Project Title: Overhaul Gas Turbine

Location: Holyrood

Category: Generation - Gas Turbines

Definition: Other

Classification: Normal

Project Description:

This project is required to overhaul the gas turbine engine at the Holyrood gas turbine plant. The scope of the work is based on an inspection by Alba Power performed on the engine in 2008. Part of the overhaul involves a detailed inspection of the internal components to finalize the scope of the work. The engine is a Rolls-Royce Avon 1533-70L.

A vendor specializing in gas turbine repairs will perform the engine overhaul. The engine will be removed from its berth at Holyrood and shipped to the vendor's repair facility for detailed inspection and subsequent repairs. Removal and reinstallation of the engine will be performed by the vendor, with assistance as required from Holyrood personnel.

Table 1 provides the budget estimate for this project.

Table 1: Budget Estimate

Project Cost: *($ x1,000)*	2011	2012	Beyond	Total
Material Supply	50.0	0.0	0.0	50.0
Labour	157.6	0.0	0.0	157.6
Consultant	0.0	0.0	0.0	0.0
Contract Work	811.4	0.0	0.0	811.4
Other Direct Costs	25.0	0.0	0.0	25.0
O/H, AFUDC & Escln.	142.9	0.0	0.0	142.9
Contingency	104.4	0.0	0.0	104.4
TOTAL	**1,291.4**	**0.0**	**0.0**	**1,291.4**

Operating Experience:

The engine was purchased by Hydro in 1966 and has an anticipated useful life of 25 years. It was last overhauled in 1991. The latest internal inspection of the inside of the engine was completed in June 2008. The report from Alba Power cited the presence of corrosion and coating loss on internal

components. In October 2009, three broken discharge nozzle brackets were noted during repair work on the unit.

Project Justification:

The Holyrood gas turbine plant is critical to the successful operation of the Island Interconnected System. Its main function is to supply power to Holyrood during a black start. A black start of Holyrood is required when the plant is unable to attain power from the Island Interconnected grid due to an emergency outage caused by other generation sources. If the gas turbine failed to supply power to Holyrood during a black start, Holyrood would not be able to start until power was restored to the grid by alternate generation sources. This would cause an unnecessary delay in restoring full power to the grid. For this reason, the gas turbine plant needs to be reliable.

Future Plans:

None.

Attachments:

See report entitled "Overhaul Gas Turbine – Holyrood Thermal Generation Station" located in Volume I, REPORTS 1 - 10, Tab 6, for further project details.

A REPORT TO

THE BOARD OF COMMISSIONERS OF PUBLIC UTILITIES

Electrical
Mechanical
Civil
Protection & Control
Transmission & Distribution
Telecontrol
System Planning

OVERHAUL GAS TURBINE

Holyrood Thermal Generating Station

April 2010

newfoundland labrador hydro
a nalcor energy company

Table of Contents

1 INTRODUCTION

The Holyrood Thermal Generating Station (Holyrood) has been producing power for Newfoundland and Labrador Hydro (Hydro) for nearly 40 years. Holyrood produces approximately one-third of Hydro's total Island Interconnected System generating capacity.

Holyrood uses some of the power it generates to operate its own equipment. This quantity of power is known as station service power. If Holyrood's generators are shut down, station service power is supplied from the Island Interconnected System (grid) through two dedicated supplies via the Holyrood switchyard. When power from the transmission grid is not available, station service power is provided by Holyrood's gas turbine plant. This gas turbine plant, shown in Figure 1, is located adjacent to the Holyrood thermal plant.

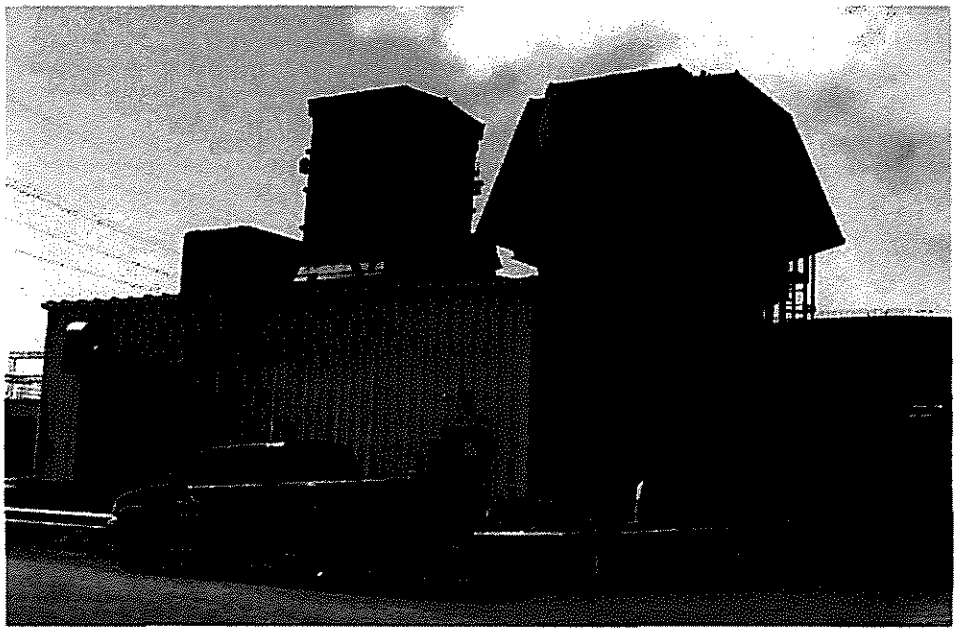


Figure 1: Holyrood Gas Turbine Plant

If Holyrood's generators are off-line during an Avalon Peninsula transmission outage, Holyrood must undergo a black start in order to begin restoring power initially to the plant

and eventually to the grid. A black start is defined as starting the plant in the absence of power from the grid. The equipment that must be started during a black start includes the boiler feedwater pumps, forced-draft combustion blowers that supply combustion air to the plant boilers, and fuel pumps. Holyrood's gas turbine plant provides power to the main plant for a black start. After a successful black start, power from the gas turbine plant is no longer required as the station service power is supplied from the plant's own generators.

In addition to supplying power to Holyrood during a black start, the gas turbine plant is also used to supply power to the Island Interconnected System during peak load and emergency periods. Holyrood's gas turbine plant is rated at a capacity of 13 MW.

2 PROJECT DESCRIPTION

This project is required to overhaul the gas turbine engine at the Holyrood gas turbine plant. The engine, shown in Figure 2, is a Rolls-Royce Avon 1533-70L model. It was last overhauled in 1991.

Figure 2: Holyrood's Gas Turbine Engine

The scope of work for the gas turbine overhaul is based on the latest boroscope inspection performed on the engine in 2008 and other inspections performed in 2009. During a boroscope inspection, a tiny camera is inserted inside the gas turbine through one of the fuel nozzle ports. The images viewed by the camera show up on an external video screen. However, a boroscope inspection is unable to identify all necessary refurbishment work. Therefore, the engine will be disassembled under this project so that a detailed inspection of internal components may be performed. The final scope of work will be developed after the completion of the detailed inspection report. This is the typical approach taken with gas turbine overhaul work.

A contractor specializing in gas turbine overhauls will perform the engine repair work. The engine will be removed from its berth at Holyrood and shipped to the vendor's overhaul facility. The vendor will be required to have access to a Rolls-Royce Avon test cell that will be used to monitor the engine during performance verification at the completion of the repair work. Removal and reinstallation of the engine will be performed by the vendor, with

assistance as required from Holyrood personnel.

The gas turbine plant at Holyrood will be out of service for approximately five months to complete the work under this project.

3 EXISTING SYSTEM

The Holyrood gas turbine plant consists of a Rolls-Royce Avon 1533-70L aero-derivative engine coupled to an Associated Electrical Industries (AEI) AP.1 power turbine that drives an AEI electrical generator. Total generating capacity is 13 MW. The engine was last overhauled in 1991.

The latest internal inspection of the inside of the engine (see Appendix A) was completed in June 2008. The recommendations from the inspection report included replacing the combustion cans and performing fuel system repairs. This work was completed in 2009. Also, the 2008 inspection report identified corrosion and protective coating loss on internal components. In October 2009, three broken discharge nozzle brackets were noted during maintenance work on the unit (see Figure 3).

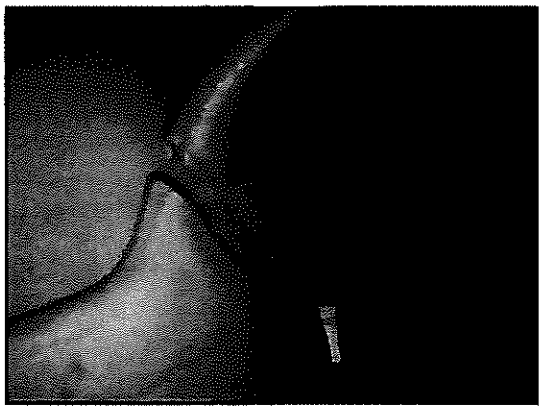


Figure 3: Cracked Discharge Nozzle Bracket

3.1 Age of Equipment or System

The Rolls-Royce Avon gas turbine engine, AEI power turbine, and AEI generator was purchased by Newfoundland and Labrador Hydro in 1966. The equipment was initially installed at the Hardwoods Terminal Station near the west end of St. John's where it was used for emergency purposes and during peak load conditions. The set was relocated to its existing location during the initial construction of the Holyrood plant. Since that time, it has served as Holyrood's black start power source and has generated power during peak load and in emergencies.

3.2 Major Work and/or Upgrades

Table 1 shows the upgrades that have occurred since installation:

Table 1: Major Work or Upgrades

Year	Major Work/Upgrade	Comments
2009	Repairs	Combustion cans replaced, fuel pumps replaced, RTC replaced
2007	Repairs	IGV Ram exchanged, burners cleaned, plenum fixed, bleed valve duct repaired, IGV brushes repaired and replaced, oil leak on power turbine repaired
2004	Starter motor changed	
1991	Overhaul	Rehabilitate Gas Turbine but fuel pump and RTC not overhauled
1985	Overhaul	Rehabilitate Gas Turbine

3.3 Anticipated Useful Life

The useful life of the gas turbine is 25 years however this overhaul is expected to extend the life of this asset for an additional 15 years.

3.4 Maintenance History

The five-year maintenance history for Holyrood's Rolls-Royce Avon gas turbine engine is shown in Table 2.

Table 2: Five-Year Maintenance History

Year	Preventive Maintenance ($000)	Corrective Maintenance ($000)	Total Maintenance ($ 000)
2009	0.0	179.3	179.3
2008	8.4	0.0	8.4
2007	26.9	40.4	67.3
2006	0.0	0.0	0.0
2005	7.0	0.0	7.0

3.5 Outage Statistics

The table below lists the 2005 to 2009 average capability factor, Utilization Forced Outage Probability (UFOP) and Failure Rate for the Holyrood Gas Turbine compared to all Hydro's gas turbine units and the latest CEA average (2003 to 2007).

Table 3: Outage Statistics
Five Year Average 2005-2009

Unit	All Causes		
	Capability[1] Factor (%)	UFOP[2] (%)	Failure[3] Rate
Holyrood Gas Turbine	88.37	15.34	803.76
All Hydro Gas Turbine Units	82.56	13.36	41.82
CEA (2003-2007)	92.36	4.95	25.74

3.6 Industry Experience

Industry experience has not been considered since this is an engine overhaul to address deficiencies reported during inspections of the gas turbine engine.

3.7 Maintenance or Support Arrangements

Holyrood's gas turbine engine is maintained by companies specializing in repairs to the Rolls-Royce Avon gas turbine engine.

3.8 Vendor Recommendations

An Original Equipment Manufacturer (OEM) certified repair shop has been contacted for advice on repairing the gas turbine engine. The vendor recommended that detailed inspections of internal components must be performed in order to finalize the scope of

[1] *Capability Factor is defined as unit available time. It is the ratio of the unit's available time to the total number of unit hours.*
[2] *UFOP is defined as the Utilization Forced Outage Probability. It is the probability that a generation unit will not be available when required. It is used to measure performance of standby units with low operating time such as gas turbines.*
[3] *Failure Rate is defined as the rate at which the generating unit encounters a forced outage. It is calculated by dividing the number of transitions from an Operating state to a forced outage by the total operating time.*

work required for the engine overhaul. This involves shipping the unit to a repair facility where the engine would undergo a disassembly and detailed inspection.

3.9 Availability of Replacement Parts

Replacement parts are available for the gas turbine engine.

3.10 Safety Performance

There are no safety performance issues relating to this project.

3.11 Environmental Performance

There are no environmental performance issues related to this project.

3.12 Operating Regime

The Holyrood gas turbine plant is mainly used to supply station service power during a black start of the main Holyrood plant. The gas turbine plant is also in continuous standby mode to supply 13 MW of power to the Island Interconnected System. This normally occurs during peak load periods as well as during an unscheduled outage at other generating facilities. Each week, the Holyrood gas turbine plant undergoes a 15 minute operational test to verify its availability for its black start function.

4 JUSTIFICATION

The Holyrood gas turbine plant is critical to the Island Interconnected System. Its main function is to supply power to Holyrood during a black start. A black start of Holyrood is required when the grid is down because of an emergency outage caused by other generation sources. If the gas turbine plant failed to supply power to Holyrood during a black start, Holyrood would not be able to start until power was restored to the grid by alternate generation sources. This would cause an unnecessary delay in restoring full power to the grid. For this reason, the gas turbine plant needs to be reliable.

Overhauls to gas turbine engines are required throughout their operating life to maintain operational reliability. The last overhaul completed on Holyrood's gas turbine took place in 1991. Inspections have indicated the presence of internal corrosion and coating loss to internal components of Holyrood's gas turbine. These issues can only be addressed through an engine overhaul. If these issues are not addressed, more damage will occur that will lead to a more costly overhaul in the future.

4.1 Net Present Value

A net present value calculation is not required as there is no viable alternative to repairing the gas turbine engine.

4.2 Levelized Cost of Energy

The levelized cost of energy is not a factor in this project.

4.3 Cost Benefit Analysis

A cost benefit analysis has not been performed, as there are no quantifiable benefits.

4.4 Legislative or Regulatory Requirements

There are no legislative or regulatory requirements that justify this project.

4.5 Historical Information

As this is not a recurring project, no relevant historical information is available.

4.6 Forecast Customer Growth

This project is not required to accommodate customer growth.

4.7 Energy Efficiency Benefits

There are no energy efficiency benefits to be gained from this project.

4.8 Losses during Construction

There will be no losses during construction, as the work will be performed during a planned outage.

4.9 Status Quo

Maintaining the status quo is not acceptable. If internal corrosion and coating loss are not repaired, the unit will continue to degrade further resulting in more costly repairs.

4.10 Alternatives

There are no viable alternatives to repairing the gas turbine engine.

5 CONCLUSION

Holyrood's gas turbine plant supplies power to the Holyrood Thermal Generating Station during a black start condition. It is critical to the successful operation of Holyrood. As well, the gas turbine plant is used to supply power to the Island Interconnected System during peak load conditions and emergency periods.

Corrosion and coating loss on internal components were found during the last boroscope inspection of the engine. Also, broken nozzle discharge brackets, discovered during maintenance work in 2009 need to be replaced. While disassembly and further detailed inspections of the engine are required to finalize the scope of work for this project, it is evident from internal inspections that the gas turbine engine requires an overhaul.

This engine has been in service since 1966. An overhaul is required to maintain continued operational reliability of the Holyrood gas turbine plant.

5.1 Budget Estimate

This budget estimate is based on information provided by Rolls-Wood for an overhaul to a typical Avon unit with an operating regime similar to the one at Holyrood. The budget estimate is shown in Table 4.

Table 4: Budget Estimate

Project Cost:*($ x1,000)*	2011	2012	Beyond	Total
Material Supply	50.0	0.0	0.0	50.0
Labour	157.6	0.0	0.0	157.6
Consultant	0.0	0.0	0.0	0.0
Contract Work	811.4	0.0	0.0	811.4
Other Direct Costs	25.0	0.0	0.0	25.0
O/H, AFUDC & Escln.	142.9	0.0	0.0	142.9
Contingency	104.4	0.0	0.0	104.4
TOTAL	**1,291.4**	**0.0**	**0.0**	**1,291.4**

5.2 Project Schedule

The anticipated project schedule is shown in Table 5.

Table 5: Project Schedule

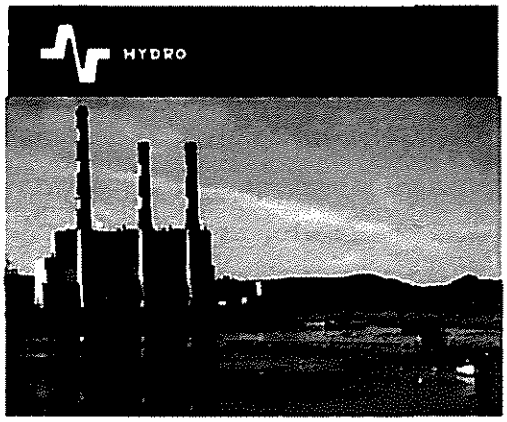
Activity	Milestone
Project Initiation	January 2011
Tender Repair Work	February 2011
Ship Engine to Repair Facility	April 2011
Repair Period	August 2011
Install Unit at Holyrood	September 2011
Project Closeout	December 2011

APPENDIX A

Borescope Inspection of Avon 37029
1533 70L

ALBA POWER

Inspection Report
To



Borescope inspection of Avon 37029 1533 70L

Proposal Number: Alba 1633

Date: June 10 2008

Alba Power Ltd
Tel: (44) 01569 730088
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Sales @albapower.co.uk

ISO9001 (2000 Revision) Approved
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Introduction

After successful repairs and assistance in 2008 Alba Power were asked to return to complete inspection works on the unit at Holyrood.

The unit has completed 26 Hours and 54 starts since the last inspection in May 2007.

The inspection was completed 10 June 1008 after site induction.

Alba Power would like to take this opportunity to thank the client and staff at Holyrood generating site for the assistance and approach to Alba Power, this was greatly appreciated an we look forward to assisting you in the future.

If you do have any questions or queries please do not hesitate to contact us, your contact for this proposal is as follows:

Campbell C Archibald

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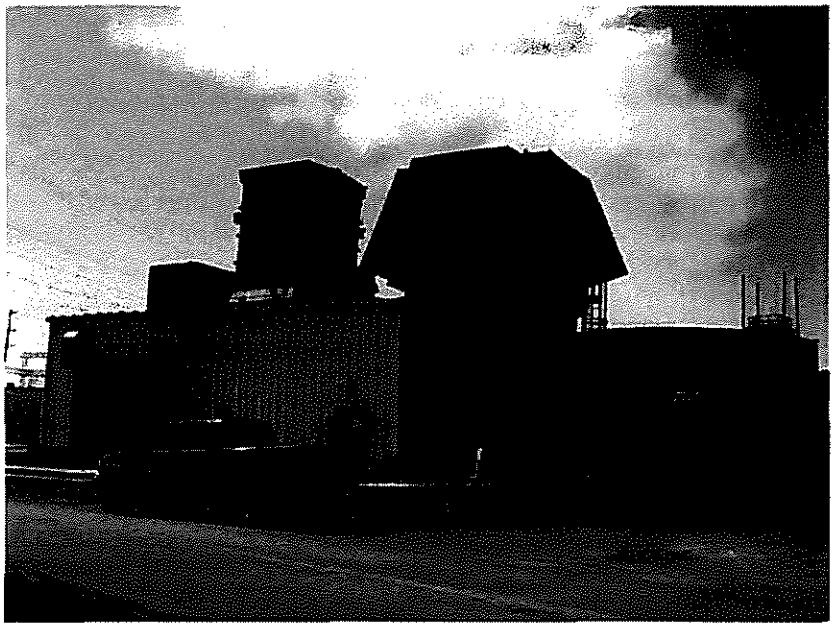
1 Avon Repair and Borescope Inspection



On Site Personnel- Mr Campbell Archibald and Mr Martin Andrews

Date of inspection – 10 June 2008

1.1 Inspection Review

On arrival at site an induction of site-specific requirements was completed with Mr Ted Smith. This was followed by a toolbox review at the workstation.

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1.2 Workscope Review

The following are details of the workscope completed at site;

1.2.1 Tuesday 10 June 2008

- Plenum inspection
- Compressor inspection
- Burner removal (Where possible)
- Combustion area inspection
- Turbine area inspection
- Package inspection

1.2.2 Unit Images

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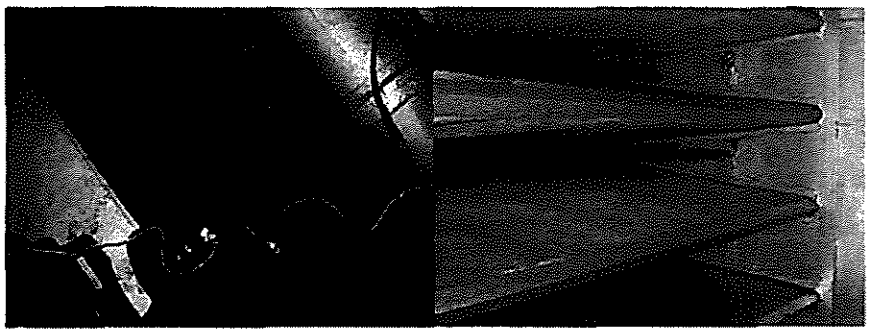
2 Borescope Results

As detailed within our workscope above the unit was borescoped throughout and within this report we will detail the sections accordingly.

All images will be provided separately on a CD for client files.

2.1 Package Plenum

On entering the plenum it was noted that a large amount of water had gathered under the intake, this will have a significant impact on the units condition, corrosion and potential for FOD ingress. In addition 2 large holes where noted in the sidewall as well as a large amount of rust particles on the floor. All of these will have a risk of ingress attached.



Water in plenum **Hole in side wall**

Rust particles Corrosion on intake

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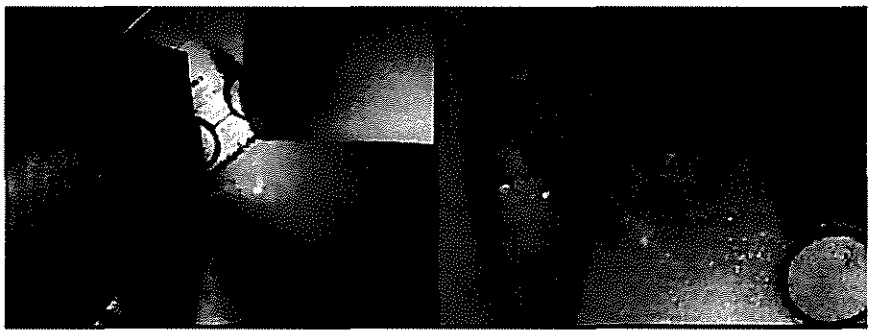
2.2 Compressor Section

It was noted that the Front bearing housing, Inlet Guide Vanes and Compressor have significant corrosion and coating loss. This has now increased greatly from last year's inspection with the addition of salt ingress and the Front Bearing housing pitting (As shown in above section)

Corrosion pitting on Front Bearing housing struts and outer casing



IGV Inner journals FBH Wear

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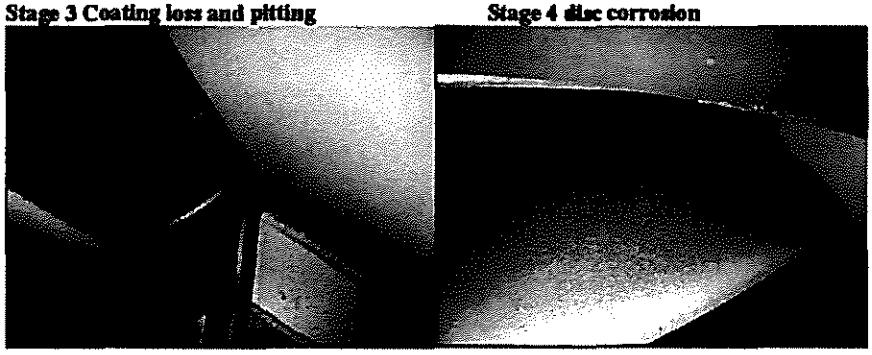
Coating loss and pitting stage 1

Stage 3 Coating loss and pitting

Stage 4 disc corrosion



Stage 5 Salt ingress

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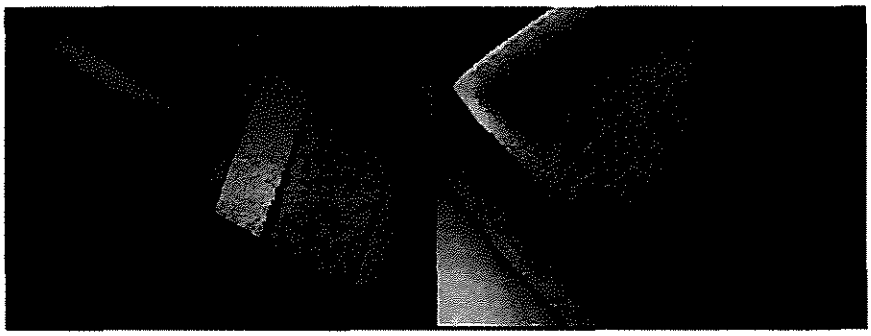
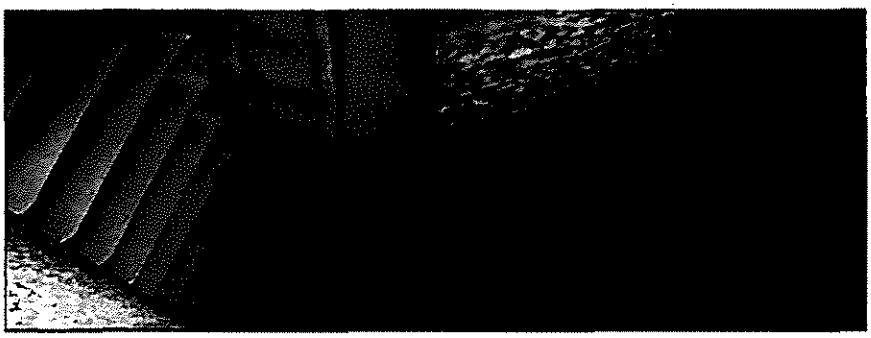


Stage 5 Disc Corrosion **Stage 4 casing and blade condition**



Stage 15 OGV Corrosion **COC Corrosion**

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2.3 Combustion Section

In 2007 the unit showed extreme wear of the Combustion cans with cracks and loss of coating. The unit has operated 26 Hours and 54 Starts since that time which has increased the level of cracking. It may only be a matter of time before this material is released and impacts the turbine.

Access could only be gained through burners 1 and 2 due to rusting bolting in other areas, all borescope ports where removed to gain minimal access in the combustion area.

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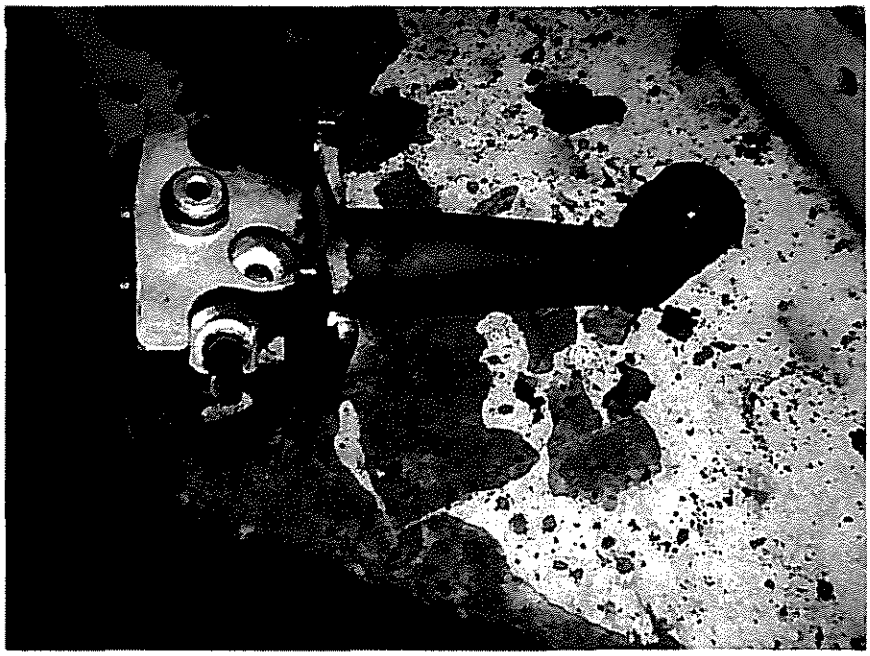

Burner No1 after removal

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2.4 Turbine Section

Access was gained in this area through the 2 available burners as well as the thermocouples at positions 3 and 4. It will become more difficult to inspect the unit with specific clarity due to the age and condition whilst trying to return to service quickly.

The turbine section showed minor impact damage from either combustion can material or corrosion flakes from the intake. Coating loss was evident throughout with some minor pitting.

HP Nozzle Guide Vane

HP Turbine Blade inner platform

HP Blade leading edge pitting

HP Blade outer platform

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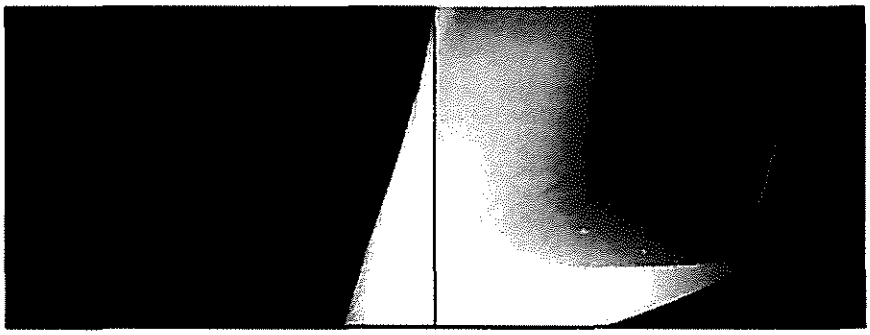
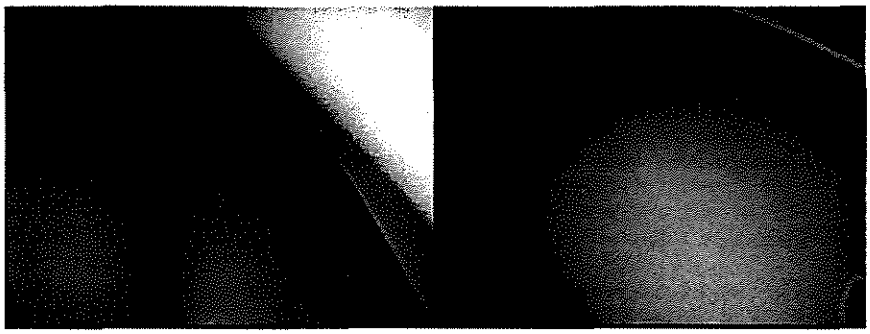


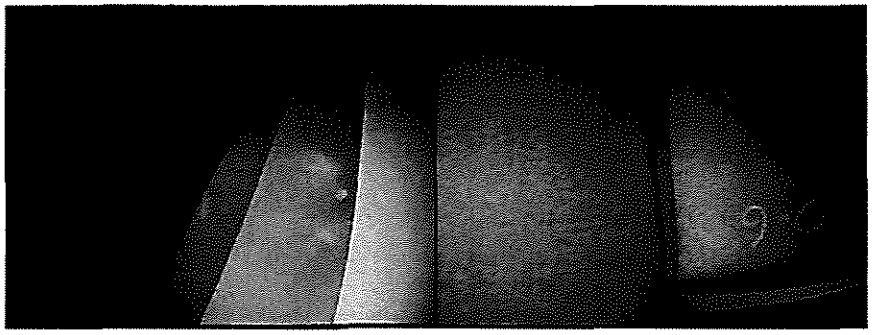
LP Turbine Blades

LP Turbine blade damage and FOD material flakes



IP Blade and NGV

IP Blade



LP Blade coating deterioration

IP Blade outer platform

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3 Conclusions / Recommendations

After the last inspection it was highly recommended that as a minimum the Combustion cans be replaced. Whilst we understand due to budgetary and operational requirements this has not happened it must now be placed as a high priority to ensure the continuous availability of this unit.

The unit showed greater salt ingress and corrosion this year, this would be attributed to the poor condition of the intake plenum, water ingress and flaking corrosion particles. This should be addressed prior to any further running.

The unit shows signs of burner leaking, it was highlighted last year that the drains tank fills continuously and the unit has some start issues. These where and continue to be attributed to the failing of the seals in the Fuel control unit, this should be addressed to improve start reliability while reducing poor burn in the combustion area and reducing leaks back through the drains system.

The unit would ideally be returned to our facility for repair / overhaul due to the coating loss, pitting, corrosion etc. If the unit continues to run in its current condition then overhaul and replacement prices will increase while the parent material decreases in reparability.

In the immediate future the combustion cans should be changed, if a part is ingested into the turbine the unit could suffer a catastrophic failure which would not only damage and increase the Avon overhaul / replacement price, but would do considerable damage to the Power Turbine as well as be a large safety risk.

Alba Power remains flexible as always and look forward to preparing options suited to your site-specific requirements.