available in three sizes: 3/8", 3/4" and 1-1/4" nominal line diameter. The sensing element consists of three internal coils. The two outside field coils are oppositely wound and are driven by an alternating current source so that their respective magnetic fields are opposed and cancel at the center point between the field coils. The centrally positioned sense coil measures the disturbances in the magnetic fields caused by metallic particles as they pass through the sensor. The magnitude of the disturbance measured as a voltage defines the size of the particle and the phase shift of the signal defines whether the metallic particle is ferromagnetic (Fe) or non-ferromagnetic (NFe).

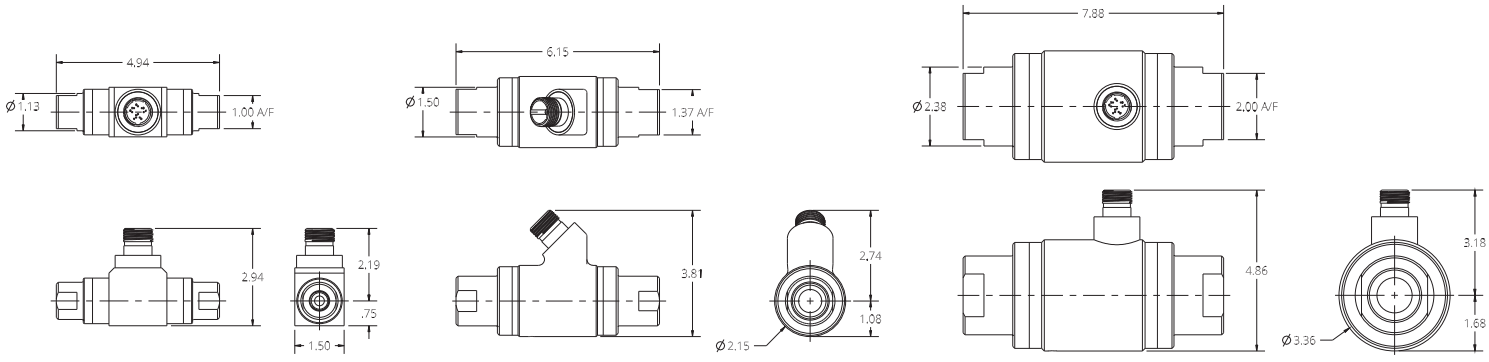
## SPECIFICATIONS

| Sensor Nominal Line Size | 3/8 inch | 3/4 inch | 1-1/4 inch |
|---|---|---|---|
| Bore | 0.30" / 7.6mm | 0.70" / 17.8mm | 1.06" / 26.9mm |
| Plumbing Connection (female) | -6 SAE O-ring Boss | -12 SAE O-ring Boss | -20 SAE O-ring Boss |
| Minimum Ambient Temperature | -40°F / -40°C | -40°F / -40°C | -40°F / -40°C |
| Maximum Ambient Temperature | 375°F / 190°C | 375°F / 190°C | 375°F / 190°C |
| Weight | 1.5lbs / 0.7kg | 2.0lbs / 0.9kg | 5.5lbs / 2.5kg |
| Electrical Connector | MIL-DTL-38999 | MIL-DTL-38999 | MIL-DTL-38999 |

| Minimum Detectable Particle Size | 3/8 inch | 3/4 inch | 1-1/4 inch |
|---|---|---|---|
| Fe (ESD*/sphere) | 65µm / 100µm | 130µm / 200µm | 180µm / 275µm |
| NFe silver (ESD*/sphere) | 200µm / 305µm | 270µm / 415µm | 345µm / 530µm |

| Fluid Conditions | 3/8 inch | 3/4 inch | 1-1/4 inch |
|---|---|---|---|
| Maximum Temperature | 375°F / 190°C | 375°F / 190°C | 375°F / 190°C |
| Maximum Pressure | 500 psi / 3500 kPa | 500 psi / 3500 kPa | 100 psi / 700 kPa |
| Minimum Flow Rate | 0.056 USGPM<br>0.21 L/min | 0.50 USGPM<br>1.9 L/min | 2.1 USGPM<br>8.0 L/min |
| Maximum Flow Rate | 4.3 USGPM<br>16.2 L/min | 48 USGPM<br>180 L/min | 175 USGPM<br>665 L/min |

* The Equivalent Spherical Diameter (ESD) of an irregular-shaped object is the diameter of a sphere of equivalent volume.




3/8 INCH SENSOR | 3/4 INCH SENSOR | 1-1/4 INCH SENSOR



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ON-LINE OIL DEBRIS MONITOR

# MS4000 CONTROL UNIT

## Description

The MS4000 Control Unit houses the modular electronics for MS4000 system and is available as either a multi-sensor unit with capacity for up to 6 sensors or a single-sensor unit designed for only one sensor. In either case, the enclosure is a steel housing designed for back-side mounting on a bulkhead or plate with all interconnecting cables entering through the bottom of the unit. Note that the electronics of the control unit cannot be relocated outside of this enclosure (i.e. in another rack) due to EMI and signal grounding control requirements.

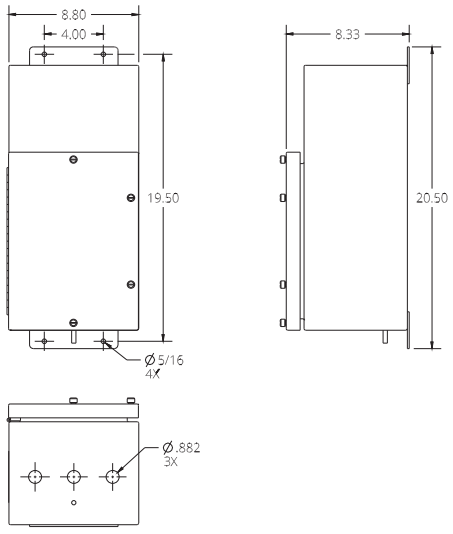
The multi-sensor Control Unit includes separate modules for power input, power supply, control, and sensor interface, each plugged into a backplane chassis. The chassis has a capacity for 6 separate sensor modules. The single sensor Control Unit is similar to the multi-sensor unit except it has the capacity to house only one sensor module.

Communication to the host is via industry standard Modbus RS485 serial communications which supports up to 30 separate Control Units (single or multi) can be linked together to a single host monitoring system communication port.

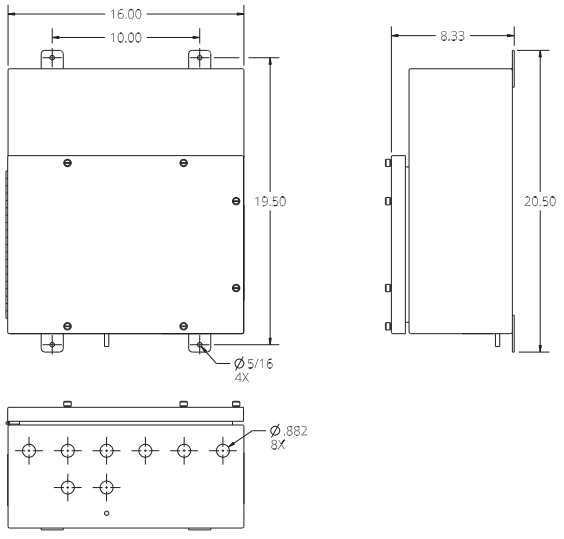



## SPECIFICATIONS

| Control Unit | Single-sensor | Multi-sensor |
|---|---|---|
| Environment | Splash proof - for outdoor and indoor installations (IP66) | Splash proof - for outdoor and indoor installations (IP66) |
| Finish | Painted mild steel (blue) | Painted mild steel (blue) or optional stainless steel |
| Enclosure Size - nominal | 8.80w x 20.5h x 8.33d (in)<br>224w x 521h x 212d (mm) | 16w x 20.5h x 8.33d (in)<br>406w x 521h x 212d (mm) |
| Minimum Ambient Temperature | -40°F / -40°C | -40°F / -40°C |
| Maximum Ambient Temperature | 131°F / 55°C | 131°F / 55°C |
| Maximum Weight | 25.5lbs / 11.6kg | 36.0lbs / 16.3kg (6 sensors) |




SINGLE-SENSOR CONTROL UNIT




MULTI-SENSOR CONTROL UNIT



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# MS4000 SENSOR CABLE

## Description

The MS4000 Sensor is electrically connected to the Control Unit using the Sensor Cables provided as part of the MetalSCAN system. The inductive coils of the sensor assembly are designed to achieve maximum sensitivity to particles present in the flow. The cabling and connectors play a significant part in achieving the level of sensitivity necessary for the system to operate properly. The cables are factory assembled and available in 12 and 20 foot lengths. The result is an extremely robust cable connection system that provides assurance of the required detection performance and sensitivity.

A double shield is provided on each of the four coaxial cables within the cable assembly. Each coaxial cable is terminated at the Control Unit end via a BNC connector while at the sensor end the cables are brought together into a single aerospace grade MIL-DTL-38999 Series III connector. The coaxial cables are further shielded by a tinned copper braid covering and then mechanically contained by a high temperature silicone impregnated fibreglass sleeve.

## SPECIFICATIONS

| **Sensor Cable Length** | **12ft / 3.7m** | **20ft / 6.1m** |
|---|---|---|
| **Connector (sensor end)** | MIL-DTL-38999 Series III | MIL-DTL-38999 Series III |
| **Connectors (Control Unit End)** | 4x BNC | 4x BNC |
| **Minimum Ambient Temperature** | -40°F / -40°C | -40°F / -40°C |
| **Maximum Ambient Temperature** | 375°F / 190°C | 375°F / 190°C |
| **Weight** | 3lbs / 1.4kg | 4lbs / 1.8kg |

# MS4000 SENSOR BRACKETS

## Description

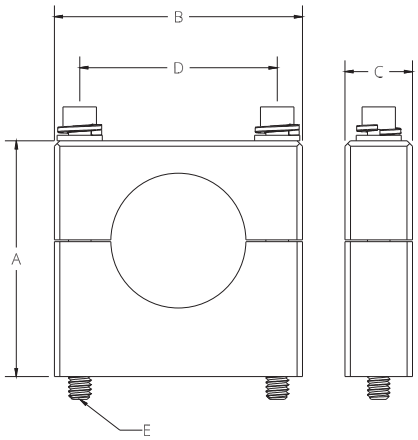
The sensors can be installed in any orientation with fluid flowing in either direction. The recommended location for the sensors is directly downstream of the wear elements in the lubrication system. There must be no debris traps or filters between the sensor and the oil wetted components being monitored.

The sensors can be supported by brackets attached to the ends of the body as shown below, or by the fluid line, provided that the fluid line is well supported. The sensor body is not designed to support mechanical loads.

Sensor bracket material: Anodized aluminum (clamps) and stainless steel (bolts and washers).

## SPECIFICATIONS

| **Sensor Bracket Dimensions** | **A** | | **B** | | **C** | | **D** | | **E** |
|---|---|---|---|---|---|---|---|---|---|
| | in | mm | in | mm | in | mm | in | mm | Bolt (Hex Socket) |
| **3/8 Inch Sensor** | 1.88 | 48 | 2.25 | 57 | 0.63 | 16 | 1.75 | 44 | 1/4-20UNC x 3 in |
| **3/4 Inch Sensor** | 2.60 | 66 | 2.75 | 70 | 0.75 | 19 | 2.19 | 56 | 1/4-20UNC x 3 in |
| **1-1/4 Inch Sensor** | 3.75 | 95 | 4.00 | 102 | 1.00 | 25 | 3.00 | 76 | 3/8-16UNC x 4.5 in |



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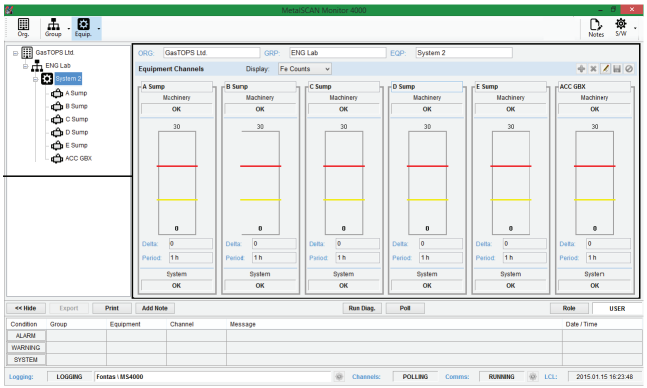
ON-LINE OIL DEBRIS MONITOR

# MS4000 MONITOR SOFTWARE

## Description

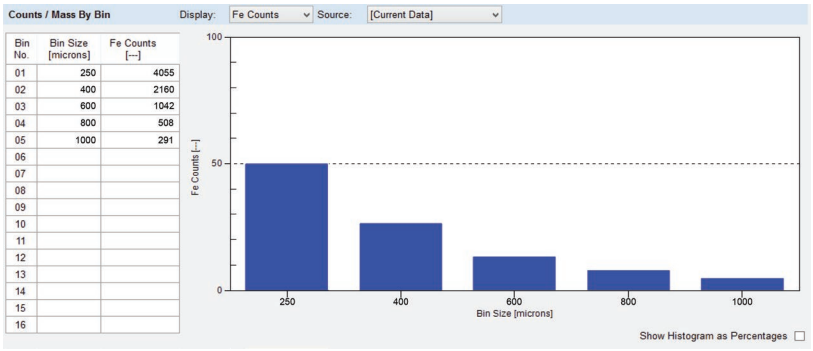
The MS4000 Monitor is a PC software application that runs under Microsoft Windows designed to interface with one or more MS4000 systems and provide the user interface for tracking the health of the machine(s) being monitored. The software provides the capability to continuously record and display MetalSCAN data, to annunciate warnings and alarms when debris accumulation exceeds user-defined limits, and to interface to external data acquisition or monitoring systems.


The MS4000 Monitor includes several display pages, which can be selected using the dedicated pushbutton controls located on the application toolbar. The three primary pages are the Status, Counts, and Trends pages.

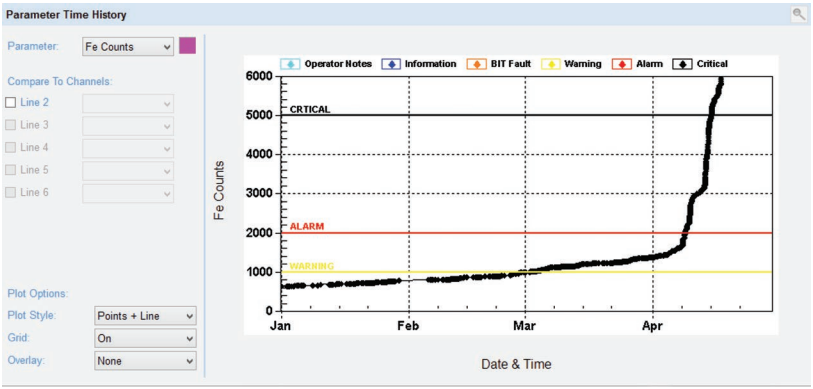


The Equipment Status page displays a summary of the debris accumulation measurements and operational health of the channel for the selected Equipment. The purpose of the Equipment Status Page is to enable the operator to quickly assess the condition of the monitored equipment. The display features bar charts that compare the accumulated debris (Fe counts, Fe mass or NFE counts) against set limits.

The Equipment Status page also provides the capability to visibly annunciate alarm, warning and system conditions. Whenever MS4000 Monitor detects a new alarm or warning condition, it automatically changes the display page to annunciate the system or equipment health condition by displaying a colored contour around the affected channel.




The Counts page provides high resolution current information of the accumulated debris including ferromagnetic (Fe) and non-ferromagnetic (NFe) count totals, categorized by size and by type, either Fe or NFe. It also provides a graphical display of size distribution by counts or mass, for any selected sensor.




The Trends page displays the time history of debris accumulation data along with the user-defined warning or alarm limits for the selected parameter, allowing the user to assess the current severity of the equipment condition, to review the time history, and to estimate the remaining operating life of the equipment.



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# MS4000 SYSTEM

## Ordering Information

### One Sensor MS4000 System (Single)

**Order: System - 01S**

Including: 24 VDC single sensor control unit, 1 x 3/4" sensor, 1 x 20 ft. sensor cable, USB/RS485 converter, MS4000 Monitor Software, user's manual, 12 month warranty.

### One Sensor MS4000 System (Multi)

**Order: System - 01M**

Including: 24 VDC multi-sensor control unit, 1 x 3/4" sensor, 1 x 20 ft. sensor cable, USB/RS485 converter, MS4000 Monitor Software, user's manual,12 month warranty.

### Two Sensor MS4000 System

**Order: System - 02M**

Including: 24 VDC multi-sensor control unit, 2 x 3/4" sensors, 2 x 20 ft. sensor cables, USB/RS485 converter, MS4000 Monitor Software, user's manual, 12 month warranty.

### Three Sensor MS4000 System

**Order: System - 03M**

Including: 24 VDC multi-sensor control unit, 3 x 3/4" sensors, 3 x 20 ft. sensor cables, USB/RS485 converter, MS4000 Monitor Software, user's manual, 12 month warranty.

### Four Sensor MS4000 System

**Order: System - 04M**

Including: 24 VDC multi-sensor control unit, 4 x 3/4" sensors, 4 x 20 ft. sensor cables, USB/RS485 converter, MS4000 Monitor Software, user's manual, 12 month warranty.

### Five Sensor MS4000 System

**Order: System - 05M**

Including: 24 VDC multi-sensor control unit, 5 x 3/4" sensors, 5 x 20 ft. sensor cables, USB/RS485 converter, MS4000 Monitor Software, user's manual, 12 month warranty.

### Six Sensor MS4000 System

**Order: System - 06M**

Including: 24 VDC multi-sensor control unit, 6 x 3/4" sensors, 6 x 20 ft. sensor cables, USB/RS485 converter, MS4000 Monitor Software, user's manual, 12 month warranty.


## OPTIONS

### MS4000 Sensor - 3/8”

**Order: Option - 13**

Substitute 3/8" Sensor (per sensor), 12 month warranty.

### MS4000 Cable - 12ft

**Order: Option - 06**

Substitute 12 ft. Sensor Cable (per cable), 12 month warranty.

### MS4000 Sensor - 1-1/4”

**Order: Option - 05**

Substitute 1-1/4" Sensor (per sensor), 12 month warranty.

### MS4000 Stainless Steel Enclosure

**Order: Option - 07**

Substitute 1-1/4" Sensor (per sensor), 12 month warranty.

### MS4000 ATEX Barrier Kit

**Order: Option - 17x**

MetalSCAN Barrier Kit for RS485 communication intrinsic safety isolation required for ATEX certification, including: barrier unit, serial null modem cable, ATEX system label, 12 month warranty.

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# APPENDIX 2b: BROCHURE FOR

# Poseidon Trident DM4500

POSEIDON SYSTEMS

# TRIDENT ™ DM4500

## Wear Debris Monitor

*Real-time monitoring leads to improved asset health management*


## PRODUCT OVERVIEW

Poseidon Systems' Trident™ DM4500 Wear Debris Monitor is a real-time, in-line fluid sensing technology for the detection of metallic wear debris and particulates in a lubrication system. By continuously monitoring wear debris generation, the device alerts users to faults in their earliest stages, allowing for lower cost correction actions than conventional schedule based maintenance.

The DM4500 Wear Debris Monitor will detect, categorize (ferrous vs. non-ferrous), and size metals within a machinery lubrication system. The monitor will detect and measure particles with an estimated spherical diameter of 40 micron ferrous and 150 micron non-ferrous and larger. A wide range of output formats are available including particle type/size, approximate mass, and particle counts in user configurable bins.

DM4500 is a standalone sensor with customizable hose fittings. Ordering with BSPP fittings provides a direct replacement for existing TA10s,. JIC, SAE Boss, and Compression fittings are available as off the shelf options. The DM4500 is also backward compatible with the popular TechAlert™ 10 (TA10) Debris Monitor.

## BENEFITS

- Optimize machinery oil sample timing & maintenance intervals
- Improve asset health state awareness
- Advanced warning enables improved asset maintenance & logistics planning
- Reduce cost of unscheduled downtime

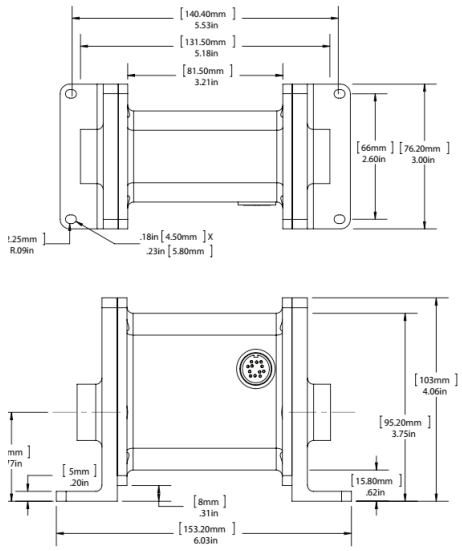
## KEY FEATURES

- 40 micron ferrous & 150 micron non-ferrous debris detection ability
- Industry standard communication interface
- Mounting footprint matched to TA10 for drop-in replacement
- Particle size/mass estimates
- Volumetric flow rate estimates
- Total particle count estimation

POSEIDON SYSTEMS

## TECHNICAL SPECIFICATIONS

| | |
|---|---|
| **Detection Sensitivity (Debris)** | 40 µm Ferrous & 150 µm Non-Ferrous Metallic Particles |
| **Communications** | RS485/RS232 Modbus RTU, Pulse Output |
| **Oil Connection** | 3/4" -16 SAE Female, -8 JIC Male, -8 BSPP Male, or 1/2" Compression |
| **Ambient Temperature** | -40 to 185˚F (-40 to 85˚C) |
| **Fluid Temperature** | -40 to 185˚F (-40 to 85˚C) |
| **Volumetric Flow Rate** | 0.25 o 10 GPM (0.95 to 38 LPM) |
| **Sensor Bore Diameter** | 0.472 inches (12 mm) |
| **Ingress Protection** | IP65 |
| **Power Supply** | 10-30 VDC, 300 mA |
| **Weight** | 1.5 pounds (0.68 kg) |




**Poseidon Systems, LLC**
200 Canal View Blvd.
Rochester, NY 14623

**Phone:**
(585) 239-6025

**Website:**
www.PoseidonSys.com

**Email:**
info@poseidonsys.com

# APPENDIX 3: OIM Manual for

# Sensonics DN2611 Dual Channel Vibration Monitor

**SENSONICS LTD**
Northbridge Road
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Herts
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United Kingdom

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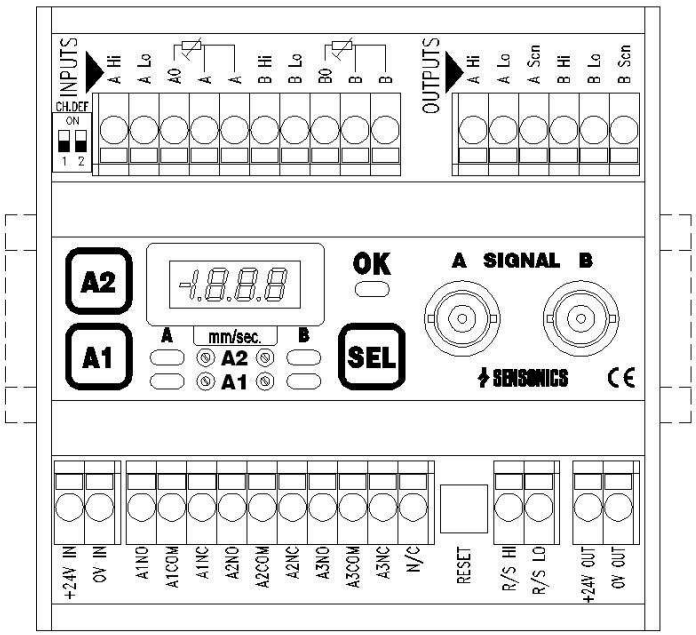
**Fax:** +44 (0) 1442 876 477
**E-mail:** sales@sensonics.co.uk
**Web site:** www.sensonics.co.uk

# DN2611 Dual Channel Vibration Monitor

## Operation, Installation, Maintenance and Safety Handbook

**Ref. HB1306-2**



## *1.1 History sheet*

| ISSUE/ DATE | COMMENT | APPROVED OWNER | ACCEPTED QA |
|---|---|---|---|
| 1 | First Issue | A. PITT | R.KING |
| 2 | Functional Safety added | A. PITT | R.KING |
| 3 | SIL Level updated | A. PITT | R.KING |
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# Contents

# Introduction

The DN2611 is a din rail mounted dual channel vibration module. It is designed to accept inputs from two wire 100mV/g accelerometers as standard but can be configured to accept both active and passive velocity transducers as well as 3-wire configurations (separate positive supply for the transducer).

The unit has been specifically designed to provide critical machine shutdown protection in the event of excessive vibration. The compact size and mounting format permits the DN2611 to be mounted locally to the machine in an existing panel.

The unit is powered by 22-28Vdc @ 150mA max and several units can be 'daisy chained' together to be fed from the same power source. It is recommended that a dedicated power supply is used that has a good grounded 0V.

The vibration measurement mode may be acceleration or velocity for accelerometer inputs (factory set) and velocity or displacement for a velocity transducer inputs (again factory set). It is possible to configure each channel independently to either of the vibration measurement modes. A transducer can also be connected to both inputs to permit dual path configurations to allow simultaneous acceleration and velocity measurements.

Both acceleration and velocity vibration can be displayed in either imperial or metric units (g, mm/s or in/s (factory set)); all units are rms values. Displacement is configured as pk to pk as standard in either um or mil.

The unit offers three alarm relay contacts for shutdown or alarming purposes. A1 and A2 represent the channel warning and danger alarms respectively (note they are shared between the two channels). The A3 alarm is utilised for transducer integrity and will alarm in the circuit if the transducer is faulty. A front panel indicator also provides the status of the A1 (red indicator) and A2 (yellow indicator) alarms. The alarm delay is set to 1 second as standard but can be factory set according to customer requirements.

The unit contains a three & a half-digit LCD display on which the current running value of vibration is displayed or the alarm set points may be displayed when setting the alarm values. A select button is available to switch the display between the two channels.

One analogue output per channel proportional to vibration level is available for integration to local systems such as a DCS. These are nominally configured as 4-20mA but other currents/voltages may be used, see appendix at rear for specific outputs for this module.

A buffered raw transducer signal is available from both channels at the BNC sockets for analysis purposes.

Scaling levels are selectable 'on site' from a standard list, by the positioning of on board switches. Likewise high and low pass filters may be selected 'on site'.

# Installation

*Mounting*

The monitor is designed to be mounted on a DIN rail (this may be of the 'G' type or the 35mm 'Top Hat' type). The monitor is **not** "weather proof" and as such should be protected against damp conditions with a suitable enclosure. The monitor should also be protected against temperatures outside of the operating range 0 to 50°C (the monitor will dissipate a maximum of 4 watts during operation).

The monitor may be mounted either vertically or horizontally.

*Connection/Cabling*

It is recommended that the cable to the transducer is a screened cable and that one end only is connected to earth (preferably connected to the 'SCN' input on the monitor).

The power-input cable can be any suitably rated cable but it is recommended that the 0V side of the supply is earthed (suitably near to the monitor). The monitor has an internal automatically re-settable fuse but the supply should also have some suitable over current protection.

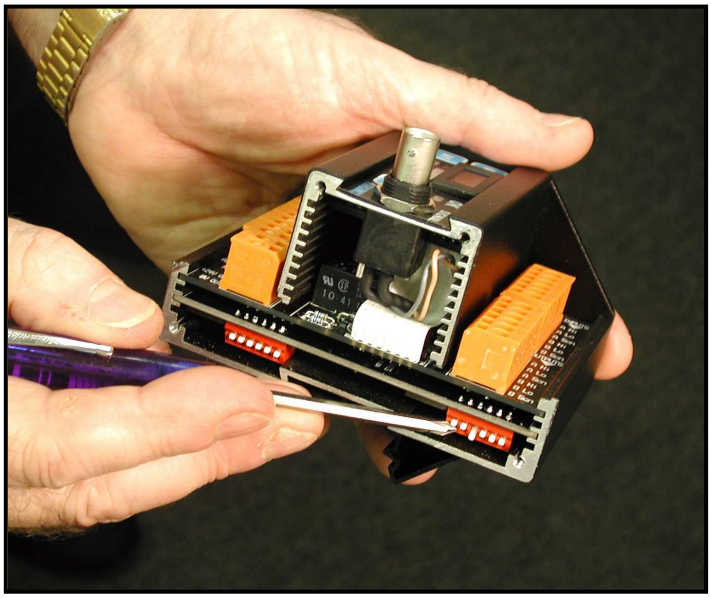
The output signal cable should also be screened and one end connected to earth (preferably connected to the 'SCN' output on the monitor).

It is recommended that if armoured conduit is used to protect the cabling that one end of the metal armouring is isolated to prevent 'earth loops'.

## Operational settings

The setting options detailed below are the standard options available with the DN2611. It is possible the settings in the unit supplied may be different due to specific customer requirements. These setting parameters will be detailed on the IS. Sheet provided with the unit and this handbook.

To gain access to the configuration switches remove the four screws securing the side of the unit (adjacent to BNC connector) as shown below. This will reveal the four sets of switches to be used to set the range and filter settings.



*Scaling*

The output scaling can be set to the following default ranges, each channel may be set to a different range by configuring the switches accordingly. Note the unit is factory set to the required units of measurement and available scale ranges, either g or mm/s or inch/s:

| **Scale in g** | **sw1 & 3** | **Scale in mm/s** | **sw1 & 3** |
|---|---|---|---|
| 0 to 10g | 6 | 0 to 20mm/s | 6 |
| 0 to 12.5g | 5 | 0 to 25mm/s | 5 |
| 0 to 15g | 4 | 0 to 30 mm/s | 4 |
| 0 to 20g | 3 | 0 to 50 mm/s | 3 |
| 0 to 25g | 2 | 0 to 75 mm/s | 2 |
| 0 to 50g | 1 | 0 to 100 mm/s | 1 |

| **Scale in inch/S…** | **sw1 & 3** |
|---|---|
| 0 to 1 inch/s | 6 |
| 0 to 1.5 inch/s | 4 |
| 0 to 2 inch/s | 3 |

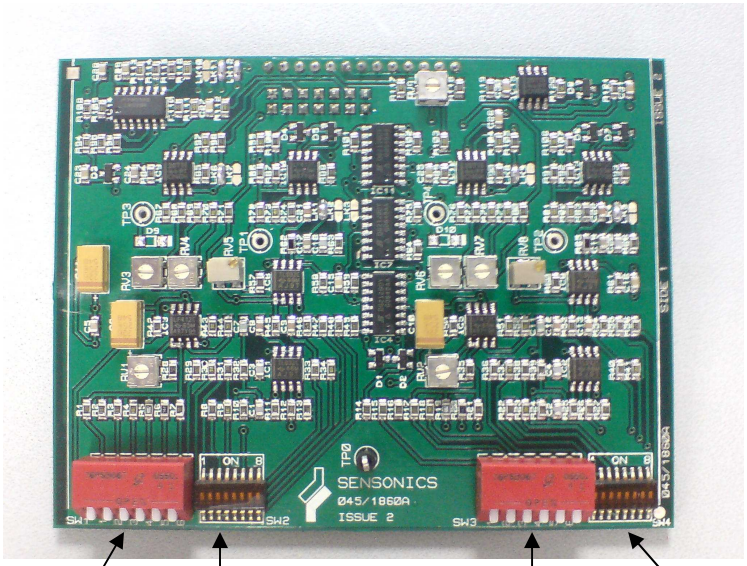
*Filters*

Switches 2 & 4 permit different filter characteristics to be set for each of the channels. The following values can be selected as standard: -

| **Low pass freq.'** | **sw2 & 4** |
|---|---|
| 1 kHz | 1, 2, 3 & 4 off (Factory default) |
| 2 kHz | 1 & 3 on |
| 10 kHz | 1, 2, 3 & 4 on |

| **High pass freq.'** | **sw2 & 4** |
|---|---|
| 2.5 Hz | 5, 6, 7 & 8 off |
| 5 Hz | 5 & 8 on |
| 10 Hz | 5, 6, 7 & 8 on (Factory default) |

The four switch sets are identified as detailed below.




SW1 Channel A Scaling

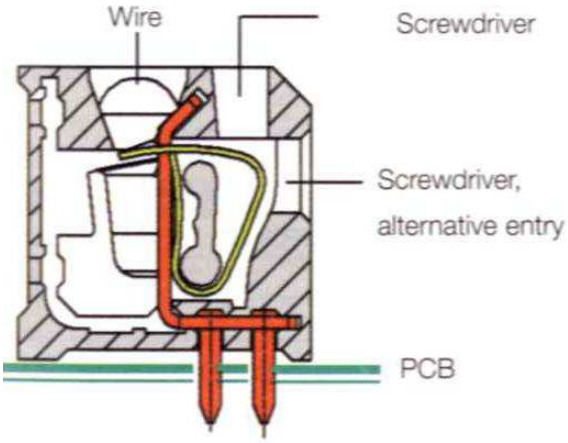
SW2 Channel A Filter Settings

SW3 Channel B Scaling

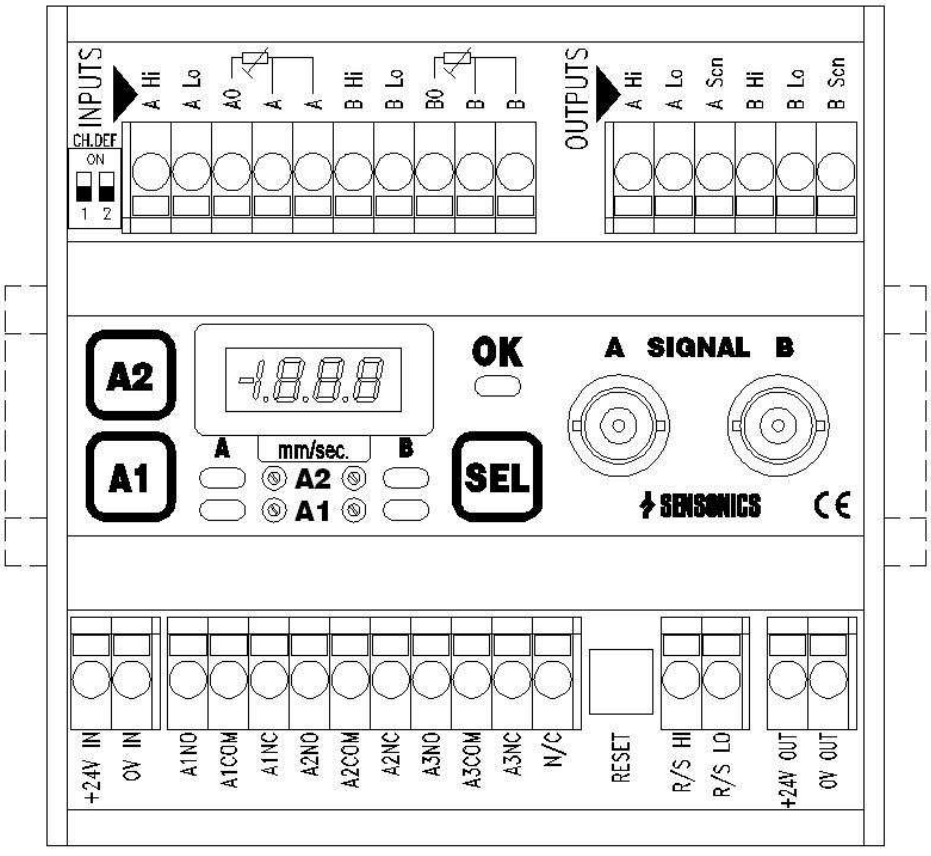
SW4 Channel B Filter Settings

## Connection Details

The module offers connections via standard 0.2” pitch terminal rail with a tension clamp connect facility operated via insertion of a terminal flat blade screwdriver in to the appropriate terminal. See below for connector operation. Note it is only possible to operate the terminal via the top access point. We recommend only appropriately crimped terminals are fixed to the rail.




The connections are arranged above and below the main display facia as illustrated below.



*INPUTS (2 wire ICP type devices)*

A Hi = Connect Channel A Accelerometer High (+ve).
A Lo = Connect Channel A Accelerometer Low (0v).
A0 = Connect Channel A Accelerometer Cable Screen.
A = Ignore for vibration (utilised for temperature option)

B Hi = Connect Channel B Accelerometer High (+ve) .
B Lo = Connect Channel B Accelerometer Low (0v).
B0 = Connect Channel B Accelerometer Cable Screen.
A = Ignore for vibration (utilised for temperature option)

*INPUTS (3/4 wire devices or 2-wire passive)*

Please see associated IS. Sheet for the wiring of alternatives to ICP

*OUTPUTS*

A Hi = Channel A Analogue Output (4-20mA) High (+ve).
A Lo = Channel A Analogue Output (4-20mA) Low (0v).
A Scn = Channel A Analogue Output (4-20mA) Cable Screen.
B Hi = Channel B Analogue Output (4-20mA) High (+ve).
B Lo = Channel B Analogue Output (4-20mA) (0v).
B Scn = Channel B Analogue Output (4-20mA) Cable Screen.

*LOWER RAIL*

+24V IN = Power Input Connection +24V d.c.
0V IN = Power Input Connection 0V.
A1NO = Alarm 1 (RED) Relay Connection for Normally Open.
A1COM = Alarm 1 (RED) Common Relay Connection.
A1NC = Alarm 1 (RED) Relay Connection for Normally Closed.
A2NO = Alarm 2 (YELLOW) Relay Connection for Normally Open.
A2COM = Alarm 2 (YELLOW) Common Relay Connection.
A2NC = Alarm 2 (YELLOW) Relay Connection for Normally Closed.
A3NO = Alarm 3 (Trans/PSU Integrity) Relay Connection for Normally Open.
A3COM = Alarm 3 (Trans/PSU Integrity) Common Relay Connection.
A3NC = Alarm 3 (Trans/PSU Integrity) Relay Connection for Normally Closed.
R/S Hi = External reset input from voltage free contacts
R/S Lo = External reset input from voltage free contacts
+24V OUT = Power Output Daisy Chain Connection +24V d.c. to Next DN2601 Monitor.
0V OUT = Power Output Daisy Chain Connection 0V to Next DN2601 Monitor.

## Module Operation

With operational switch settings selected and +24V power applied, the module will power up and display either a channel A or channel B reading (dependant on last state prior to power down). By pressing the select button the display will switch between channel A and channel B vibration values. The channel selected is indicated by the backlight behind either A of B located below the display. With no transducer connected the display should read virtually zero (0.00) on the selected channel. The OK light will be red indicating a transducer integrity fault.

With the transducer connected a low reading will now be obtained in the presence of no detected vibration i.e. <0.1mm/s. The OK light will only return to green once valid transducer inputs are present on both channels unless defeated (see below).

If single channel operation is required the channel defeat switch adjacent to the accelerometer input terminals can be utilised. Switching 1 for channel A or 2 for channel B will defeat the alarm functions (A1, A2 and A3 relays and associated lamps) effectively disabling the channel.

The alarm window for both A1 and A2 can be adjusted within the set range of the channel. With the appropriate channel selected, press and hold either A1 or A2 and adjust the appropriate potentiometer accessible through the front panel to the required alarm level.

Note the module has an optional reset facility (factory configured). If enabled, A1 and A2 relay functions are latching (de-energised to alarm) – operating the reset facility clears the latched status. If the reset facility is disabled, all relays and alarm indications are fleeting / non-latching only (de-energised to alarm). The A3 transducer integrity relay is fixed as non-latching and de-energised to alarm.

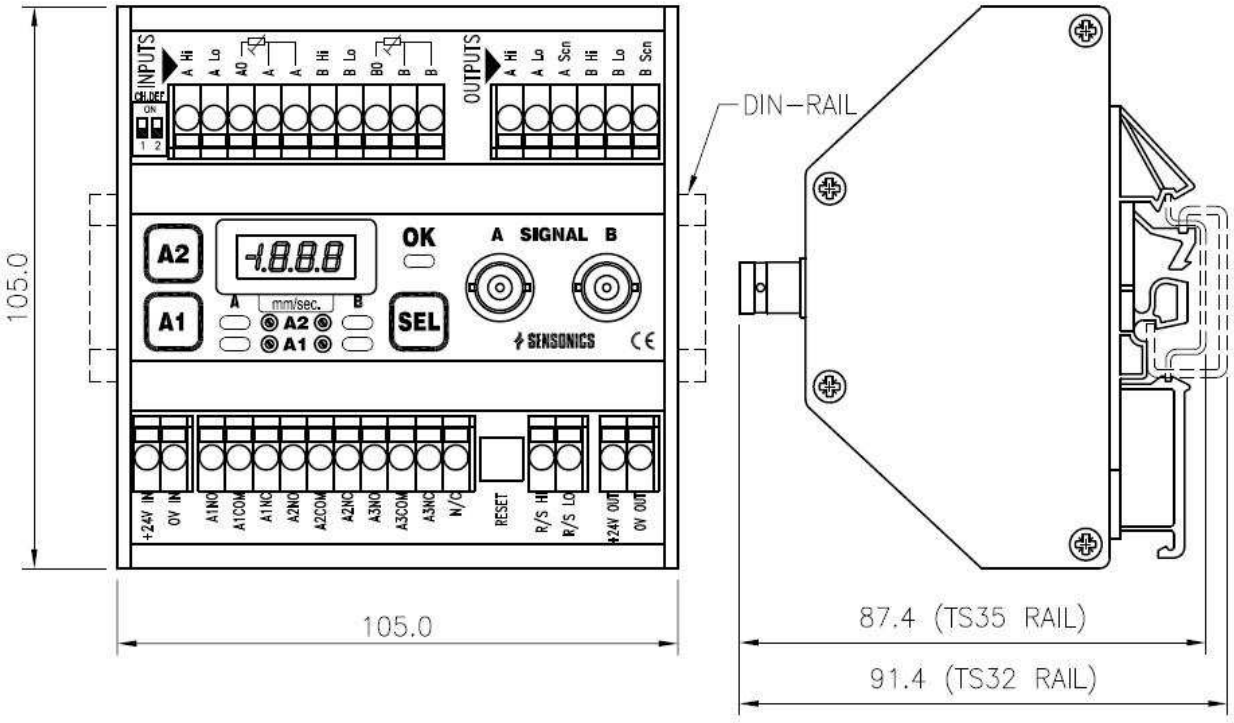
The transducer signal is available at the front panel BNC buffered outputs with unity gain and a DC frequency response. This facility enables the user to carry out a more detailed analysis of the vibration signal using a portable device.

## Module Specification

| | | |
|---|---|---|
| Power Supply Voltage Range | : | 18V – 36V dc |
| Power Consumption | : | 3.6W typ 5W max |
| Re-settable Fuse rating | : | 250mA |
| Signal | : | Two ICP type inputs +18V typ<br>2.4mA current source |
| Sensitivity | : | 100mV/g or 4mV/mm/s<br>Other sensitivities can be factory set |
| Measurement range | : | Various selectable up to 50g / 100mm/s<br>Higher ranges can be factory set. |

| | | |
|---|---|---|
| Measurement accuracy | : | ± 0.5%, 1g @ 80Hz |
| Filters | : | 12dB / octave LPF and HPF<br>2.5Hz to 10kHz max bandwidth (-3dB) |
| Transducer Integrity | :<br>: | ICP alarm window <8V & > 16V<br>Passive sensor integrity based on SC/OC detection |
| Current Outputs | : | 4-20mA nominal load 220Ohm<br>± 0.5%, ±0.08mA accuracy<br>± 1.0%, ±0.16mA linearity |
| BNC Outputs | : | Buffered transducer inputs typically ±1% accuracy |
| Relay Rating | : | 0.5A @ 125Vac |
| Operating Temperature Range | : | 0ºC to 50ºC |
| Din Rail Mount | : | TS32 or TS35 |
| Mass | : | 0.45 kg |

Mechanical Outline – see below.



# Functional Safety

This section of the manual describes the user responsibilities for installation and operation of the DN2611 monitor in a Safety Instrumented Function. In order to ensure the safe usage of this product, all procedures in this section must be followed in conjunction with the general instructions provided in the rest of this manual.

### *Safety Related parameters*

The following variables and interfaces can be used as part of the Safety instrumented Function.

Variables: Vibration

Interfaces: Alarm Relay Contacts.

Safety Response Time: 1000ms maximum

Measurement Updates: 100ms.

Failure of the system is indicated through A3 relay which is set as normally energised. Note: Alarm relays A1 and A2 should be configured as de-energised to alarm to ensure a fail safe condition.

### *Reliability Data*

The data is valid with the following requirements:

The system operates in a low demand mode (The frequency of demands for operation made on the system is no greater than one per year and no greater than twice the proof test frequency). The connected system must detect both the integrity A3 relay in conjunction with the configured alarm relay (A1, A2)

Failure Data According to IEC 61508

| | |
|---|---|
| DN2611 | Single measurement channel |
| Total Failure Rate | 1.813 per million hours |
| λdd – Dangerous Detected Failures | 0.157 per million hours |
| λdu – Dangerous Undetected Failures | 0.583 per million hours |
| λs – Safe Failure State | 1.073 per million hours |

The PFD value for a single channel is 2.6e-3 (Proof test interval is 1 year).

The DN2611 module continuously monitors the attached sensor for a detected fault.

For environmental and operational limits refer to the Module Specification.

***Electromagnetic Compatibility***

The DN2611 conforms to the following EMC requirements.

EMC directive 2004/108/EC as per EN61326

***Certification Data***

The DN2611 monitor is classified as a Type A system according to IEC 61508 with a hardware fault tolerance of 0.

Based on internal diagnostics the monitor has a Safe failure Fraction of 68% and therefore may be used up to SIL 2 as a single simplex channel based on the latest MTBF field failure data. Higher certification is possible when configured as a duplex system, please refer to Sensonics for further details.

The DN2611 monitor has a proof test interval of 1 year in order to maintain a SIL-2 rating. It is the responsibility of the user organisation to ensure that personnel involved in the use and maintenance of the product are properly training and qualified to carry out the required activities.

***Installation and Configuration***

Refer to the relevant sections of this handbook for configuration to the required application.

The DN2611 should be located in a secure panel to prevent tampering of the user settings specific to the SIL application.

***Start Up***

Following initial configuration of the module to the required measurement mode and alarm settings, on cycling the power the module shall automatically perform the measurements without any further user interaction.

Should a static alarm exist due to the dynamic nature of the sensor performance under start up, the alarm can be reset through either the front panel push button or the remote reset facility (closed contact) on the terminal rail.

The diagnostic monitoring and associated relay shall clear within the module start up period which shall exceed the bias stabilisation time of the connected sensors.

***Module Overide***

The following functions can be utilised to over ride the module safety function

Reset (permanent closed contact)

Manual shutdown of the system, manual activation of the safe state or manual de-activation of safety function are not within the scope of this specification and specific to the customer interfaces to the equipment.

***Periodic Testing Requirements***

The required proof test interval for the DN2611 Monitor is 12 months. This test shall encompass:-

- Signal injection to simulate the transducer output to confirm accuracy and operation of the alarm relays. Removing the sensor shall also confirm operation of the module integrity relay.

- It is also recommended, but not essential, to calibrate the module on an annual cycle to check and adjust if necessary the measurement accuracy.

***Periodic Inspection***

Other than the proof test, no other periodic inspection is required.

***Periodic Parts Replacement***

No periodic parts replacement is required.

***Other Preventative Maintenance***

No other preventative maintenance is required.

***Required Maintenance Documentation***

A record of each channel configuration should be maintained.

A maintenance log shall be kept. Each log entry shall include:

- The cause for the maintenance activity (scheduled maintenance such as proof test, calibration check, etc) and its date and the maintenance action taken.
- The personnel performing the maintenance.
- The date(s) on which the maintenance was initiated and concluded.

In addition, any faults occurring with the monitor should be recorded in the maintenance log and also reported to Sensonics (+44 1442 876833).

In order to verify the mode of operation (low demand or high demand), each demand on the Safety System involving the DN2611 equipment should be recorded in the maintenance log and reported to Sensonics (+44 1442 876833).

***Fault Handling and Detection***

The DN2611 monitor offers the following diagnostics for the anticipated sensor interfaces as listed below.

- Accelerometer, window monitoring of bias voltage.

Window monitoring detects both short circuit and open circuit faults on signal cables as well as failure of operation of the device. A fault detected in any of the above shall result in the module integrity relay (A3) being de-energised and the front panel OK LED changing from green to red.

***Repair and Replacement***

Parts replacement for the DN2611 monitor is limited to the electronic assemblies and housing. A proof test must be performed following any repair. However, it is recommended on all failure conditions the monitor is returned to Sensonics for repair and adequate stock of complete module spares are maintained by the end user to affect the 24hour mean time to repair period.

***Shutdown***

No special procedures are required when removing power to the Monitor. No change to the module configuration shall occur. Note:- Alarm relays will de-energise and therefore the system safety function may be activated.

***Tools Necessary for Maintenance***

- Means to provide a measured and injected signal to stimulate the channel and verify the channel measurement accuracy and alarm trip points (Sensonics can provide suitable sensor simulators). The measurement accuracy of the injected signal should be at least ten times better than the measurement accuracy of the module.
- Means to verify the alarm relay changeover of contacts when an alarm condition occurs.

## Breakdown Maintenance

The equipment is factory set and designed for reliable operation without maintenance. Should a failure occur, then it is recommended that the equipment be returned to Sensonics for examination and repair.

On-site repair or re-adjustment of internal settings should only be carried out, if considered essential, by a qualified electronic engineer after careful study of the circuit diagrams and other relevant data provided in the handbook.

Sensonics offers an out of warranty repair and or re-calibration services please contact the sales department for more details (see the front page for telephone/web site numbers).

## Warranty Policy

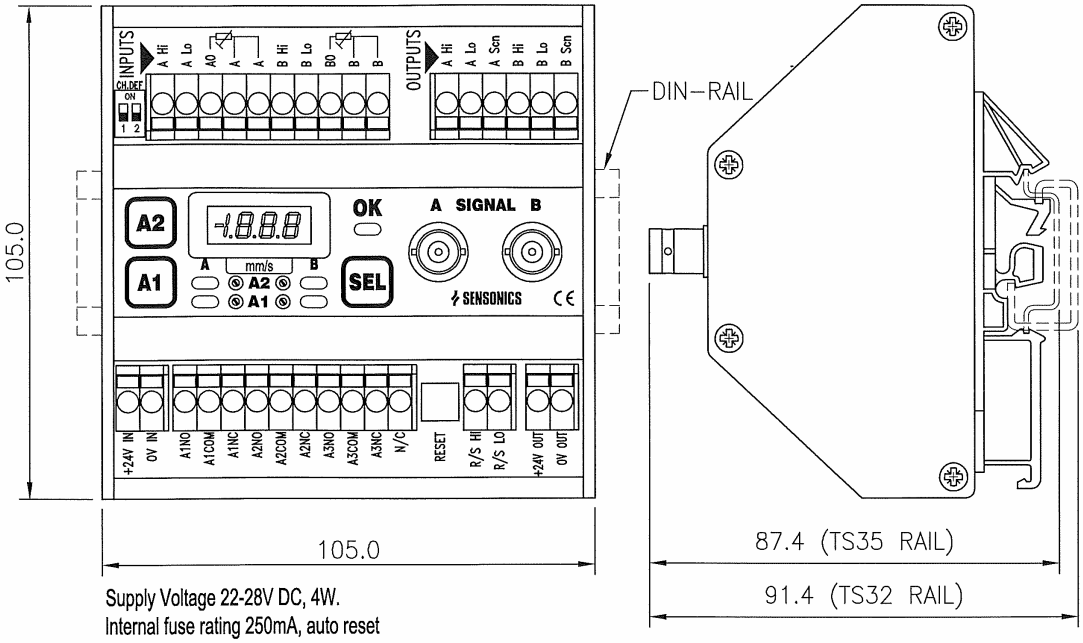
All Sensonics products are warranted against defects in materials and workmanship. The warranty applies to transducers and analogue signal conditioning for a period of one year. Certain components, listed in the applicable instruction manuals with other warranty periods specified, are accepted. All warranty periods apply from the date of delivery. Sensonics will repair or replace products that prove to be defective during the warranty period, providing the failure or misuse or abnormal operating conditions have not caused damage. Fuses and lamps are specifically excluded from warranty. If the malfunction or a portion thereof is determined by Sensonics to have been caused by misuse or abnormal conditions of operation, an estimate of cost to repair will be submitted to the purchaser for approval before beginning any repair work. This warranty is also invalidated if an unauthorised person carries out re-adjustment or attempted repair.

Liability under the warranty is limited to servicing and adjusting the equipment returned to the factory, with transportation charges prepaid by the purchaser. No other warranty is expressed or implied and no liability for consequential damage is accepted.

# Specification Sheet Specific to Contract Attached

**IS3456/X**

F.U.W. | BS.308 THIRD ANGLE




Supply Voltage 22-28V DC, 4W.
Internal fuse rating 250mA, auto reset

Input sensitivity: 100mV/g. Via P&F VR4 Galvanic Isolator.
TXD excitation 18V (±5%), 2.4mA (±20%)

Outputs: 4-20mA. Scaling internally selectable by switches (see handbook).
Output accuracy: 0.5% (±0.08mA).
Factory set to: CH A 4-20mA = 0-100mm/s , CH B 4-20mA = 0-100mm/s.
BNC connectors: buffered transducer signals.

Display accuracy: ±1%, or 1 digit, whichever is greater.
Amplitude linearity: ±1%.

Filters: Internally selectable by switches for each channel.
High pass: 2.5, 5, 10Hz. (+0, -10%)
Low pass 1, 2, 10kHz. (+10, -0%) Roll off: 12dB/octave.
Factory set to: CH A 2.5Hz-1kHz, CH B 2.5Hz-1kHz.

Alarms: A1 and A2 level alarms. Level adjustable per channel
Common relays for both channels, latching, 5 Sec. delay.
A3 common transducer integrity relay. Integrity window: 8-16 Volts.
Switching current 1mA-0.5A. Switching Voltage: 125V AC max.
Local & remote reset

Operating temperature: 0-50°C.

Mounting: 35 mm DIN rail or G type.

**SIL CERTIFIED PRODUCT**
THIS PRODUCT IS ONLY SIL CERTIFIED IF ALL OF THE ASSOCIATED SIL DOCUMENTATION FOR THE SPECIFIC ORDER HAS BEEN COMPLETED

FOR ASSEMBLY SEE EA3420C/17
FOR PARTS LIST SEE 046/5668A/17
FOR TEST SPEC. SEE TS.1205

| ISSUE | DATE | CN. No. | MOD'BY | CHECKED |
|---|---|---|---|---|
| 2 | 20/2/13 | CN.3946 | A.PITT | D.SIPOS |

CHANGE NOTES

| | |
|---|---|
| PROJ.ENG. D.SIPOS | SCALE 1:2 |
| DRAWN D.WELBOURN | DIM'NS mm |
| CHECKED D.SIPOS | DATE 19.10.2011 |
| CUST.REF. 11782 | SHEET No. SHT 1 OF 1 |

SENSONICS LTD NORTHBRIDGE ROAD, BERKHAMSTED, HERTS, HP4 1EF, ENGLAND
Tel : +44 (0)1442 876833 Fax : +44 (0)1442 876477

TITLE: DN2611 DUAL CHANNEL VIBRATION MONITOR WITH RESET DIN RAIL MOUNTING (SIL RATED)

THIS DOCUMENT IS SUBJECT TO THE CONDITIONS IN THE ENCLOSED MEMO DS 742

DRAWING No. IS.3456/13 | ISSUE 2

APPLICATION SOFTWARE USED : AUTOCAD 2004

# SENSONICS LTD

## Certificate No: SIL1111_2

## SIL Declaration of Conformity
## Functional safety according to IEC 61508

### DN2611 Vibration Monitoring System
### and PZS4 Accelerometer

has demonstrated a proven reliability and is manufactured and supported in a manner suitable for application to

### SIL 2 of IEC 61508 as a Type A Safety Related Subsystem

The following Failure rates were determined by FMEA using FARADIP.THREE data base from Technis and returns analysis

| | | |
|---|---|---|
| λdd - Dangerous Detected Failure | 0.157 | |
| λdu - Dangerous undetected Failure | 0.583 | |
| λs Safe Failure | 1.073 | |
| Total Failure Rate | 1.813 | per million hours |

| | | |
|---|---|---|
| DN2611 MTBF - Field Data | 99 | Years |
| PZS4 MTBF - Field Data | 324 | Years |
| TI - Manual Test interval | 1 | Year |
| MTTR - Mean Time To Repair | 24 | Hours |

| | | |
|---|---|---|
| SFF - Safe Fail Fraction | 68 | % |
| PFD - Probability of Failure on Demand | 2.60E-03 | |

The above figures are certified as being correct and have been extracted from :-
Technis Report No T272

Russell King
Managing Director
Sensonics Ltd

SENSONICS LTD

# DN2611 Dual Channel Vibration Monitor

Operation, Installation, Maintenance and Safety Handbook

Handbook Ref. HB1306-2

# APPENDIX 4:

# AGAT Analysis Reports

Client: 3769512
NEWFOUNDLAND & LABRADOR HYDRO
P.O. BOX 2002
BISHOP'S FALLS, NL A0H 1C0
ATTN: JIM WHEELER/RAY ROWE/PAUL KEOUGH

Unit #: GGA LUBE SYSTEM
Unit Location: #1-GGA LUBE OIL
Component: ENGINE
Location:
Serial #: 0L-202204
Make:
Model: OLYMPUS JET ENGINE SVL GT
OAS #: #1-GGA LUBE OIL

AGAT Laboratories
Equipment Reliability and Lubricants Testing Services
3650 21st Street N.E., Calgary, AB, T2E6V6
Phone:(403)299-2000 Fax:(403)299-2105

Date analyzed: 05/13/16
Work order: 16C117043
Oil brand & grade: MOBIL JET II (NFLD. & LAB. HYDRO)
Client Ref #:

LEGEND - LC -Lower Critical | LR -Lower Reportable | UR -Upper Reportable | UC -Upper Critical | * *Ital* -Custom Limit

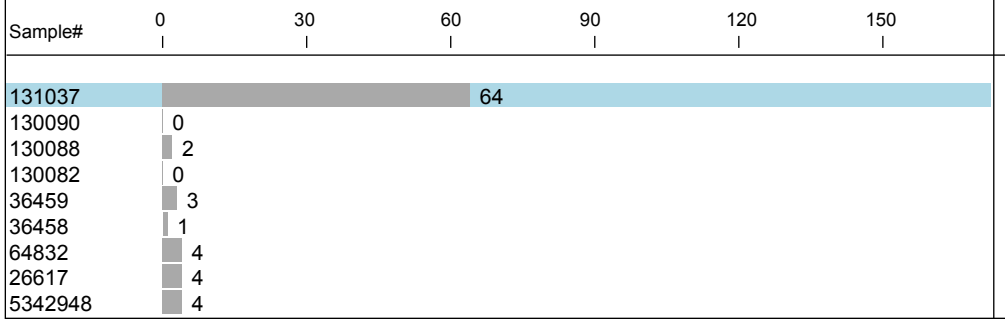
## UNIT DATA / SPECTROGRAPHIC ANALYSIS (PPM)

| Sample# | Date Sampled | Component Service | Oil Service | Oil Changed | Al Aluminum | Cr Chromium | Cu Copper | Fe Iron | Sn Tin | Pb Lead | Si Silicon | Mo Molybdenum | Ni Nickel | Ag Silver | K Potassium | Na Sodium | B Boron | Ba Barium | Ca Calcium | Mg Magnesium | Mn Manganese | P Phosphorus | Zn Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New Oil | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2907 | 0 |
| 131037 | 05/06/16 | 450 hrs | | hrs N | 7 | 5 | 1 | 49 UR | 2 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2450 | 0 |
| 130090 | 03/16/15 | 175.2 hrs | 175.2 hrs | | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2790 | 0 |
| 130088 | 11/07/14 | | | | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2690 | 0 |
| 130082 | 10/25/14 | | | N | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2640 | 0 |
| 36459 | 03/08/13 | | | N | 0 | 0 | 1 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 5 | 0 | 0 | 2610 | 4 |
| 36458 | 02/07/12 | | | N | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 2614 | 1 |
| 64832 | 02/23/10 | 281 hrs | | N | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 8 | 0 | 0 | 2912 | 2 |
| 26617 | 04/25/08 | 219.2 hrs | | | 1 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 4 | 0 | 0 | 2960 | 2 |
| 5342948 | 01/04/07 | | | N | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 13 UR | 1 | 0 | 0 | 7 | 1 | 0 | 3174 | 4 |

## PHYSICAL PROPERTIES / ISO CLEANLINESS / OIL DEGRADATION

| Sample# | Glycol | H2O | % Fuel | Viscosity 40°C | Viscosity 100°C | % Solids | KF | °C Flash Point | Micron size 4 | Micron size 6 | Micron size 14 | ISO Code | % SOOT | abs/cm-1 OXD | abs/cm-1 NOX | abs/cm-1 COX | abs/cm-1 SO4 | abs/cm-1 ZDDP | TAN | TBN | Min. RPVOT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New Oil | | | | 25.8 | 5.1 | | | | | | | | | | | | | | 0.08 | | |
| 131037 | N | N | | 26.7 | 5.4 | | 344 ppm | | | | | | 0.0 | 5 | 0 | 0 | 0 | 0 | 0.06 | | |
| 130090 | N | N | | 28.1 | 5.3 | | 189 ppm | | | | | | 0.0 | 66 UC | 0 | 0 | 0 | 0 | 0.07 | | |
| 130088 | N | N | | 24.4 | 4.6 | | 170 ppm | | | | | | 0.0 | 0 | 0 | 0 | 0 | 0 | 0.74 | | |
| 130082 | N | N | | 26.4 | 5.4 | | 302 ppm | | | | | | 0.0 | 35 UC | 0 | 0 | 0 | 0 | 0.01 | | |
| 36459 | N | N | | 25.8 | 5.4 | | 109 ppm | | | | | | 0.1 | 118 UC | 1 | 3 | 3 | 0 | 1.84 UR | | |
| 36458 | N | N | | 23.9 | 5.5 | | 136 ppm | | | | | | 0.0 | 93 UC | 0 | 2 | 5 | 0 | 0.08 | | |
| 64832 | N | N | | 26.1 | | 0.0 | | | | | | | | | | | | | 0.26 | | |
| 26617 | N | N | | 24.9 | | 0..0 | | | | | | | | | | | | | 0.61 | | |
| 5342948 | N | N | | 26.3 | | | | | | | | | | | | | | | 1.20 | | |

## WEAR CONTROL CHART




## COMMENTS

Comments:

REFER TO REVERSE FOR QUALITY CONTROL REPORT, EXPLANATION OF VARIANCE AND POSSIBLE CAUSES.

Should you wish to provide feedback to AGAT Laboratories, please access our Customer review form at www.agatlabs.com/review.htm. This input is extremely important to us because your well being and satisfaction is our number one priority.

* COMPONENT SERIAL NUMBER MUST BE GIVEN TO GENERATE HISTORY. Bold faced elements are included in Wear Control Chart.

Client: 3769512

NEWFOUNDLAND & LABRADOR HYDRO
P.O. BOX 2002

BISHOP'S FALLS, NL A0H 1C0

ATTN: JIM WHEELER/RAY ROWE/PAUL KEOUGH

Unit No.: GGA LUBE SYSTEM
Unit Location: #1-GGA LUBE OIL
Component: ENGINE
Location:
Serial No.: 0L-202204
Make:
Model: OLYMPUS JET ENGINE SVL GT
OAS No.: #1-GGA LUBE OIL

AGAT Laboratories

Quality Control Report

Date analyzed: 05/13/16

Work order: 16C117043

Oil brand & grade: MOBIL JET II (NFLD. & LAB. HYDRO)

Client Ref #:

| Flagged Result | Possible Causes | Significance of Result / Recommended Action |
|---|---|---|
| Fe - Iron | Iron is the base element in steel and is therefore present in many lubricated components (liners, piston rings, pistons, rockers arms, cylinders, shafts, gears, valve bridges, oil pump rolling element bearings, housings and cases). Iron is also present in rust and may indicate water contamination. | Higher than expected iron levels may indicate wear or contamination. Identify and evaluate the source. Check for signs of rust, scale and corrosion. Consider filtering or changing the oil. |

Client: 3769512
NEWFOUNDLAND & LABRADOR HYDRO
P.O. BOX 2002
BISHOP'S FALLS, NL A0H 1C0
ATTN: JIM WHEELER/RAY ROWE/PAUL KEOUGH

Unit #: GGA LUBE SYSTEM
Unit Location: #1-GGA LUBE OIL
Component: ENGINE
Location:
Serial #: 0L-202204
Make:
Model: OLYMPUS JET ENGINE SVL GT

Oil brand & grade: MOBIL JET II (NFLD. & LAB. HYDRO)
Sample #: C-677969
Date Sampled: 05/13/16
Date Analyzed: 05/13/16
Work order: 16C117043
Client Ref #:

AGAT Laboratories

# Sample Status and Trending

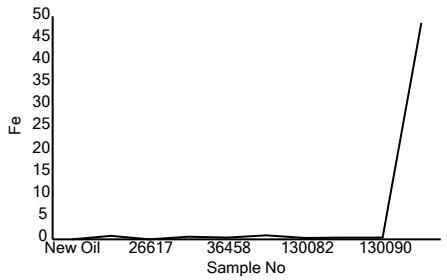
Sample Score:

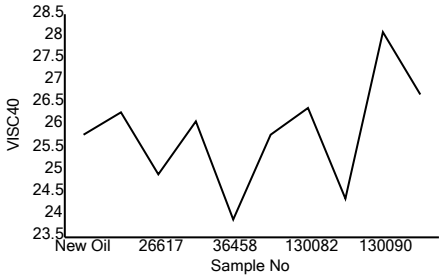
Your Sample Score: 2

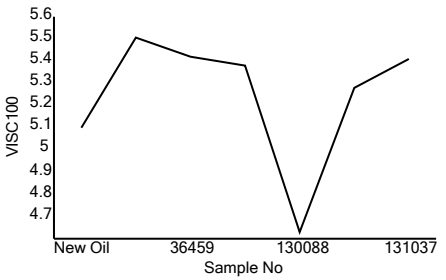
Rankings: 0-3 Normal, 4-6 Reportable, 7-10 Critical

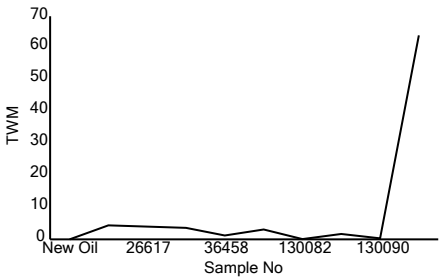
Normal | Reportable | Critical

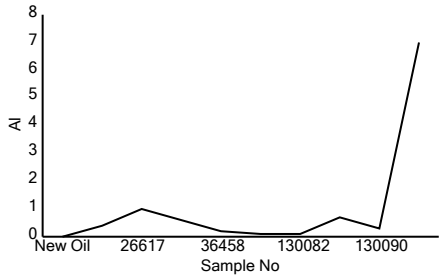
## Trend Graphs

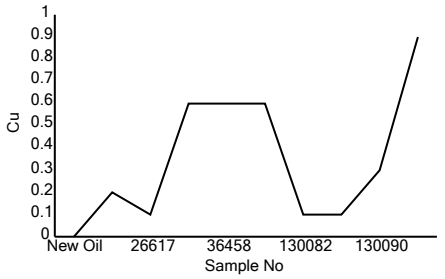


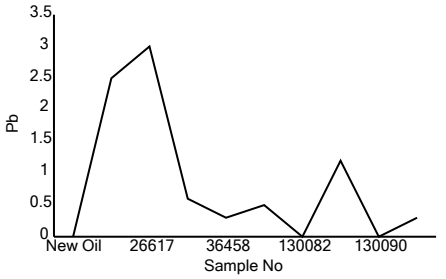



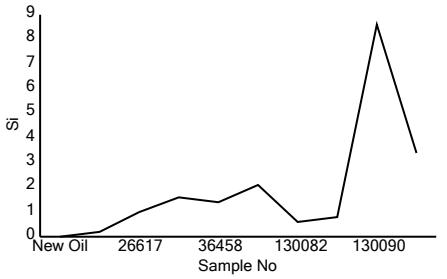



Client: 3769512
NEWFOUNDLAND & LABRADOR HYDRO
P.O. BOX 2002
BISHOP'S FALLS, NL A0H 1C0
ATTN: JIM WHEELER/RAY ROWE/PAUL KEOUGH

Unit #: MOBIL JET II
Unit Location:
Component: NEW OIL
Location:
Serial #:
Make:
Model:
OAS #:

AGAT Laboratories
Equipment Reliability and Lubricants Testing Services
3650 21st Street N.E., Calgary, AB, T2E6V6
Phone:(403)299-2000 Fax:(403)299-2105

Date analyzed: 05/13/16
Work order: 16C117043
Oil brand & grade: MOBIL JET II (NFLD. & LAB. HYDRO)
Client Ref #:

LEGEND - LC -Lower Critical | LR -Lower Reportable | UR -Upper Reportable | UC -Upper Critical | * *Ital* -Custom Limit

## UNIT DATA / SPECTROGRAPHIC ANALYSIS (PPM)

| Sample# | Date Sampled | Component Service | Oil Service | Oil Changed | Al Aluminum | Cr Chromium | Cu Copper | Fe Iron | Sn Tin | Pb Lead | Si Silicon | Mo Molybdenum | Ni Nickel | Ag Silver | K Potassium | Na Sodium | B Boron | Ba Barium | Ca Calcium | Mg Magnesium | Mn Manganese | P Phosphorus | Zn Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New Oil | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2907 | 0 |
| 131038 | 05/06/16 | | | N | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2770 | 0 |

## PHYSICAL PROPERTIES / ISO CLEANLINESS / OIL DEGRADATION

| Sample# | Glycol | H2O | % Fuel | Viscosity 40°C | Viscosity 100°C | % Solids | KF | °C Flash Point | Micron size 4 | Micron size 6 | Micron size 14 | ISO Code | % SOOT | abs/cm-1 OXD | abs/cm-1 NOX | abs/cm-1 COX | abs/cm-1 SO4 | abs/cm-1 ZDDP | TAN | TBN | Min. RPVOT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New Oil | | | | 25.8 | 5.1 | | | | | | | | | | | | | | 0.08 | | |
| 131038 | N | N | | 26.0 | 5.2 | | | | | | | | | | | | | | 0.04 | 1.7 | |

## WEAR CONTROL CHART

| Sample# | 0 | 30 | 60 | 90 | 120 | 150 |
|---|---|---|---|---|---|---|
| 131038 | 0 | | | | | |

## COMMENTS

Comments:

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* COMPONENT SERIAL NUMBER MUST BE GIVEN TO GENERATE HISTORY. Bold faced elements are included in Wear Control Chart.

AGAT Laboratories
Equipment Reliability and Lubricants Testing Services
3650 21st Street N.E., Calgary, AB, T2E6V6
Phone:(403)299-2000 Fax:(403)299-2105

Client: 3769512
NEWFOUNDLAND & LABRADOR HYDRO
P.O. BOX 2002
BISHOP'S FALLS, NL A0H 1C0
ATTN: JIM WHEELER/RAY ROWE/PAUL KEOUGH

Unit #: GGB LUBE SYSTEM
Unit Location:
Component: ENGINE
Location:
Serial #: 202223
Make:
Model: OLYMPUS SVL GT
OAS #:

Date analyzed: 05/13/16
Work order: 16C117043
Oil brand & grade: MOBIL JET II (NFLD. & LAB. HYDRO)
Client Ref #:

LEGEND - LC -Lower Critical  LR -Lower Reportable  UR -Upper Reportable  UC -Upper Critical  * *Ital* -Custom Limit

## UNIT DATA

| Sample# | Date Sampled | Component Service | Oil Service | Oil Changed |
|---|---|---|---|---|
| New Oil | | | | |
| 131039 | 05/06/16 | hrs | hrs | N |
| 130091 | 03/16/15 | 122.9 hrs | 122.9 hrs | |
| 130081 | 10/25/14 | | | N |

## SPECTROGRAPHIC ANALYSIS (PPM)

| Sample# | Al Aluminum | Cr Chromium | Cu Copper | Fe Iron | Sn Tin | Pb Lead | Si Silicon | Mo Molybdenum | Ni Nickel | Ag Silver | K Potassium | Na Sodium | B Boron | Ba Barium | Ca Calcium | Mg Magnesium | Mn Manganese | P Phosphorus | Zn Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New Oil | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2907 | 0 |
| 131039 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2630 | 0 |
| 130091 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 2800 | 0 |
| 130081 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2440 | 0 |

## PHYSICAL PROPERTIES

| Sample# | Glycol | H2O | % Fuel | Viscosity 40°C | Viscosity 100°C | % Solids | KF | °C Flash Point |
|---|---|---|---|---|---|---|---|---|
| New Oil | | | | 25.8 | 5.1 | | | |
| 131039 | N | N | | 26.2 | 5.6 | | 327 ppm | |
| 130091 | N | N | | 26.1 | 5.6 | | 375 ppm | |
| 130081 | N | N | | 26.1 | 5.5 | | 341 ppm | |

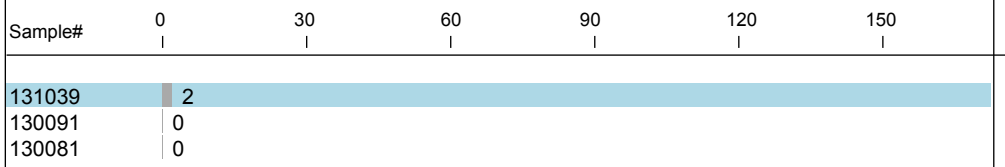
## ISO CLEANLINESS

| Sample# | Micron size 4 | 6 | 14 | ISO Code |
|---|---|---|---|---|
| New Oil | | | | |
| 131039 | | | | |
| 130091 | | | | |
| 130081 | | | | |

## OIL DEGRADATION

| Sample# | % SOOT | abs/cm-1 OXD | NOX | COX | SO4 | ZDDP | TAN | TBN | Min. RPVOT |
|---|---|---|---|---|---|---|---|---|---|
| New Oil | | | | | | | 0.08 | | |
| 131039 | 0.0 | 8 | 0 | 0 | 0 | 0 | 0.11 | | |
| 130091 | 0.0 | 48 UC | 0 | 1 | 0 | 0 | 0.12 | | |
| 130081 | 0.0 | 37 UC | 0 | 0 | 0 | 0 | 0.09 | | |

## WEAR CONTROL CHART




## COMMENTS

Comments:

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* COMPONENT SERIAL NUMBER MUST BE GIVEN TO GENERATE HISTORY. Bold faced elements are included in Wear Control Chart.

Client: 3769512
NEWFOUNDLAND & LABRADOR HYDRO
P.O. BOX 2002
BISHOP'S FALLS, NL A0H 1C0
ATTN: JIM WHEELER/RAY ROWE/PAUL KEOUGH

Unit #: GGB LUBE SYSTEM
Unit Location:
Component: ENGINE
Location:
Serial #: 202223
Make:
Model: OLYMPUS SVL GT
OAS #: 2022, B

Date analyzed: 05/26/17
Work order: 17C127461
Oil brand & grade: MOBIL JET II (NFLD. & LAB. HYDRO)
Client Ref #:

AGAT Laboratories
Equipment Reliability and Lubricants Testing Services
3650 21st Street N.E., Calgary, AB, T2E6V6
Phone:(403)299-2000 Fax:(403)299-2105

LEGEND - LC -Lower Critical LR -Lower Reportable UR -Upper Reportable UC -Upper Critical * Ital -Custom Limit

## UNIT DATA / SPECTROGRAPHIC ANALYSIS (PPM)

| Sample# | Date Sampled | Component Service | Oil Service | Oil Changed | | Al Aluminum | Cr Chromium | Cu Copper | Fe Iron | Sn Tin | Pb Lead | Si Silicon | Mo Molybdenum | Ni Nickel | Ag Silver | K Potassium | Na Sodium | B Boron | Ba Barium | Ca Calcium | Mg Magnesium | Mn Manganese | P Phosphorus | Zn Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New Oil | | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2907 | 0 |
| 131026 | 05/12/17 | hrs | hrs | N | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2870 | 0 |
| 131041 | 02/10/17 | hrs | hrs | N | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2960 | 1 |
| 131045 | 01/19/17 | hrs | hrs | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2730 | 0 |
| 131042 | 09/09/16 | 357 hrs | hrs | N | | 0 | 0 | 1 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 3460 | 2 |
| 131039 | 05/06/16 | hrs | hrs | N | | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2630 | 0 |
| 130091 | 03/16/15 | 122.9 hrs | 122.9 hrs | | | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 2800 | 0 |
| 130081 | 10/25/14 | | | N | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2440 | 0 |

## PHYSICAL PROPERTIES

| Sample# | Glycol | H2O | % Fuel | Viscosity 40°C | Viscosity 100°C | % Solids | KF | °C Flash Point |
|---|---|---|---|---|---|---|---|---|
| New Oil | | | | 25.8 | 5.1 | | | |
| 131026 | N | N | | 26.1 | 5.5 | | 348 ppm | |
| 131041 | N | N | | 26.1 | 5.5 | | 154 ppm | |
| 131045 | N | N | | 26.1 | 5.3 | | 143 ppm | |
| 131042 | N | P | | 25.3 | 5.3 | | 0.09% | |
| 131039 | N | N | | 26.2 | 5.6 | | 327 ppm | |
| 130091 | N | N | | 26.1 | 5.6 | | 375 ppm | |
| 130081 | N | N | | 26.1 | 5.5 | | 341 ppm | |

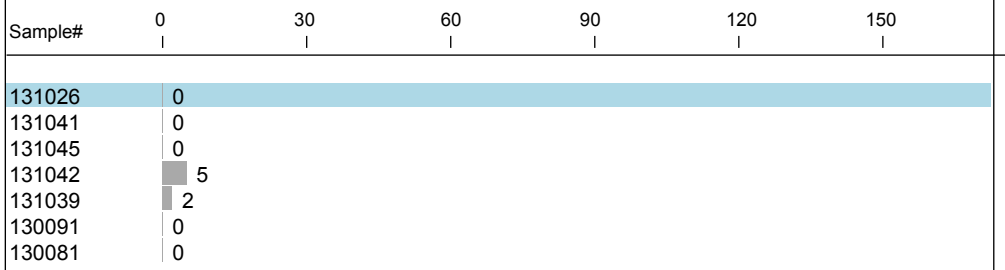
## ISO CLEANLINESS

| Sample# | Micron size 4 | 6 | 14 | ISO Code |
|---|---|---|---|---|
| 131026 | 1981 | 642 | 61 | 18/17/13 |
| 131041 | 9024 | 2804 | 138 | 20/19/14 |
| 131045 | 12754 | 4473 | 376 | 21/19/16 |
| 131042 | 39881 | 14066 | 1745 | 22/21/18 |

## OIL DEGRADATION

| Sample# | % SOOT | abs/cm-1 OXD | NOX | COX | SO4 | ZDDP | TAN | TBN | Min. RPVOT |
|---|---|---|---|---|---|---|---|---|---|
| New Oil | | 43 | | | | | 0.08 | | |
| 131026 | 0.0 | 0 | 1 | 3 | 0 | 0 | 0.04 | | |
| 131041 | 0.0 | 37 UC | 0 | 1 | 0 | 0 | 0.51 | | |
| 131045 | 0.0 | 35 UC | 0 | 1 | 0 | 0 | 0.06 | | |
| 131042 | 0.0 | 0 | 2 | 3 | 0 | 0 | 0.12 | | |
| 131039 | 0.0 | 8 | 0 | 0 | 0 | 0 | 0.11 | | |
| 130091 | 0.0 | 48 UC | 0 | 1 | 0 | 0 | 0.12 | | |
| 130081 | 0.0 | 37 UC | 0 | 0 | 0 | 0 | 0.09 | | |

## WEAR CONTROL CHART




## COMMENTS

Comments:

The ISO Code and Particle Count can only be evaluated as acceptable in conjunction with a consultation of the manufacturer's guideline's for the specific unit.

Should you wish to provide feedback to AGAT Laboratories, please access our Customer review form at www.agatlabs.com/review.htm. This input is extremely important to us because your well being and satisfaction is our number one priority.

* COMPONENT SERIAL NUMBER MUST BE GIVEN TO GENERATE HISTORY. Bold faced elements are included in Wear Control Chart.

AGAT Laboratories
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3650 21st Street N.E., Calgary, AB, T2E6V6
Phone:(403)299-2000 Fax:(403)299-2105

Client: 3769512
NEWFOUNDLAND & LABRADOR HYDRO
P.O. BOX 2002
BISHOP'S FALLS, NL A0H 1C0
ATTN: ROBERT SHANDERA/PAUL KEOUGH

Unit #: GGA LUBE SYSTEM
Unit Location:
Component: TURBINE
Location:
Serial #: 202040
Make: ROLLS ROYCE
Model: TYPE 2022,
OAS #: OLYMPUS C

Date analyzed: 05/26/17
Work order: 17C127461
Oil brand & grade: MOBIL JET II (NFLD. & LAB. HYDRO)
Client Ref #:

LEGEND - LC -Lower Critical  LR -Lower Reportable  UR -Upper Reportable  UC -Upper Critical  * Ital -Custom Limit

## UNIT DATA / SPECTROGRAPHIC ANALYSIS (PPM)

| Sample# | Date Sampled | Component Service | Oil Service | Oil Changed | Al Aluminum | Cr Chromium | Cu Copper | Fe Iron | Sn Tin | Pb Lead | Si Silicon | Mo Molybdenum | Ni Nickel | Ag Silver | K Potassium | Na Sodium | B Boron | Ba Barium | Ca Calcium | Mg Magnesium | Mn Manganese | P Phosphorus | Zn Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New Oil | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2907 | 0 |
| 131030 | 05/12/17 | | hrs | hrs N | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2740 | 0 |
| A475020 | 08/22/16 | | hrs | 0 hrs Y | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2960 | 0 |
| A475021 | 07/01/16 | | hrs | hrs | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2480 | 0 |
| A475014 | 04/26/16 | | | N | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 2390 | 1 |

## PHYSICAL PROPERTIES / ISO CLEANLINESS / OIL DEGRADATION

| Sample# | Glycol | H2O | % Fuel | Viscosity 40°C | Viscosity 100°C | % Solids | KF | °C Flash Point | Micron size 4 | Micron size 6 | Micron size 14 | ISO Code | % SOOT | abs/cm-1 OXD | abs/cm-1 NOX | abs/cm-1 COX | abs/cm-1 SO4 | abs/cm-1 ZDDP | TAN | TBN | Min. RPVOT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New Oil | | | | 25.8 | 5.1 | | | | | | | | | 43 | | | | | 0.08 | | |
| 131030 | N | N | | 26.3 | 5.4 | | 237 ppm | | | | | | 0.0 | 36 | 0 | 1 | 0 | 0 | 0.05 | | |
| A475020 | N | N | | 26.0 | 5.4 | | 496 ppm | | | | | | 0.0 | 77 UC | 0 | 4 | 2 | 0 | 0.04 | | |
| A475021 | N | N | | 26.8 | 5.4 | | 390 ppm | | | | | | 0.0 | 38 UC | 0 | 0 | 0 | 0 | 0.01 | | |
| A475014 | N | N | | 26.2 | 5.6 | | 145 ppm | | | | | | | | | | | | 0.03 | | |

## WEAR CONTROL CHART

| Sample# | 0 | 30 | 60 | 90 | 120 | 150 |
|---|---|---|---|---|---|---|
| 131030 | 1 | | | | | |
| A475020 | 0 | | | | | |
| A475021 | 1 | | | | | |
| A475014 | 1 | | | | | |

## COMMENTS

Comments:

Should you wish to provide feedback to AGAT Laboratories, please access our Customer review form at www.agatlabs.com/review.htm. This input is extremely important to us because your well being and satisfaction is our number one priority.

* COMPONENT SERIAL NUMBER MUST BE GIVEN TO GENERATE HISTORY. Bold faced elements are included in Wear Control Chart.
AGAT Laboratories Liability Shall Not Exceed The Cost Of Analysis. *Results relate only to the items tested