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15TH SYMPOSIUM ON INDUSTRIAL APPLICATIONS OF GAS TURBINES

A COLLABORATIVE APPROACH TO RESOLVING ISSUES WITH RB211 DLE/6562 UNITS

by

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Biographies Session 2.1

Robert Betts

Bob has been in the field of Rotating Equipment for more than 35 years. For the past thirteen years Bob has worked for TransCanada Pipelines as a Senior Rotating Equipment Specialist.

Bob graduated from Southend Technical College in England in 1968 with a City & Guilds diploma an later an Engineering degree. Bob has been a member of the American Society for Mechanical Engineers for 24 years.

Bob has presented many technical papers at the Gas Turbine Users Conference, past Canadian Gas Association Conferences, the National Petroleum Refining Association, and the Vibration Institute on a variety of subjects.

For the past ten years Bob has been specializing in TransCanada's Rolls-Royce compression units and has served as the technical leader on the Rolls-Royce & TransCanada "Alliance" team.

Peter Handy

Peter Handy holds a BSc in Mechanical Engineering from the University of Manchester Institute of Science and Technology and is an AMIMechE.

He joined Rolls-Royce, Industrial & Marine in 1966 and held positions in Applications, Test and Sales Engineering within the U.K..

In 1984 he transferred to Rolls-Royce Canada Ltd. He currently holds the position of Director Technical Support – Americas within the Customer Service Business, Energy Group.

Colin Lucas

Joined Rolls Royce in 1974 as Fuel Controls Development Engineer for approx 3 years, then as UK-based Field Service Engineer until October 1981. The latter included approx 18 months based in Tehran, Iran at the National Iranian Oil Company.

Transferred to Rolls Royce Inc (USA) in October 1981 as Field Service Representative in Atlanta, Georgia. Based near Maracaibo, Venezuela for approx 18 months with PDVSA then transferred to Rolls office in Anchorage, Alaska. Moved to current Coeur d'Alene, Idaho location for first DLE engine support in 1993.

Approx 3 years as US Field Support Manager and currently Technical Services Manager for approx 3 years now with CSB Energy Group, reporting to Peter Handy.

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Title of Paper

A collaborative approach to resolving issues with RB211 DLE/6562 units.

INTRODUCTION

In the fall of 2001 an agreement was reached on the formation of an alliance between two companies, Rolls-Royce Energy Systems Inc. and TransCanada Pipelines Limited. The mission was to provide solutions and benefits that would enhance both companies' performance.

One of the first issues to be addressed by the Alliance involved the RB211 DLE 6562 fleet and TransCanada's focus on reducing unscheduled outages and demonstrating satisfactory DLE operation throughout the year.

This paper deals with the formation of a technical team within the Alliance, the team's mandate, possible solutions, risk management, applied solutions and results to-date.

The technical team comprised of a core of 5 technical staff from both Rolls-Royce and TCPL with additional resource seconded to the team as necessary.

Mandate:

To get a reliable 24,000 hours on the

RB211 DLE 6562 units between overhauls

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INTRODUCTION (Continued)

The technical team identified the following key areas as those requiring resolutions to meet the mission statement.

(1) How to optimise combustor noise and it's protection system.

(2) Power pull back due to higher than desired combustor noise predominant at very low ambient temperatures.

(3) Unscheduled outages and downtime creating unbudgeted repair costs caused by hot section component limitations.

(4) Higher than expected mid-life overhaul costs.

(5) Optimisation of gas fuel delivery to prevent fuel system contamination.

POSSIBLE SOLUTIONS

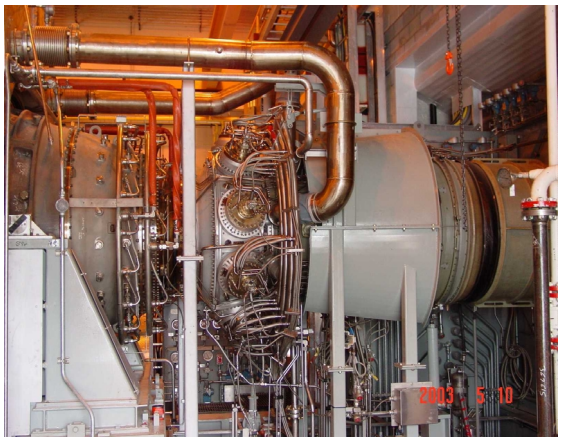
A proposed solution was put to TransCanada and Rolls-Royce senior management in the form of three alternatives with estimated costs and a risk evaluation. These three alternatives were: -

A) Retrofitting a package of modifications to the existing DLE long combustor including a fixed split flow system on the TCPL twenty-three RB211 DLE sites.

B) Retrofitting the short DLE combustor with fixed split flow system in place of the existing long combustor with the associated package changes.

C) Retrofitting the short DLE combustors with the variable split flow system in place of the long combustor and with the associated package changes.

Short DLE Combustor with variable split flow



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POSSIBLE SOLUTIONS (Continued)

The senior management reviewed the options and selected the team's recommended solution of retrofitting the package of modifications to the existing long combustor including a fixed split flow system on TCPL twenty-three RB211 DLE sites.

Significant in this decision process was the cost and downtime impact of each of these possible solutions. The selected solution offered a technical solution at 20% of the cost of any alternative whilst minimising site disruptions.

RISK MANAGEMENT

One of the challenges whist implementing the package of modifications was the risk management of the existing TCPL fleet which contained various mod standards and operating hours. Therefore the team took the DLE units and catagorized them into the following risk priorities.

RISK MANAGEMENT (Continued)

HIGH RISK Imminent risk of unscheduled outage without modification, these units had a documented history of high combustor noise due to low mod standard and fuel conditioning concerns.

MEDIUM RISK No history of problems, however requiring further inspection to document current condition.

LOW RISK These units had recently been inspected and were found to be in good condition and were without documented issues.

With the above risk categories defined and based upon gas generator hours, a work chart was drawn up to determine site priorities, site work content, downtime availability, labour resources, site test equipment and overhaul shop work.

RISK MANAGEMENT (Continued)

Testing One of the key areas of risk management is the ability to quantify the conditions of the in-field equipment. The team was faced with a wide range of 'as is' conditions at each site. Knowing the required modification package allowed us to plan the hardware change but the difficult part was to manage the varied condition of the equipment until each site was upgraded. We needed to develop tools to assess and monitor the condition or health of the units.

Three key areas were selected:-

(1) Verify DLE gas injector condition.

Fuel injectors are always high on the list of importance as their operation affects not only the downstream hot gas components but, with the DLE, emissions output and combustor noise.

An injector flow test kit was developed to flow check the DLE injectors on-site and determine their flow performance relative to the 'as new' condition.

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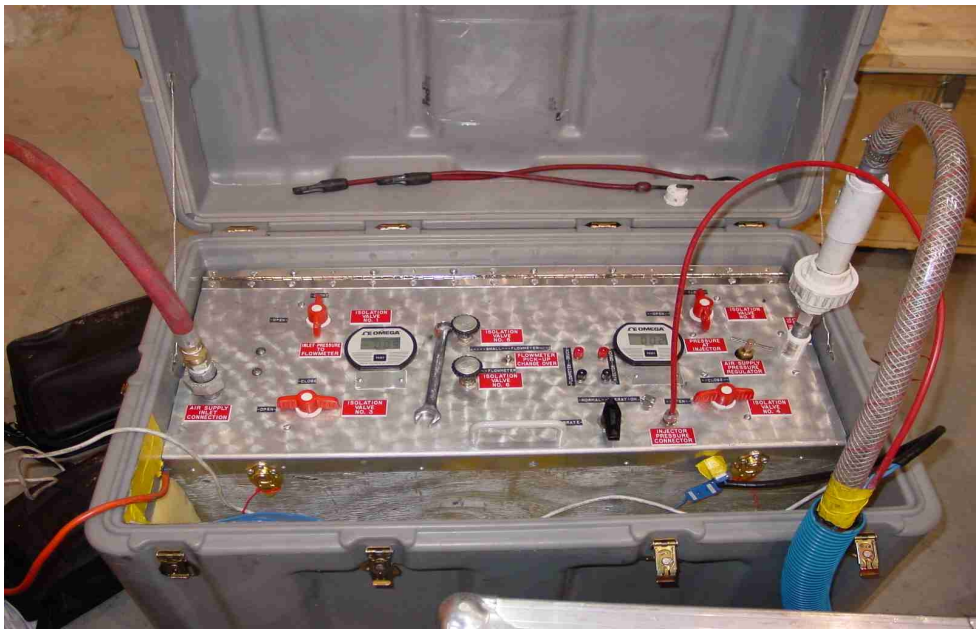

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RISK MANAGEMENT (Continued)

Testing

(Continued) (1) The kit was designed to be transportable and can be re-calibrated against a new set of injectors. The kit has been used to check out injectors suspected to have suffered contamination as well as to verify the acceptable condition of injectors as a part of the documented database.

(2) DLE Combustor Noise Survey.

One of the key driving forces leading to unscheduled outages has been DLE combustor generated noise. On site noise protection was based on a test bed noise survey on all 9 combustors, but often, subsequent in-field component changes negated those surveys. An in-field test kit, able to measure all 9 combustor signatures was developed to obtain noise datums at sites where none existed and also to enable a review of the optimum location for the 2 noise probes used to protect the DLE RB211 in normal operation.

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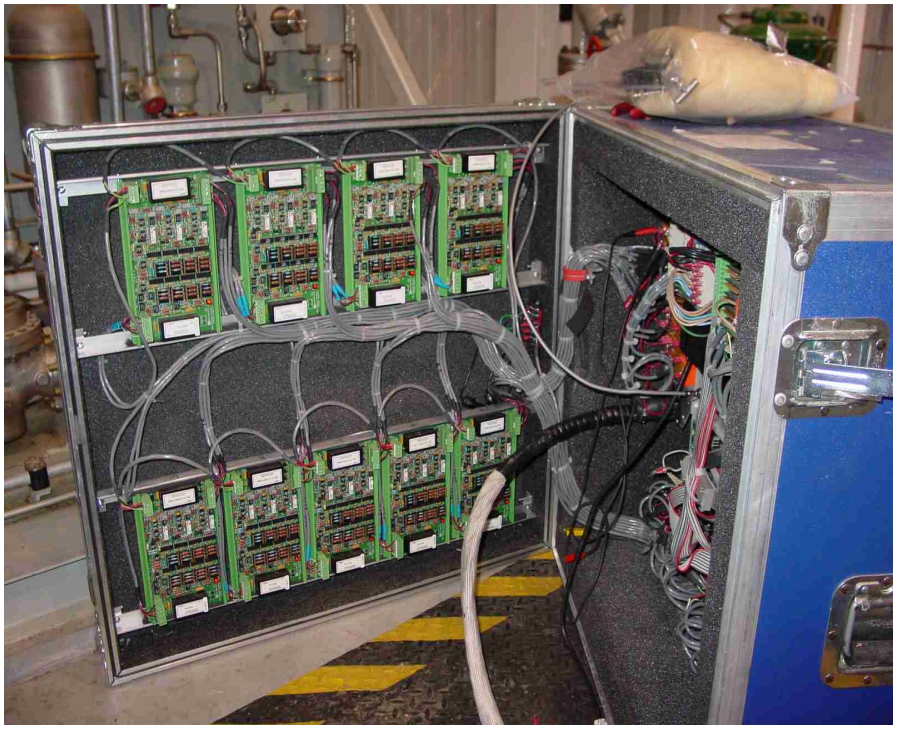

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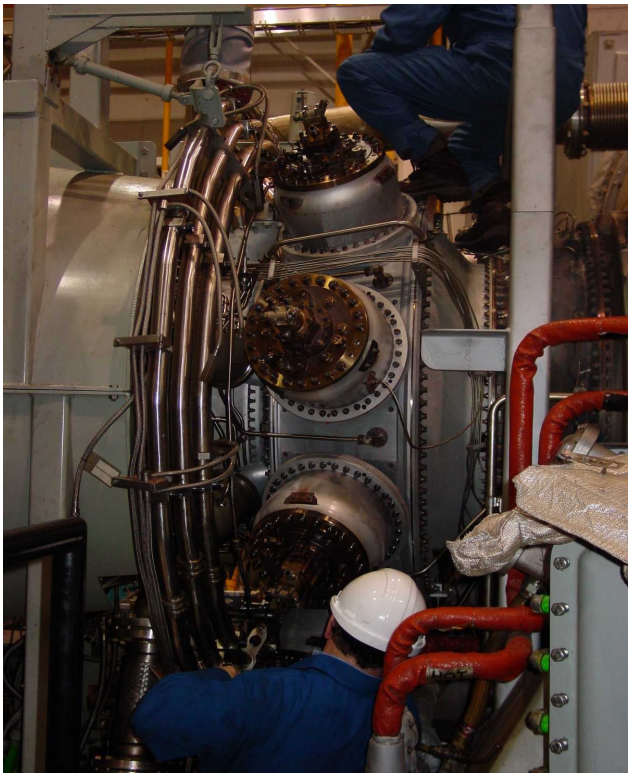

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RISK MANAGEMENT (Continued)

Testing

(Continued) (2) This kit has proved extremely beneficial in both the data recorded and also in the minimal downtime required to set up the equipment and test. Note the alternative was a return to shop for test which adversely affects unit availability and increases costs significantly.

(3) Exhaust Gas Temperature (EGT) Trending

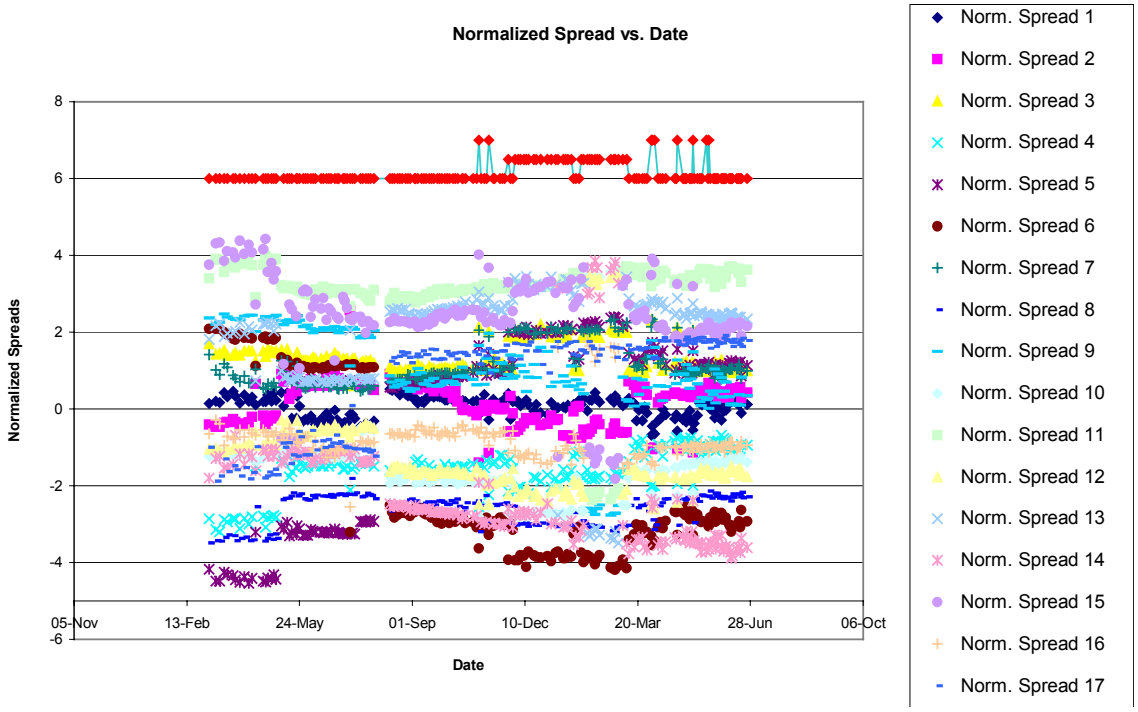
The third important tool used to minimise risk was the derivation of trending and grouping of on line EGT data.

We found that detection of discharge nozzle cracking (caused by high combustor noise) could be detected in its early stages thus preventing the risk of secondary damage caused by the release of material into the hot gas path. The formation of cracks affected the air flow to the DLE combustor causing a shift in EGT pattern. This shift was found to be trendable.

RISK MANAGEMENT (Continued)

Testing

(Continued) (3)



Individual EGT trending also served to pinpoint sites where injector flow tests should be performed if discharge nozzle cracking was not substantiated by boroscope inspection.

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SOLUTIONS

Dry low emissions technology and gas generator manufacturers around the world have learnt over the past years that the narrow band high-energy release associated with pre-mix combustion can cause a resonance within the combustion system. It is this resonance that if allowed to persist at abnormal levels may cause premature degradation of the combustion components.

The following Rolls-Royce modifications were applied by the Alliance team to prevent such an occurrence.

Modifications Rolls-Royce modification #1293 permitted all nine combustors to be noise monitored, this allowed the team to optimise the in-field noise protection system by continuously monitoring the two noisiest combustors and ensuring they remained within normal Rolls-Royce acceptance limits. This modification could be installed on site or at an overhaul and repair base.

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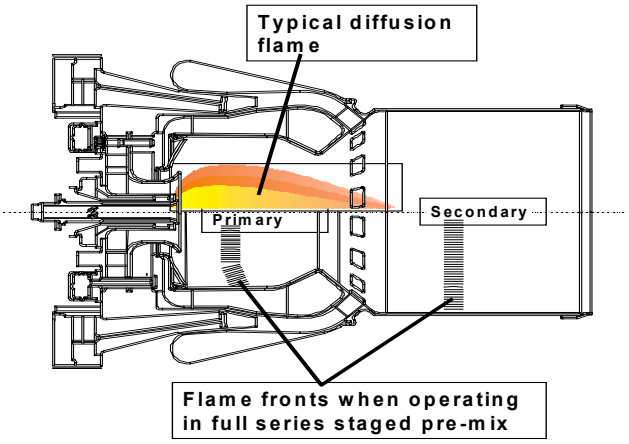
SOLUTIONS (Continued)

Modifications

(Continued) The next vugraph demonstrates the original concept of dry low emissions technology where air and fuel are premixed and introduced into a staged combustion system to burn quickly at each stage. However, this system has been found to be sensitive to the level of energy release – particularly on colder days when mass flows increase. The focused energy release can excite combustor/discharge nozzle hardware with the risk of subsequent cracking.

DLE combustion process



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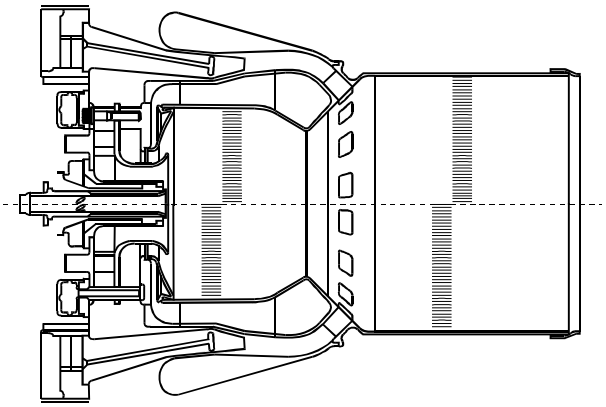
SOLUTIONS (Continued)

Modifications

(Continued) In this next Vugraph Rolls-Royce modification #1358 introduces an asymmetry to both stages of combustion. The net effect is to detune the focused energy release from the hardware resonant point by spreading it over a longer section of combustor. The improved flame pattern has significantly reduced combustor noise without increasing emissions levels.

RB211 DLE - Split secondary fuelling



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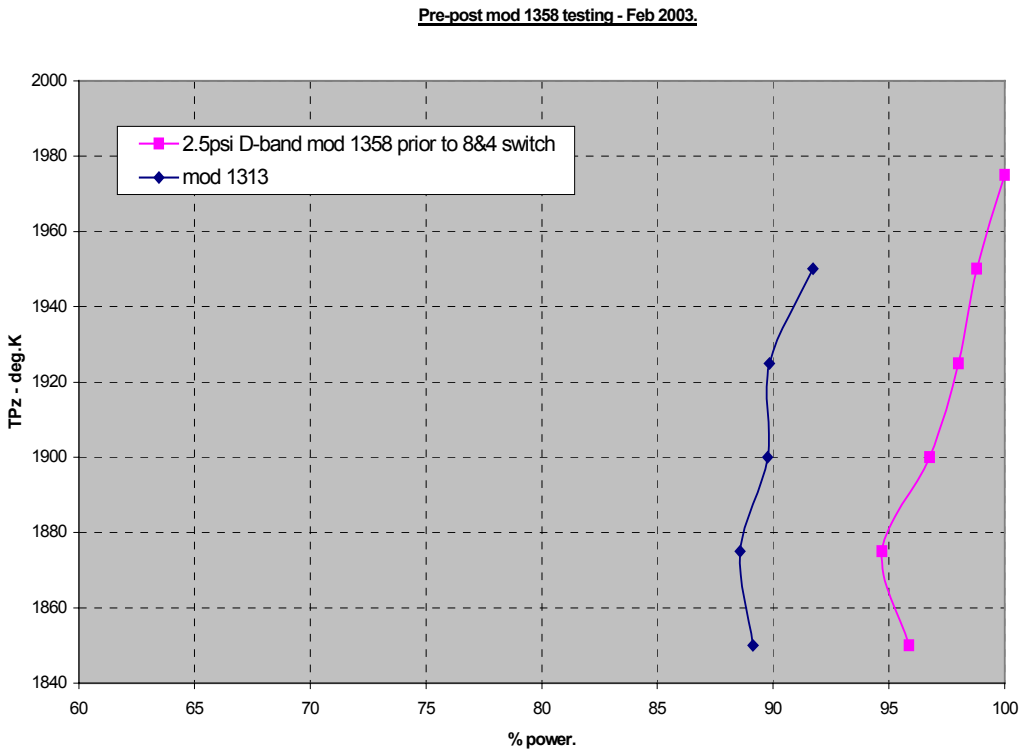
SOLUTIONS (Continued)

Modifications

(Continued) This modification was installed both on site and, when convenient, at overhaul and repair bases. The results of a before and after back to back test are shown here –



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SOLUTIONS (Continued)

Modifications

(Continued) The addition of this modification alone increased the ability to run in full DLE mode from 90%power to full power on a –23°C day. Further component changes/tests are planned for this winter to extend this units DLE operation.

The second significant factor in generating unscheduled removals was determined to be limited to sites with limited capacity for fuel gas conditioning. These sites were found to be depositing a fine sulphur powder downstream of the final gas filters. This powder would not only restrict fuel valve operation but also create blockage within the DLE fuel injectors with one unit suffering severe secondary damage as a result.

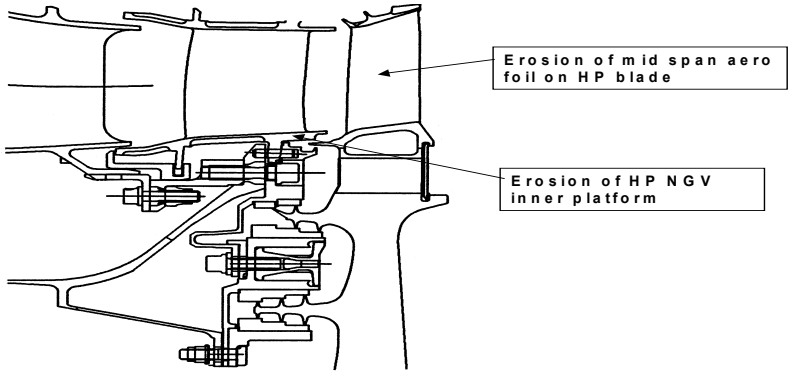
SOLUTIONS (Continued)

Modifications

(Continued) The solution was to replace the existing filters with improved filter/coalescers and to increase the fuel heating capability downstream of the filter/coalescer. Seven sites were addressed, having experienced sulphur drop-out. Subsequent to the modifications, over 12 months of operation has been achieved without sulphur drop-out.

Overhaul & Repair One of the resultant effects of the early DLE injector was found to create an 'inboard' temperature traverse, which resulted in premature degradation of the HP NGV inner platform. Of particular concern was the rear lip which, when allowed to degrade too far, could adversely affect the cooling flow to the HP disc/blade assembly.

HP Blade Erosion & HP NGV Inner Platform Erosion



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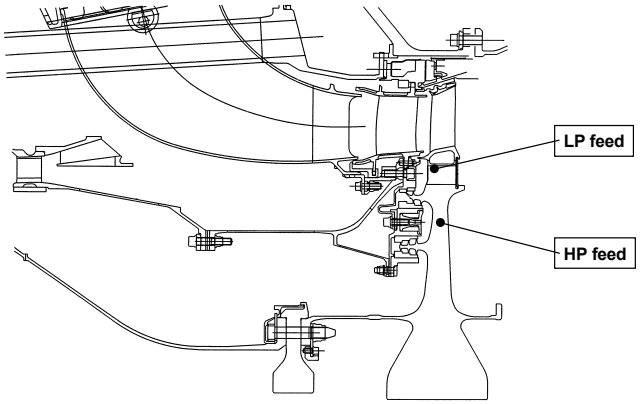
SOLUTIONS (Continued)

Overhaul & Repair

(Continued) The introduction of asymmetry to the DLE injector system discussed earlier (mod 1358) not only reduced combustor noise but also significantly reduced this 'inboard' traverse effect. However, due to the earlier history on these components, TCPL requested the embodiment of a further improvement to the cooling of the HP NGV/HP turbine area. This RR mod is 1362. The modification redirects cooling air specifically to the underside of the HP NGV platform as well as to better control the air to the HP disc/blade assembly.

LP pre-swirl nozzles



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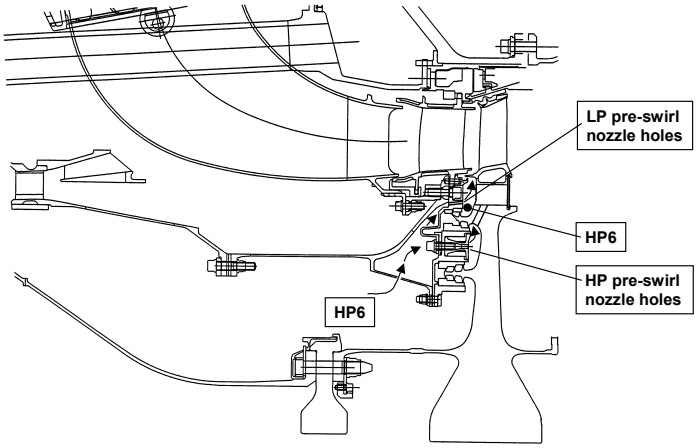
SOLUTIONS (Continued)

Overhaul & Repair

(Continued)

LP pre-swirl nozzles



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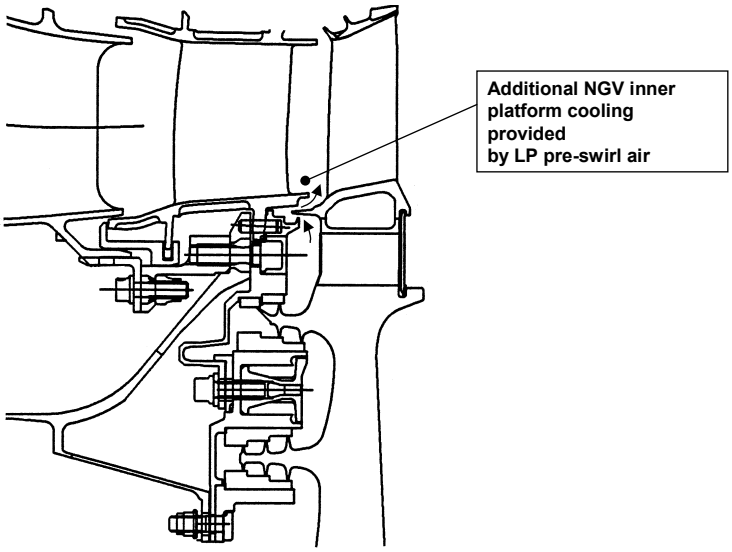
LP pre-swirl nozzles



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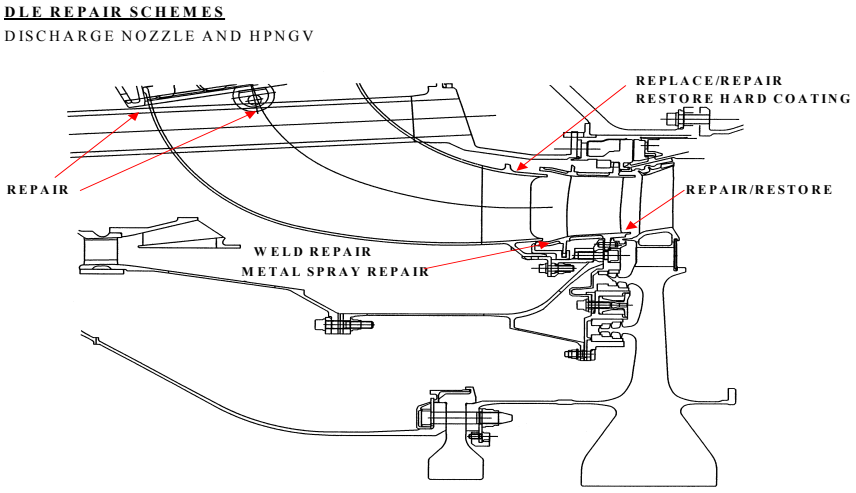
SOLUTIONS (Continued)

Overhaul & Repair

(Continued) To-date, experience globally has resulted in excellent condition of the HP NGV at 16,000+ hours.

This modification is progressively being installed in TCPL's DLE fleet by rework during the mid life refurbishment with 67% completed at the time of writing.

Additional repair schemes have been produced to salvage various components found to have fretted significantly in early pre asymmetric injector operation. Examples are:-



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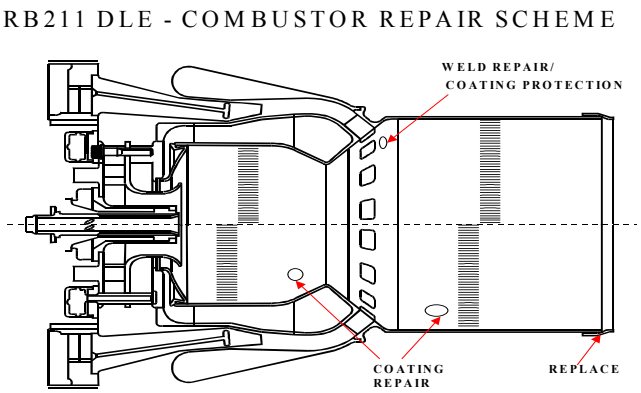
SOLUTIONS (Continued)

Overhaul & Repair

(Continued)



Rolls-Royce

During the re-test at mid life overhauls an emissions concern surfaced and had to be addressed by the team. This concern was that on some gas generators higher than expected levels of Nox were reported on test. An investigation revealed a direct link between actual gap between the rear of the discharge nozzle and its support structure and emission levels.

A revised tolerance was introduced at the repair facilities to control air leakage at that location and consequently the problem was eliminated with a dramatic 50% lowering of the emission levels to ensure contracted acceptable levels.

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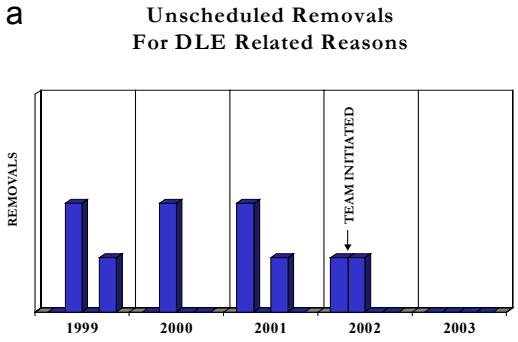
Results

The positive results seen by the team include a reduction in unscheduled gas generator removals. We have now experienced the first DLE unscheduled removal free 12 month period.



The following chart describes the current RB211 DLE operating mode experiences as the above modifications are implemented.

WINTER 2002 / 2003 OPERATION

Summary Date:	26th March 2003			
Station	**% Points In Premix**	**% Points In Cen-Sec**	**Lowest T1 In Premix**	**Mod Status**
A	100	0	-17C	1358
B	23.1	76.9	-27C	1358
C	37.5	62.5	-18C	1313
D	45	55	-13C	1358
E	100	0	-25C	1358
F	75	25	-23C	1313 to 1358
G	39	61	-7C	1358
H	69	31	-18C	1358
I	100	0	-24C	1358
J	100	0	-25C	1358
K	100	0	Not Known	1313
L	100	0	Not Known	1358

Actual % in Premix	Actual % in Cen-Sec		
74.05	25.95		

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Results (Continued)

The chart is a 3 month winter snapshot of sites with varying modification standards. Some sites already achieve 100% operation in DLE mode whilst others demonstrate a lesser %. As we revisit and apply our latest understanding to specific sites the % time in DLE mode increases towards 100%. One interesting observation is that several sites can be improved in DLE mode simply by modifying the noise control software, ensuring that excursions out of DLE mode are optimised between tight limits.

Automated combustor noise monitoring and power pull back has protected units in service prior to the ability to modify to latest standard. However the software did not optimise the time spent in diffusion mode. A tuneable pullback facility allowed the power level to be adjusted to a DLE mode level just below the onset of noise. In addition changes to the central secondary logic are being validated at TCPL in order to permit DLE mode to be reselected sooner.

Results (Continued)

The next chart demonstrates the improved DLE operation over the period March-June as the ambient temperature increases and solutions are applied.

SPRING 2003 OPERATION

Summary Date:	March 28 – June 10			
Station	% Points In Premix	% Points In Cen-Sec	Lowest T1 In Premix	Mod Status
A	100	0	-1C	1358
B	100	0	-7C	1358
C	100	0	-8C	1313 to 1358
D	100	0	14C	1313
E	100	0	5C	1358
F	100	0	5C	1358
G	100	0	-7C	1358
H	90	10	-6C	1358
I	100	0	4C	1358
J	100	0	-8C	1358

Actual % in Premix	Actual % in Cen-Sec		
99.167	0.833		

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Conclusions

- The Alliance teamwork that has been performed on the TransCanada RB211 DLE powered fleet has significantly reduced the frequency of unscheduled outages such that we have now run the fleet in excess of 12 months without a DLE related unscheduled outage.

- The DLE operation is running 100% on many units, with a fleet average exceeding 90%.

- The ability to operate at any required power level has been restored.

- The application of rework schemes together with the modifications applied to the package as a whole is expected to significantly improve the overall cost of ownership of the unit.

- The benefits of working the issues as a team have resulted in a better understanding of the problems and their effects on each Company. This has enabled a positive and highly responsive effort by all parties to identify and manage the risks whilst solutions are being applied. These techniques and solutions are demonstrating that we are on track towards our team goal.

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