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INDUSTRIAL APPLICATION OF GAS TURBINES COMMITTEE

RB211 G-T DLE / RT61 Demonstrator Experience at TCPL Nordegg

by

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Abstract

In 1997 Rolls-Royce initiated a programme to upgrade the successful 6562 package which combined the RB211-24G gas generator and the RT62 power turbine, to increase both power and thermal efficiency. This resulted in the RB211 G-T gas generator and the RT61 power turbine, together designated the 6761. The gas generator modifications included an upflowed IP compressor, an Aero Trent HP compressor, a revised 'short' combustor DLE system and improvements to turbine materials. The power turbine was completely redesigned going from 2 to 3 rotor stages. The 6761 package gives a nominal 15% increase in power and a 2% increase in thermal efficiency over the 6562.

In 2003 a demonstrator 6761 was installed at a Trans Canada Pipe Lines (TCPL) gas pumping station in Nordegg Alberta. TCPL already operate the worlds largest fleet of RB211 packages with over 80 RB211 based units of various types and ratings. The unit ran over the next 3 years in normal operational duty and in November 2006 the gas generator was removed for a routine hot end refurbishment having completed 24,233 hours and being the lead unit of the 6761 fleet. Removal of the engine also provided an opportunity to inspect the PT whilst still installed.

The engine was returned to the Rolls-Wood overhaul facility in Aberdeen Scotland where it was inspected and a refurbishment workscope defined to enable the engine to complete a further 25-30,000 hours when a full overhaul will be conducted. Overall the engine was found to be in very good condition with little work required over that normally expected for a G rated RB211 at the same running hours. Inspection of the PT whilst still installed in the berth also identified no problems requiring repair work.
This paper summarises the design changes incorporated into the 6761 package, the operational experience at Nordegg and covers in detail the condition of the engine and PT after 24,233 hours running.

Note: Since April 2007 the RB211 and RT series power turbine range have been re-designated. Thus the 6761 package is now marketed as the RB211-GT61.

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Nomenclature

BOV	Blow Off Valves
DLE	Dry Low Emissions
FOD	Foreign Object Damage
HP	High Pressure
IP	Intermediate Pressure
NGV	Nozzle Guide vane
OGV	Outlet Guide Vane
PT	Power Turbine
RVDT	Rotary Variable Displacement Transducer
SB	Service Bulletin
TBC	Thermal Barrier Coating
VIGV	Variable Inlet Guide Vane

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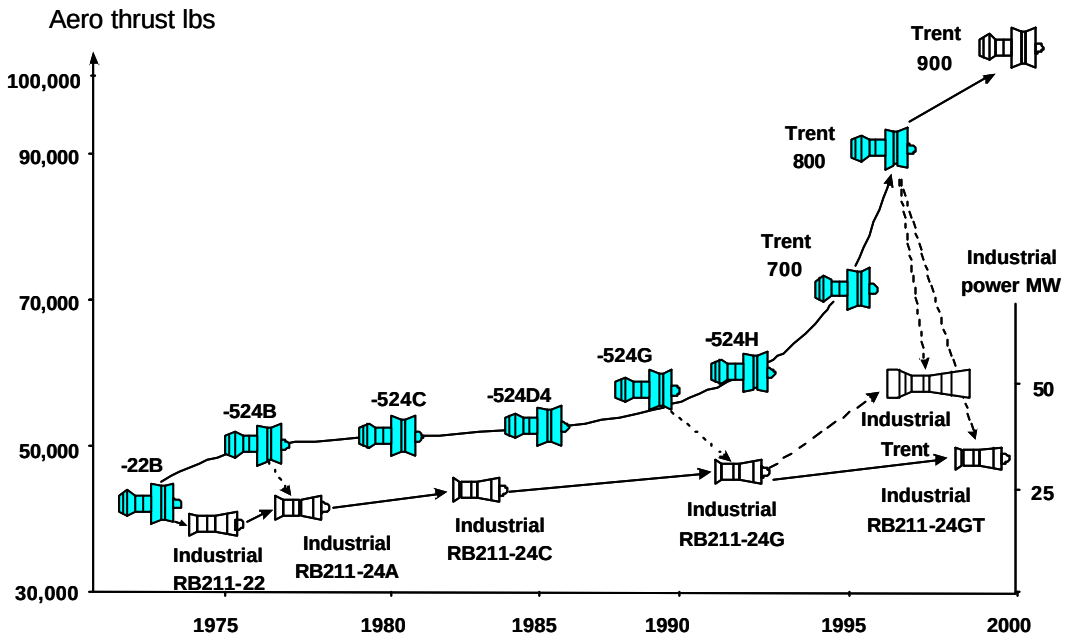
1.0 RB211 / RT61 Uprate Programme.

Since its introduction in 1975 the Industrial RB211 and the RT-series power turbine have been progressively uprated in power, thermal efficiency and temperature capability. The original RB211-22 / RT56 PT entered service at approx 29,000 SHP and 35% efficiency whilst the –24G introduced in 1992 was rated at 39,600 BHP and 38% efficiency. For the gas generator this increase has been achieved primarily by the introduction of improved compressor and turbine components from the parent aero engine.

As a result of market demands a program was initiated in 1997 to further increase power and efficiency. This project was a coordinated program to uprate both the RB211 and also the power turbine. The resulting RB211 G-T and RT61 PT combination is rated at 44,000bhp and 40.5% efficiency.

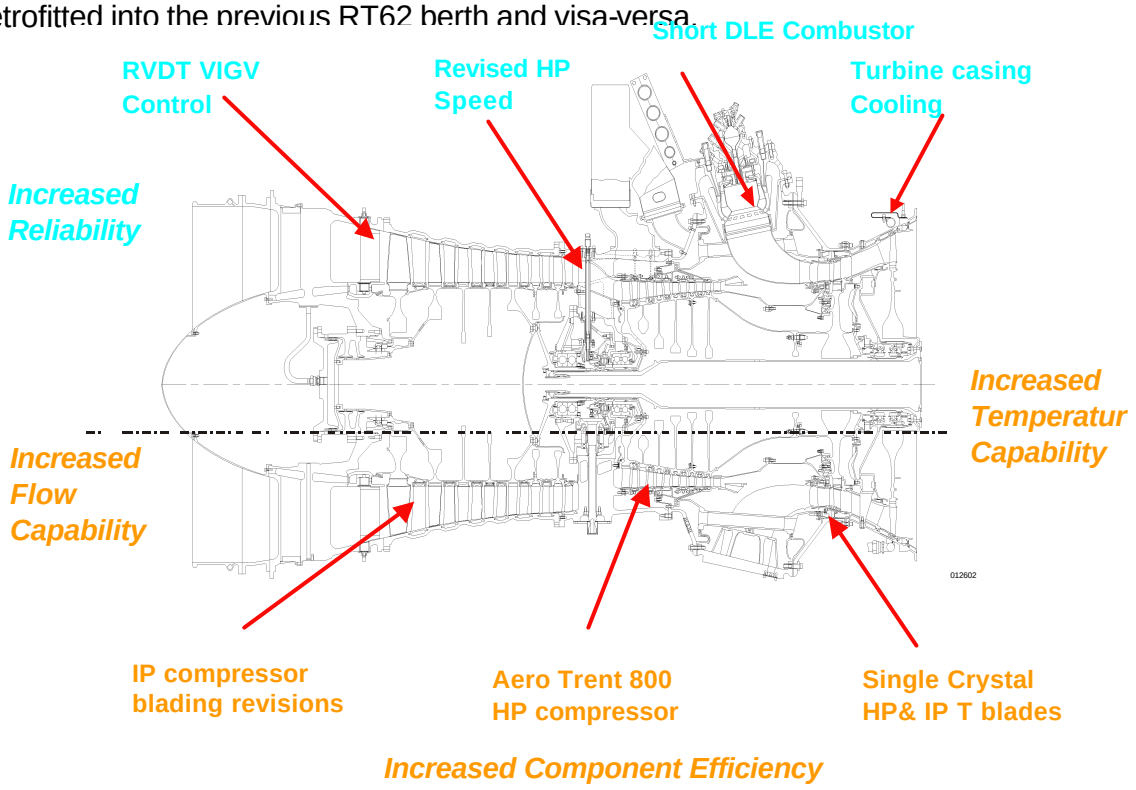


Aero & Industrial Engine Power Growth

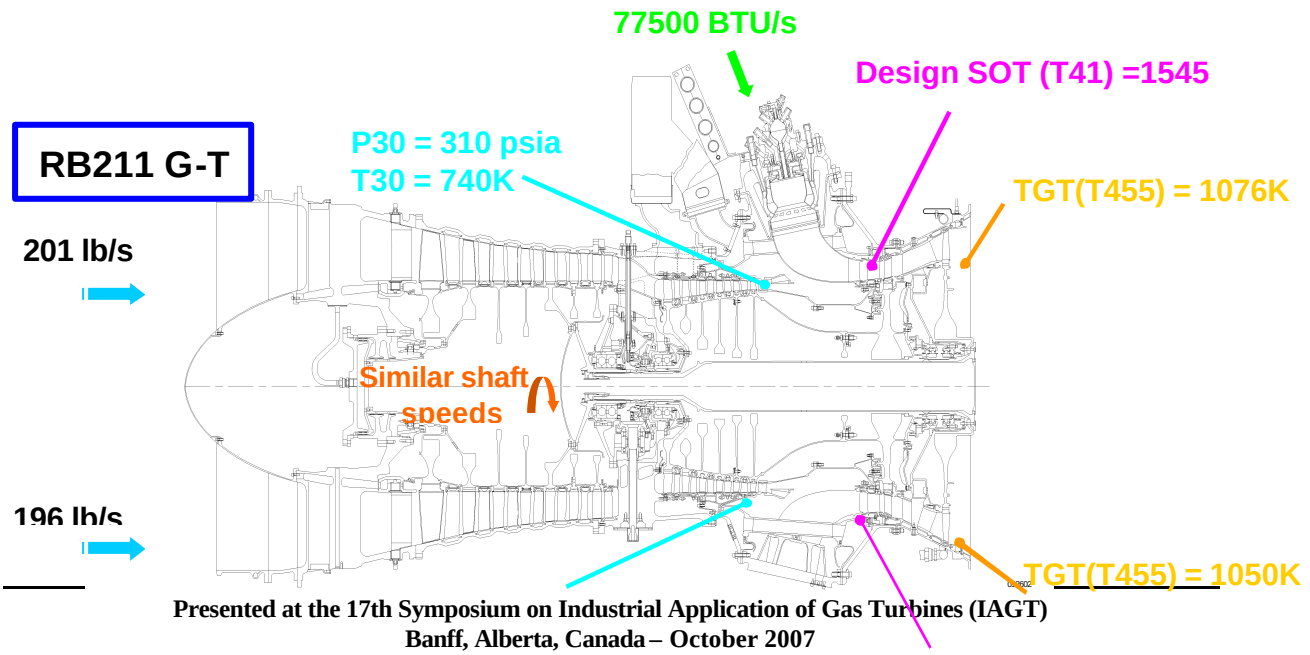
2.0 RB211 G-T Features

The existing –24G rated engine was uprated by introducing components to allow a modest increase in the flow and temperature capability, combined with a improved efficiency HP compressor. In parallel to the engine uprate program was a project to further develop the DLE combustion system. This resulted in the 'short' DLE combustor which was fitted as

standard onto the 7th G-T engine onwards. The short DLE combustor reduced the NoX emissions capability from the previous 45vppm down to <25vppm. This was combined with much improved combustor acoustic noise margins that could be further controlled with a variable split secondary (VSS) fuel system. One of the objectives of the uprate program was to retain the main package and PT interfaces. Therefore the G-T engine can be retrofitted into the previous RT62 berth and visa-versa.



RB211 G-T DLE Major Changes from RB211 G DLE



RB211 G

P30 = 295 psia
T30 = 748K

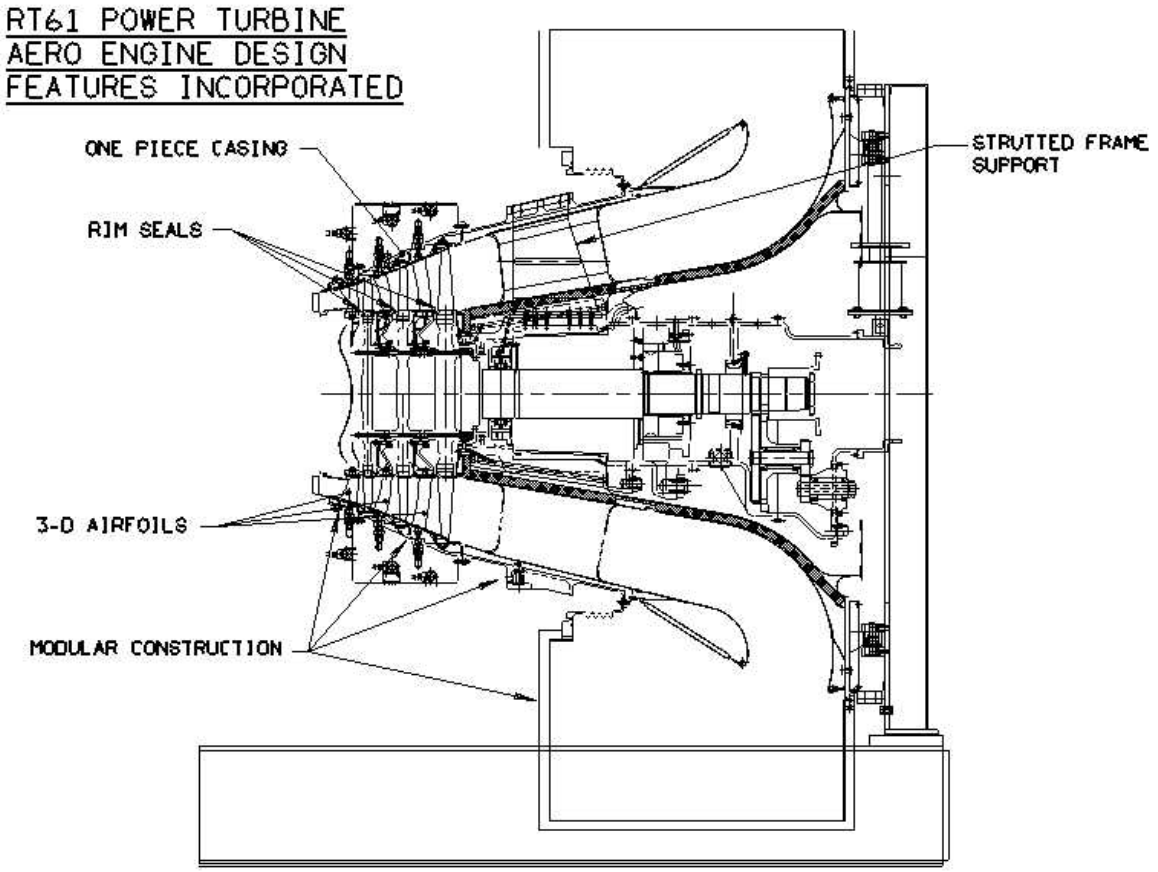
73000 BTU/s

Design SOT (T41) = 1495K

RB211 G-T DLE Operating conditions relative to RB211 G DLE

3.0 RT61 Features

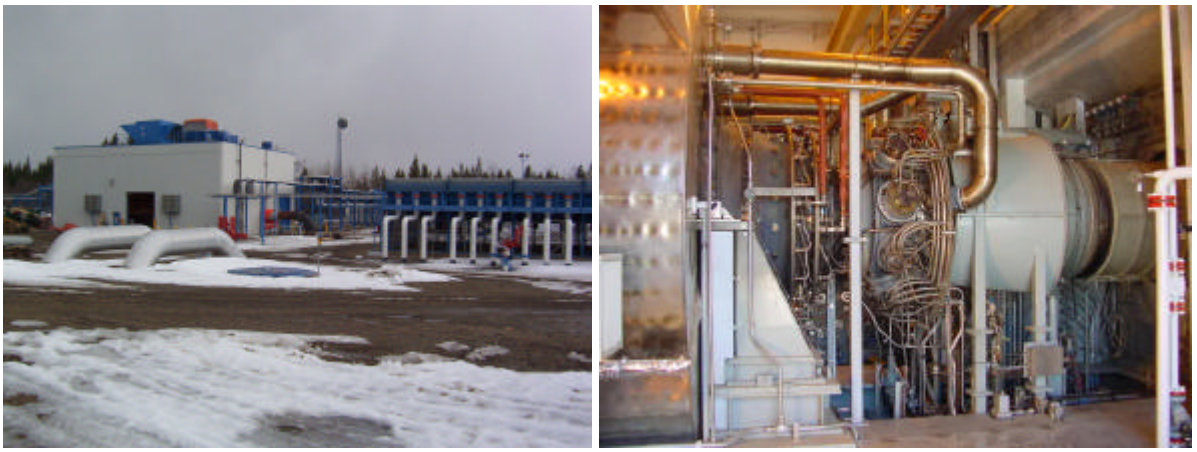
The power turbine was completely redesigned going from 2 to 3 stages, a new frame and bearing support and a new exhaust diffuser. The blading was designed using the latest aero engine technology. Improved rotor tip seals, rim seals and NGV sealing all contributed to the overall efficiency improvement. Materials were also revised to cope with the increased operating temperatures.



4.0 TCPL Nordegg Site Operational Experience

In 2002 TCPL elected to convert the existing 6456 (RB211C / RT56 PT) pipeline compression station at Nordegg Alberta to take a RB211 G-T DLE and the RT61 power turbine as a demonstrator. Although designated as a demonstrator the unit was expected

to operate in normal duty and achieve the 25,000-hour life typically achieved by G rated RB211's before removal for refurbishment of the combustion system and turbines.



TCPL Nordegg Compression Station and 6761 Berth

In addition to the new turbo machinery and Unit Health Monitoring (UHM) system was installed. This collects data from numerous measurement points on the unit, which is then processed and compared with performance models. The data is plotted as trends and published over the internet so that it can be viewed by engineers based at remote locations. The trends also have pre-defined alarm levels which will generate alarms in the event of significant changes from the baseline.

The engine was first installed in April 2003 and, following a commissioning period, entered commercial service in May 2003. It was finally removed for refurbishment in November 2006 having completed 24,233 hours and 190 starts.

4.1 Service History Summary.

During the operational period the most significant 6761-specific issues were as follows.

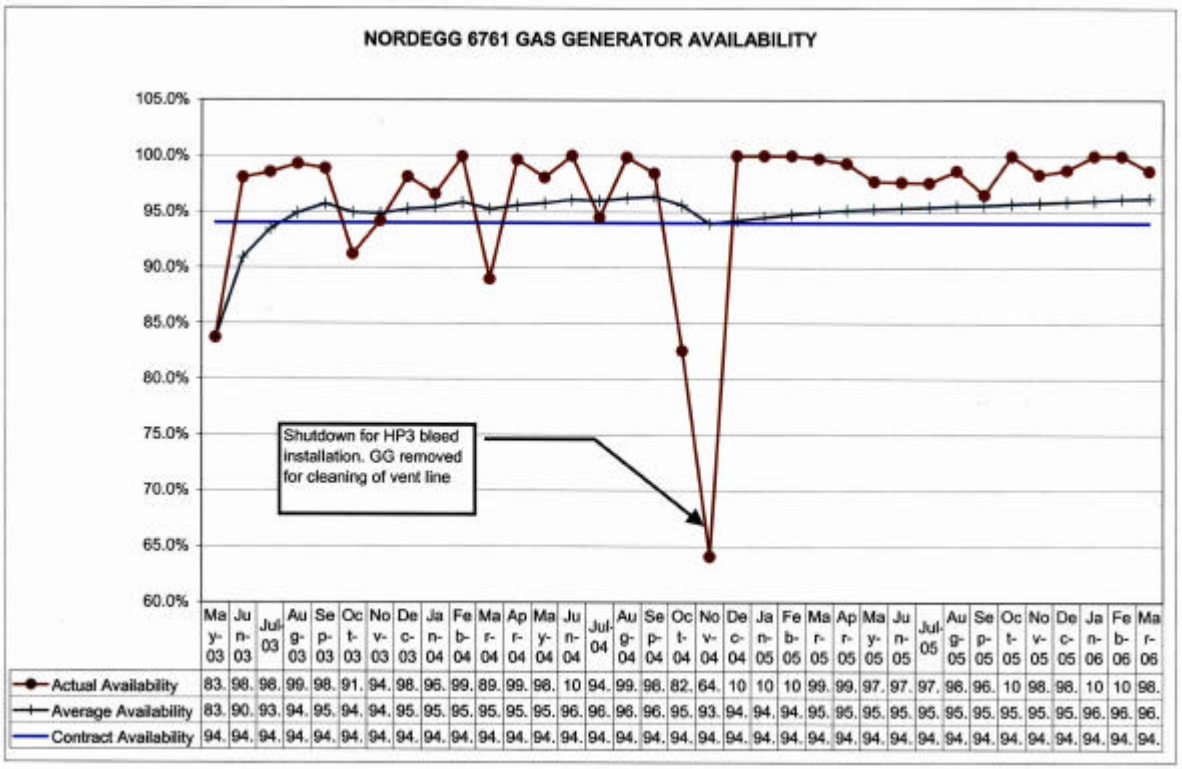
The most notable engine problem was that in June 2004 the IP Turbine bearing vent was found to be blocked with carbon. At this time the unit was out of service while a modification upgrade was carried out. The engine was therefore removed to a local overhaul base and the vent line cleaned. The cause of the carbon was found to be due to contamination of the oil by Zinc from the Dollinger oil system demister element. This is a known problem, which is resolved by fitting of a stainless steel element ref Service Information Letter 057.

The unit was shutdown during this period to allow installation of a modification to the engine to prevent compressor surges on trip shutdowns. Service experience had

shown that G-T 's are prone to surges particularly if the compressors are allowed to get dirty. The modification converts two of the starting HP BOV's by adding solenoids to open them immediately if the unit trips hence increasing the surge margin. This modification is now standard on all G-T's. Also in June 2004 the engine tripped due to a faulty centre bearing vibration probe. During subsequent start attempts the engine was found to have seized although, after cooling, it freed itself. When the engine was stripped for refurbishment the likely cause of the seizure was established as a damaged turbine labyrinth seal.

Between July 2003 and January 2004 the unit suffered a number of failures of the main oil pump. This is a gear pump driven by shaft from the PT and provides the primary oil supply to the PT and compressor bearings as well as a hydraulic drive for the RB211 oil pump. A comprehensive investigation was carried out including vibration surveys of the pump and optical measurements of the relative thermal growths of the pump and power turbine. This investigation resulted in significant changes to the system including selection of a different pump manufacturer, realignment of the pump with the PT and the use of flexible hoses for the pump inlet and outlet connections. The flow control for the hydraulic drive was also changed to provide better speed stability for the RB211 oil pump. These modifications have been very successful with no further main oil pump problems since October 2004 when the system was upgraded.
During this period running on the electrically driven standby pump minimized loss of unit availability.

Overall the unit performed very well in service, and after the RB211 was reinstalled in November 04 no further problems are recorded until final removal in Nov 06 having completed 24,233 hours and 190 starts. Since commercial service commenced the unit exceeded the contact availability of 94%. No combustor components were replaced during its life in order to maintain start reliability or noise / emissions compliance.

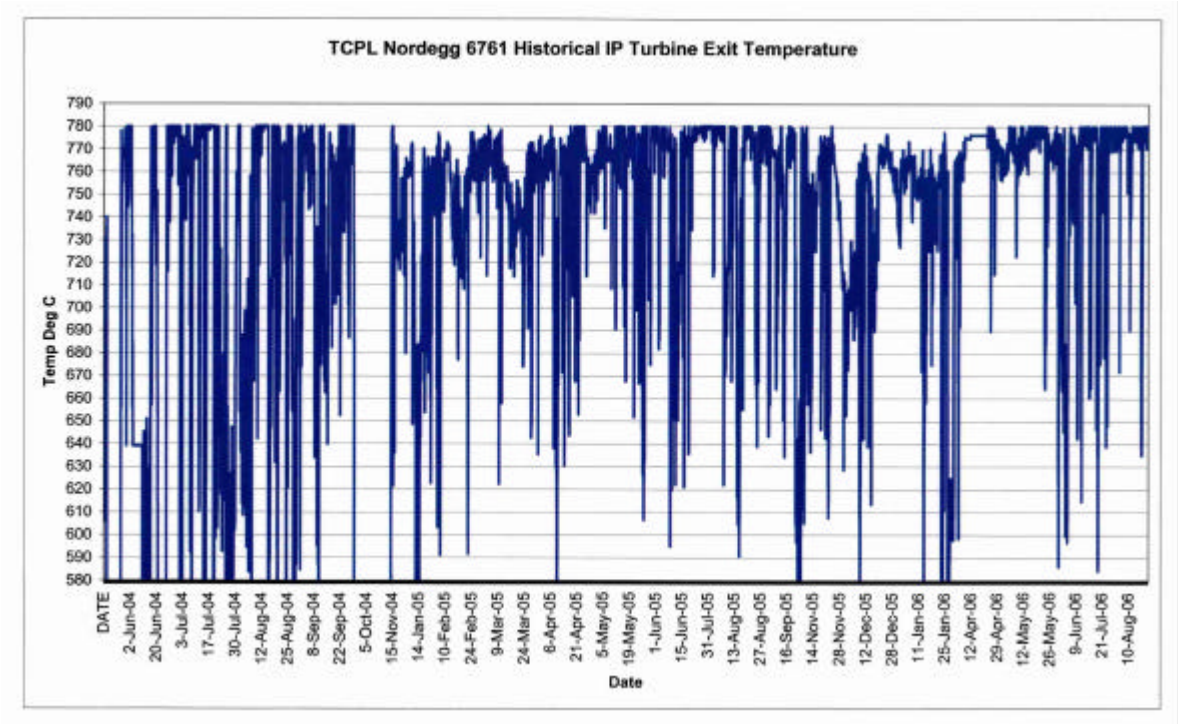


	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04	Jan-05	Feb-05	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05	Jan-06	Feb-06	Mar-06
Actual Availability	83.	98.	98.	99.	98.	91.	94.	98.	95.	99.	89.	99.	98.	10	94.	99.	96.	82.	64.	10	10	10	99.	99.	97.	97.	97.	98.	96.	10	98.	98.	10	10	98.
Average Availability	83.	90.	93.	94.	95.	94.	94.	95.	95.	95.	95.	95.	95.	96.	96.	96.	96.	95.	93.	94.	94.	94.	95.	95.	95.	95.	95.	95.	95.	95.	95.	95.	96.	96.	96.
Contract Availability	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.	94.

4.2 Running Profile

In conjunction with installation of the new turbo machinery a unit health monitoring (UHM) system was installed. This system records data from the unit control system, which is transmitted to RR for processing, analysis and trending. Data from UHM first became available from Feb 2004 and from then until the engine was removed no trends or step changes were observed that indicated any developing problems or the occurrence of faults.

The unprocessed data available on UHM was examined to understand the normal operating power / temperatures etc and hence the RB211 and PT mechanical condition. The typical IP turbine exit temperatures (T455), for instance, were generally 760-770 during the winter and between 770 and the limiting 780 Deg C during the winter. Over the range of ambient temperatures in Canada this represents powers between 23 and 33 Mw.



The combustion system is fitted with acoustic noise probes (CP103's) to detect the presence of combustor noise. If noise is detected the control system will change the secondary stage fuel distribution thus reducing noise. CP103 noise plots show D band noise of around 0.7psi although there was a change from April 06 with D band noise falling to approx 0.3psi. Whilst well within the running limit of 1.5psi experience from other short combustor engines indicates that, with tuning of the primary zone temp (TPZ), D-band noise levels of 0.3psi can be achieved. The running data shows that the primary zone temperature (TPZ) had been set at 1909K. This is very low and generally a higher TPZ of between 1920-1945 K can be used whilst maintaining acceptable NOx limits and reducing D-band noise. Minimising the combustion noise may have further reduced the wear seen on the combustor components ref section 5.1.4.2

5.0 RB211 Engine and Power Turbine Strip Condition

In November 2006 the Nordegg RB211, serial number 1890-2013, became the first G-T to be removed for a scheduled half-life refurbishment. This was carried out at the Rolls-Wood facility in Aberdeen. As the first RB211 G-T to achieve this milestone the opportunity was taken to carry out a detailed inspection to identify any problem areas. As is normal at mid-life the PT was not removed but inspected whilst installed in the berth. The following describes the condition of the engine and power turbine.

5.1 RB211 Engine Strip Condition

The engine was received at RWG on 27 November 2006, inducted into the workshop on Dec 5 and the bulk strip condition was viewed on Dec 12 with a representative from TCPL present. Although a thorough inspection was required, to minimise downtime the work

scope for the engine was based around that normally carried out on 25,000 hour engines i.e. refurbishment of the turbines and combustion system with minimal work on the compressors. Therefore wherever possible main assemblies were not detail stripped but were inspected in the built-up condition. On completion of the refurbishment the engine was tested and shipped back to TCPL on 30 March 2007.
The following describes the findings for each engine module and summarises the work carried out.

5.1.1 Module 1 Intake Casing

The M01 was inspected in the built-up condition and was found to be in normal condition with no particular defects. The module was clean overall and the condition of the VIGV's relative to rotor 1 suggested they have been hand cleaned at some time in service.
It was noted that the RVDT appeared to not have been aligned with the VIGV shaft resulting in deflection of the flexible coupling. It is not known if the RVDT has been disturbed whilst in service or if this condition has existed since new build. The bracket was a pre mod 1503 standard and therefore should have been aligned with use of a tool as instructed in SB129. This standard of bracket has been superseded by mod 1503, which incorporates a spigot location to ensure correct alignment without the use of a tool.
The thrust piston seals exhibited typical wear to the abradable linings.
Due to its good condition the M01 was left assembled with only routine maintenance carried out on the external accessories.

5.1.2 Module 2 IP Compressor

5.1.2.1 IP Compressor Casings

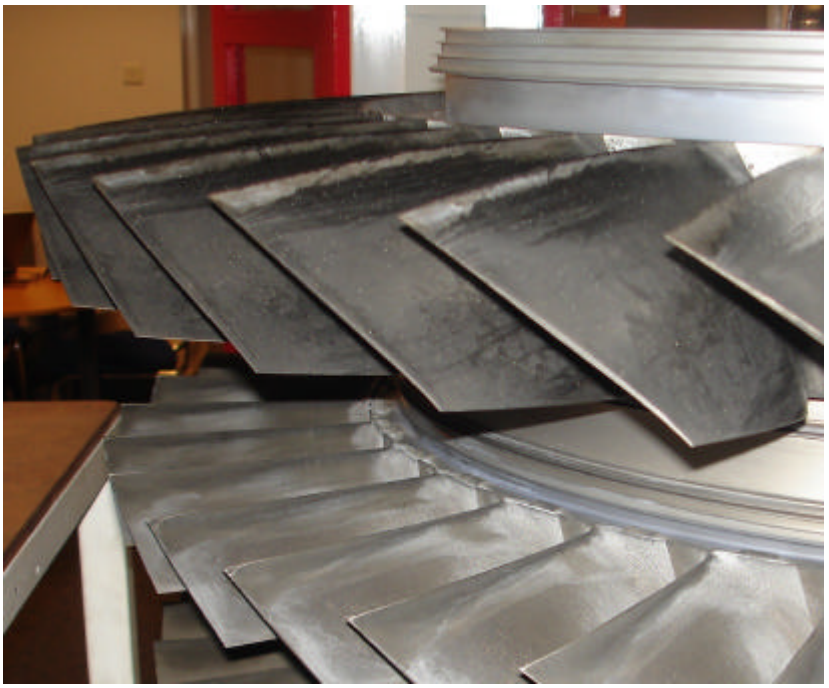
The IP stator case assemblies were examined in the built-up condition. Stator 1 was dirty mainly on the convex surface with a slight build up on the leading edge. The later stages became progressively cleaner with stages 4, 5 and 6 very clean with the coatings in good condition. The stator shroud rings on stage 5 and 6 were slightly loose indicating deterioration of the rubber however this is normal for the hours run. These stages were subsequently stripped for replacement of the shroud ring damping rubber, which is routine for all RB211's at 25,000 hours.

The only indications of rotor tip rubs were across the split line on rotor 1 and around most of the circumference on rotor 2, biased towards the trailing edge. However both took the form of swept clean areas with no material actually removed from the abradable lining. Measurements of the blade lengths and casing diameters confirmed the tip clearances to be within new build limits.

Rubs in the stator seals were heaviest on stage 1, progressively reducing on the later stages with no rubs present on stages 5 and 6. Due to their good condition no replacement of either rotor path or stator abradable linings was found necessary.

5.1.2.2 IP Compressor Rotor

The IP compressor rotor assembly was inspected in the built-up condition. The IP rotor stage 1 and 2 blades were dirty with a hard black contaminant. There was a slight build-up on the leading edge of rotor 1. Stage 3-6 blades were relatively clean.



IP Compressor Rotor First and second stage blades

One rotor 2 blade was noted as missing a 2x2mm corner from the leading edge. Examination indicated this was as the result of FOD and it was subsequently dressed out. The stage 3,4 and 5 blade lockplates were loose but this is normal for the hours run. No further work was carried out on the IP rotor assembly.

5.1.3 Module 3 Intermediate Casing

The M03 was inspected in the built-up condition and was found to be in good condition externally.

The G-T standard IPOGV assembly was in very good condition with no movement detectable by hand in the shroud ring or the vanes when inspected in the casing. The vanes were clean with the coating in very good condition. As is normal at 25,000 hours the IPOGV assembly was removed for replacement of the shroud ring damping rubber. Detailed inspection confirmed that no wear was present on the vane feet.

Removal of one of the HP speed probes revealed heavy oil contamination outboard of the inner O-ring seal. The other speed probe was stuck in the casing presumably due to heavy oil / carbon build-up which initially prevented it being removed from the housing. Leakage

of oil past the inner O-ring has been seen on most G-T's stripped to date although no operational problems have been seen as a result and this was not considered a concern. The M03 was stripped sufficiently to enable the time expired HP thrust bearing to be removed and replaced with a modified version giving improved life. The G-T engine generates higher bearing thrust loads and consequently a HP bearing with improved material was introduced to ensure the required 50,000+ hours life. The mod 1368 bearings were not available when the early G-T engines were built and therefore the pre-mod bearings are being replaced at the first shop visit.

5.1.4 Module 4 HP Spool & Combustion Assembly

5.1.4.1 HP Compressor

The HP compressor rotor was inspected in the built-up state and found to be in good condition although minor FOD was present on a numerous blades throughout the compressor. No corrosion was present and the coating on rotor 2 was in good condition although there were minor impact chips. It was necessary to replace 13-off stage 1, and 5-off stage 6 blades as they were deemed to be outside the available FOD dressing limits.

The rotor path linings were in good condition with only stage 2 showing any obvious indication of a blade rub over 270 Deg. The surface of the rotor path linings on stages 1, 4, 5 and 6 did exhibit a slight glaze over most of the circumference that may indicate very light contact with the rotor blades. No glaze was visible on stage 3.

Measurement of the tip clearances indicated very small increases over new build limits and as the linings were in good condition they were not replaced.

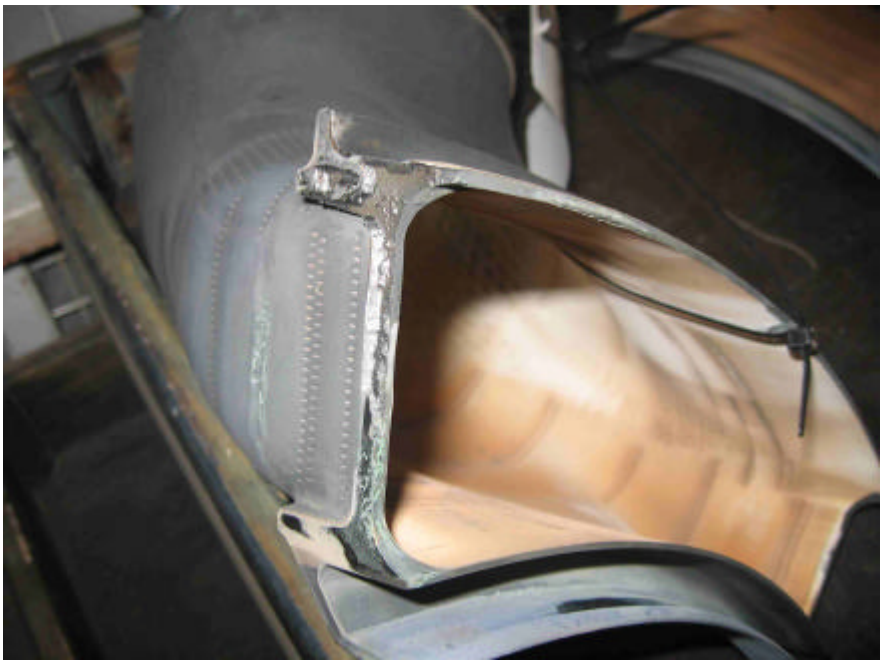
The stator vane aerofoils were in good condition although FOD was present on a number requiring 2-off stage 1 and 1-off stage 5 vanes to be replaced. Rubs were present on the stage 1, 2, 3 and 4 platform seals over 180-360 degrees. No rub was present on the stage 5 stator seal. As the stator seal linings were in good condition they were not replaced.

5.1.4.2 Combustion System

All of the combustion supports exhibit typical wear on the discharge nozzle pads upto approx 0.020 – 0.030'' in depth. The discharge nozzle upper location bore generally exhibited polish marks only with very little material loss. The combustor lower location bore appeared to be in 'as new' condition.

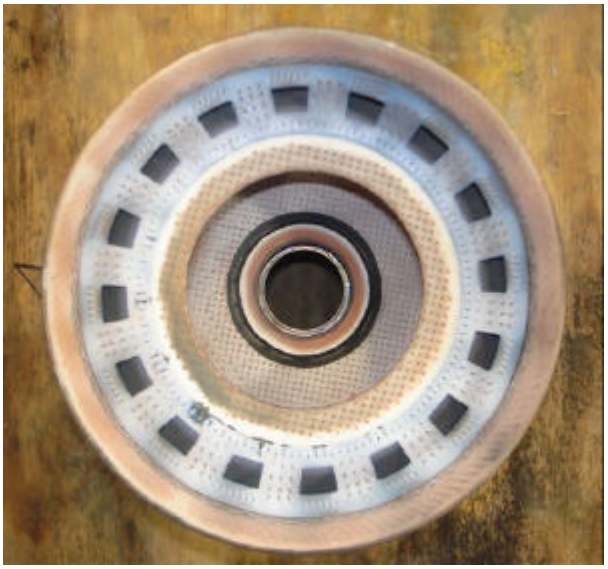
The discharge nozzles were in typical condition with the various surfaces found as follows:-

All exhibit typical wear to the exit casting side cheeks of upto to 1,5mm in depth. The TBC was in good general condition except for a hot streak evident in the centre of the outer annulus at the exit end. A similar effect was recently seen on a 'G' rated short combustor engine.
The outer rail TBC was in good condition with only # 7, 8 and 9 having lost any of the coating. The inner rail location dogs showed significant wear of up to 1,5mm in depth. The inner rail birds-mouth surfaces showed light wear only with little material loss.
The location dogs exhibited significant wear but less than the mating surface on the combustion support.



Combustor Discharge Nozzle

The combustion liners were in very good condition. The secondary rings were in excellent condition with a few small cracks around the secondary windows and very few areas of sulphidation. The cracking around the secondary windows was well within the limits for continued service running ref SB139. The primary splitter had a small amount of erosion around the exit diameter. The primary and secondary barrels were in good condition with no corrosion or significant TBC loss.



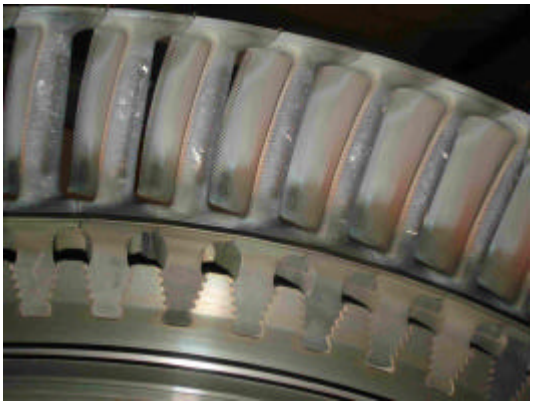
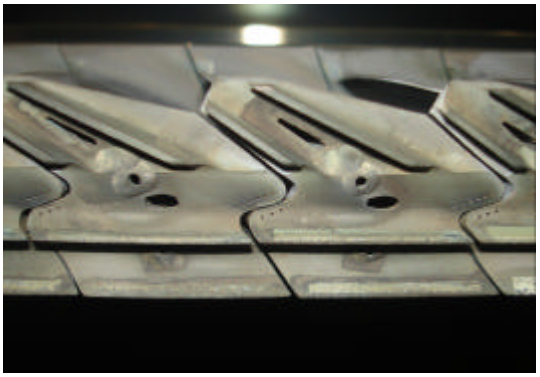

Combustor General View and detail of Secondary Window Area

All of the combustion liners, discharge nozzles and supports were repaired using standard repair schemes.

There were no mechanical issues noted with the fuel injector assemblies and these were sent to the manufacturers for 'as received' flow checks prior to cleaning.

5.1.4.3 HP Turbine

The HP turbine blade interlocks were tight generally with slight movement of only 20 blades possible by hand. There was no erosion evident of the non-abutment faces, which still achieved as new clearances. The interlock abutment faces all had a black shiny appearance although some had a slightly uneven hammered appearance. However aero experience is that this appearance is typical for this type of blade. The shroud seal fins were in good condition with no erosion or wear visible. The tip fences exhibited only very light contact marks with the honeycomb. The aerofoils were in good condition with no indications of coating loss or erosion. There was some white splatter on the leading edges, which is often as a result of impact from TBC released from the combustion system.

HP Turbine Rotor General View and Shroud Detail

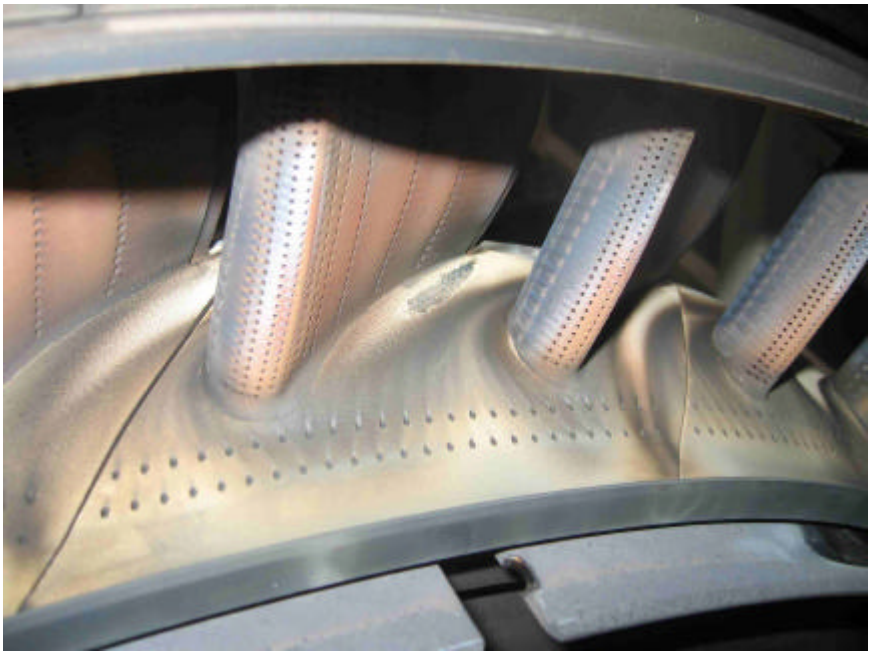
Strip of the HP turbine rotor assembly revealed heavy wear to the blade root dampers. On some, this wear was sufficient to result in the damper breaking in half. There were also matching frettage marks on the blade lockplates where the damper makes contact. Wear to this extent has not been seen on aero engines and therefore it is likely to be related to the speeds and temperatures typically seen in industrial operation. However as the HP turbine assembly had satisfactorily achieved its required life and, as the dampers are sacrificial parts normally replaced whenever the turbine rotor is dismantled, this is not regarded as a life-limiting problem. Further investigation will be carried out to understand the wear mechanism. Additional G-T engines, 2 of which are due to have 25K overhauls conducted within the next 6 months, will be inspected to further assess the damper condition.

HP Turbine Root Dampers

As repair schemes for the G-T HP blades are still under development they were replaced with new components for rebuild. The old blades are held awaiting overhaul although a number have been used for investigation into cleaning of the damper surface, internal sulphidation and coating trials.

The HP rotor stub shaft was found to have a deposit of metal adhering to the seal fins, this was found to be Metco from the bearing seal lining (ref sect 4.1 and 5.1.5).

The HPNGV's were in good condition with some TBC loss but no significant erosion of the inner trailing edge platforms as often seen on DLE engines. Other than small patches of TBC loss there were no hot spots on the outer platform or the aerofoils. All of the HPNGV's were subsequently overhauled using standard repair schemes.



HP Nozzle Guide Vane leading Edge

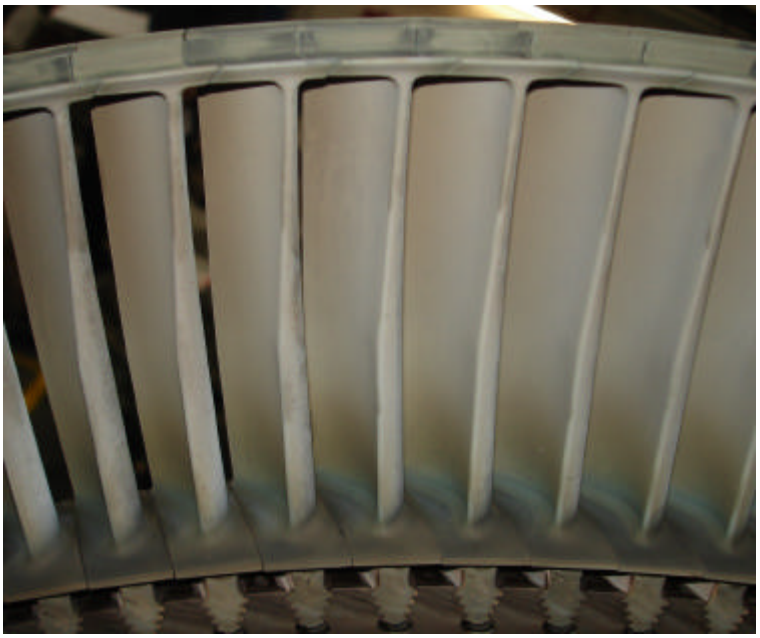
The discharge nozzle inner rail dog slots exhibited heavy wear, matching that on the discharge nozzles dogs. This is not unusual and was repaired using standard repair schemes.

The HP seal segments were in good condition with slight bowing of the backing evident and thinning of the bird's mouth at the IPNGV interface. There was some high temperature erosion in the centre of the backing but no cracking was evident visually. The honeycomb was in very good condition and the front stage, which is often eroded down level with the backing, was only eroded down level with the filler. However despite their good overall condition all the segments were subsequently rejected for thinning of the rear inner birdmouth at the centre and ends down to 0.061''-0.066'' against a min thickness of 0.071''. Although some thinning and cracking in the centre is commonly seen rejection at only 25k hours is unusual. However there is some evidence from the development programme that the short combustor has a slightly more outboard traverse

than that of the long combustor, which could explain the HP seal segment condition. A modification to apply Sermaloy J to the seal segments is now becoming available and it is likely that had it been applied the segments would have been sufficiently protected for them to be repairable at this point.

5.1.5 M05 IP Turbine

The IP turbine rotor was in good condition and therefore not stripped, but inspected in the built-up state. The blade interlocks all very tight with no movement of the shrouds possible by hand. Measurements confirmed the level of interlock wear was sufficiently small for a further life to be achieved without repair at this stage. No contact was evident on the knife seal land on the disc. The shaft was clean with no corrosion or oil staining present. No wear was present on the shaft splines. Due to its condition no further work was carried out on the IP turbine rotor.



IP Turbine Rotor Blades.

The IP seal segments within the casing assembly showed a typical green appearance with patches of light surface erosion. Gaps between some of the segments were beginning to open up. The honeycomb lining was in good condition for the hours with a few patches on the front stage eroded down close to the backing. All the seal segments were repaired and refitted.

The seal segment retainers and exit liners were in excellent condition with no distortion, erosion or corrosion evident.

IP Turbine Nozzle Guide vanes and Seal Segments

The HP turbine roller bearing Metco seal was found to be almost completely removed from the carrier. Ref also section 5.1.4.3. This is probably due to a heavy rub with the rotor labyrinth at some point resulting in the Metco being torn out. With reference to section 4.1 note that the engine was reported as seizing in June 2004 following a trip shutdown. This is probably the event that damaged the seal. However there did not appear to have been any detrimental effects as a result as the area outside the seal was still clean and dry. Both HP and IP roller bearings were felt to run smoothly which indicates that there has been no significant carbon accumulation inside the housing.
The IPNGV's had a grey / green colouration, but were in good condition with no apparent deterioration of the coating. Subsequent visual inspection revealed cracks in 2 of the IPNGV's in the radius between the trailing edge aerofoil and outer platform. Cracks in this area have not been seen before and therefore these two vanes were replaced with new components and the rejected vanes returned to Montreal for engineering lab investigation.

5.1.6 M06 Externals

Both vent covers (mushrooms) were noted as missing from the IP BOV pistons. One was found trapped in the IP BOV cage. In the other IP BOV a dent was noted in the cage possibly from impact with the mushroom but it could not be located. As the BOV cage was intact the mushroom must have been drawn into the engine and may have been responsible for the FOD damage at the front of the HP compressor. Loss of the IPBOV mushroom is commonly seen and improved fitting or complete removal is being investigated. A longer-term solution involving a completely new design of IPBOV is also in progress.

No other problems of significance were found in any of the external dressing items and all were subjected to normal inspection and overhaul before refitting

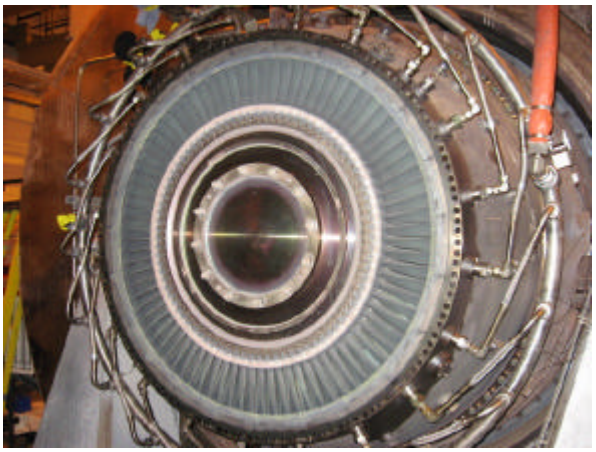
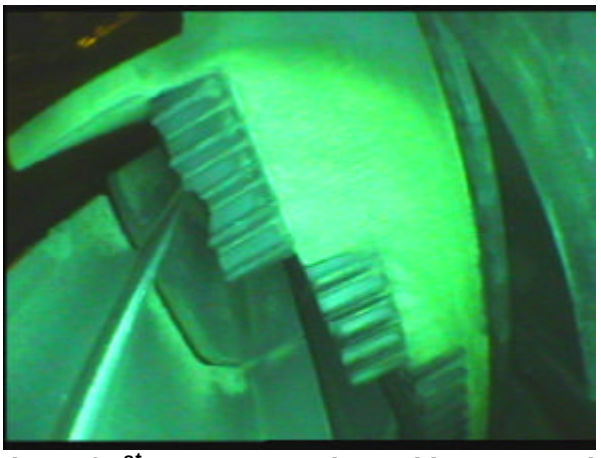
5.2 RT61 Power Turbine Strip Condition

The Power turbine was inspected in the Nordegg berth. The 'D' module, which comprises the inlet guide vanes, was removed to facilitate the inspection of the 'T' module, which comprises the main rotor, stator and casing assembly.

The 'D' module was found to be in good condition with no cracking or oxidation of the vanes present although FOD was evident in the trailing edge of one aerofoil. Measurements of the front inner seal showed some deformation. However there had been no contact with the matching rotating seal on the rear of the RB211 IP turbine disc and therefore this is not of concern.

'D' Module removed.

The 'T' module was in excellent overall condition. The first stage blades were inspected directly, the remaining rotor and stators viewed by borescope. All the rotor and stator aerofoils were in good condition with no cracking or oxidation present.
Wear of the stage 1 rotor tip seals was good with a clear, concentric witness in the honeycomb over the front fin and light rubs in the intermediate and rear honeycomb stages. The second stage tip seals were inspected by borescope and this showed heavier wear with a rolled edge evident in the rotor fin. Inspection of the third stage tip seals was not possible as access to the exhaust volute was not available.

'T' Module General view and borescope view of 1st stage rotor tip and honeycomb Seal

The exterior of the PT was in good condition although some heat staining was evident around the rear of the exhaust hood. This is caused by gas leaks though the bolted joints between the hood sections. These joints are difficult to access and as the leakage is acceptable currently this will be rectified during a future major maintenance outage.

Examination of the PT bearings was not possible as both the crane capacity and access are limited. This is primarily due to the crane being configured for the previous RT56 PT installation. This will be rectified prior to the next major inspection at 50,000 hours.

6.0 Conclusions

Overall the engine and power turbine were in very good condition and following normal refurbishment and servicing were cleared for a further 25,000 hours operation.

The only significant problem in the RB211 was the HP turbine blade damper frettage. The dampers are regarded as sacrificial parts and normally replaced when the rotor is stripped. The frettage to the blade damper surfaces is not a life-limiting problem and it is anticipated it would be repaired as part of the normal overhaul process.

Wear to the combustion system components was similar to that exhibited for long combustor DLE machines and the components were all within the normal repair limits. There is little experience as yet on 25k hour short combustor G-T engines although a G rated short combustor engine exhibited significantly less wear than 1890-2013. This may indicate that with better optimisation of the fuel map, a further reduction in combustor noise and therefore wear could have been achieved. The combustion liners themselves were in very good condition with little cracking and oxidation around the secondary windows.

Functionally the combustion system had performed very well in service with no reported starting problems or operational restrictions as a result of acoustic noise problems. As a result of the Nordegg experience TCPL have initiated a programme to convert their existing fleet of 'long' combustor RB211 DLE's to the 'short' combustor.

Cracking and oxidation of the HPNGV platforms was minimal indicating that the short combustor has been successful in reducing temperatures in this area.

Although the HPNGV inner platform were in good condition the HP seal segments were rejected due to thinning of the inner bird's mouth. It is likely that this could have been avoided by the application of Sermaloy J coating to mod 1504.

The PT was in very good condition with no defects or areas of concern. Failures of the main oil pump were encountered in the first year of operation. Following a detailed investigation a revised pump and installation was fitted in October 2004 and there have been no further problems since.

Over the next 4 months two further G-T engines are scheduled for overhaul having achieved 25k hours and these will provide additional evidence on the condition of G-T engines and RT61 PT's after 25,000 hours.

Since the TCPL Nordegg unit commenced operation the G-T fleet has grown, and now comprises a total of 27 DLE engines in service with a further 15 on order. In addition to the DLE units a further 26 conventional combustor 6761's are in service or on order. Total 6761 fleet running hours are approx 250,000.

Overall the 6761 service experience has been remarkably trouble free. The Nordegg RB211 and PT condition have shown no major lifing issues and the 6761 fleet is expected to demonstrate the same exemplary service experience as the previous variants.

7.0 References

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