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Rolls-Royce Canada

9545 Côte de Liesse

Dorval, Québec

H9P 1A5

Tel.: (514) 631-6562, Fax.: (514) 631-8931

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GTER

A Report Series

Gas Turbine Engineering Report - Performance

B Report Number

GTER 13848

C Issue

1

D Title

Industrial Trent 60: 50Hz DF WLE engine 58 pass-off performance results – Centrax/Gas de France

E Author(s)

L Leclerc

Tel Number

X 7524

F SUMMARY

A factory test was performed on the 21st October 2009 on ESN058. This engine is a 50Hz Industrial Trent DF WLE and is to be packaged by Centrax for Gas De France. The engine passed all internal RR PAT performance criteria.

The baseload data was referred to site reference conditions and RR PAT reference conditions using the ratio method and eTrent version 7.0.2. The results are presented in this report for formal declaration and communication to the customer. They show that ESN058 meets the customer guarantees and the PAT performance criteria. The key results are presented in the tables below.

	GAS WET				LIQUID WET			
	Engine 58 corrected	Guarantees	Diff.	STATUS	Engine 58 corrected	Guarantees	Diff.	STATUS
Electrical Power (kW)	57999	58000	0.0%	PASS	58000	58000	0.0%	PASS
Electrical Heat Rate (KJ/kWhr)	8803	9002	-2.2%	PASS	8727	9109	-4.2%	PASS

Engine 58 performance relative to contract guarantee

	GAS WET				LIQUID WET			
	Engine 58 corrected	PAT acceptance	Diff.	STATUS	Engine 58 corrected	PAT acceptance	Diff.	STATUS
Shaft Power (kW)	56140	53908	4.1%	PASS	55998	53965	3.8%	PASS
Shaft Heat Rate (KJ/kWhr)	8724	8975	-2.8%	PASS	8718	9107	-4.3%	PASS

Engine 58 performance relative to PAT acceptance limits

Note 1: Negative heat rate margin means lower fuel consumption.

Note 2: The 0% margin against contract guarantee power shows the test was conducted at this power limit.

G Additional Keywords

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J Blackburn, P Prado

R Hamby

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N. Budeanu, J. Ford, S. Tebbs, S. Nolen

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Date: 27th October 2009H Engine Type
Industrial Trent 60

J Ref. No.

K Date

27 Oct 2009

L Dept. No.

32

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REVISION LEVEL

Issue	Reason	Date
1	Original issue	27 Oct 2009

Note: Changes made between the current and previous revision levels are indicated by vertical change bars.

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1.0 Summary and Conclusions

A factory test was performed on the 21st October 2009 on ESN058. This engine is a 50Hz Industrial Trent DF WLE and is to be packaged by Centrax for Gas De France. The engine passed all internal RR PAT performance criteria.

The baseload data was referred to site reference conditions and RR PAT reference conditions using the ratio method and eTrent version 7.0.2. The results are presented in this report and show that ESN058 meets the customer guarantees and the PAT performance criteria. This report formally declares this performance, previously communicated in LGT3745.

2.0 Test data & results

ESN058's factory test took place in Test Cell 7 on 21 October 2009, to the Industrial Trent 60 WLE Dual Fuel – Production Acceptance Test procedure, (GTES 10540 issue 4).

2.1 Inputs and Method

Raw data:

A full output of the raw data taken in the factory test and used in the analysis is provided in Appendix A. The engine was fully stabilized at baseload.

The following table summarises storage location, time, power and ambient temperature.

	ALICE Experiment	Scan	Test Date	Time	TCELL (K)	Generator Power (kW)
Gas Wet	90158010	18	21/10/2009	13h13	283.8	58071
Liquid Wet	90158010	41	21/10/2009	17h12	283.9	58062

Emissions:

Emission were recorded during the test. The reports are attached in Appendix B:

NOx recorded during the tests:

Gas Wet: NOx = 26.0 vppm

Liquid Wet: NOx = 41.7 vppm

Diesel Analysis:

A sample of Diesel was taken during the test. The result of the sample analysis is attached in appendix C. The Lower Heating Value of the Diesel during the test was 18532 BTU/lb.

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Generator efficiency:

To obtain shaft power the generator efficiency curve below is interpolated (linearly) at the generator power obtained during the test. Then a factor of 0.985 is applied to the value obtained. This was derived from cross-calibration with Test Cell #3 where measurements were taken with a torquemeter calibrated to traceable standards.

Power (HP)	Gen. Effy
0	0
530	0.2528
1745	0.7685
7143	0.9387
13894	0.9639
27386	0.9789
40878	0.9839
54376	0.9863
67876	0.9877
81371	0.9887
100000	0.9887

Note: 1HP = 0.7457 kW

Installation losses assumptions:

The assumptions for the installation losses for testcell 7 are as follows:

Temp (C)	-0.67
Inlet (mm H2O)	27.94
Exhaust (mm H2O)	309.88

Analysis Method:

The CWT data was analysed using the ratio method (see attachment in Appendix D for a fuller description) and eTrent 7.0.2.

The spreadsheets containing the calculation details are attached in Appendix E, tables 1 to 4. A summary of the results of referral to contract and PAT reference conditions are provided in sections 2.2 and 2.3.

Note: The emissions used in the analysis came from the lab reports. However eTrent version 7.0.2 can not be run to specified NOx. For the analysis, the NOx of the test were assumed to be 24.3vppm for Gas and 42vppm for Diesel.

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2.2 Results of referral to Contract Reference Conditions

The contract reference conditions and performance guarantees are summarized in the tables below. They are for gas wet and liquid wet applications.

Ambient conditions

	Saint-Brieuc
Tamb (C)	11
Pamb (kPa)	99.418
RH (%)	80
Generator efficiency (%)	98.3
Installation losses losses	
Temp (C)	11
Inlet (mm H2O)	125
Exhaust (mm H2O)	125

Fuel properties:

Gas Properties	
Gas Composition	
Methane (%)	92.40%
Ethane (%)	5.30%
Propane (%)	1.60%
n-Butane (%)	0.00%
i-Butane (%)	0.50%
Nitrogen (%)	0.20%
Carbon Dioxide (%)	0.00%
Gas LHV (kJ/kg)	49397
Gas temperature (C)	50

Diesel Specification	
Carbon Atoms	-
Hydrogen Atoms	-
Cp (BTU/lbF)	-
LHV (kJ/kg)	41900
Fuel temp (C)	15

NOx control:

Gas	24.3
Diesel	42

Performance Guarantees:

	GAS	DIESEL
Electrical Power (kW) - Gas	58000	58000
Electrical Heat Rate (kJ/kW.hr) - Gas	9002	9109

The results from the analysis of the factory test, shown in summary below, demonstrate that the engine meets contractual guarantees.

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Electrical Heat Rate (KJ/kWhr)	8803	9002	-2.2%	PASS	8727	9109	-4.2%	PASS

Note 1: Negative heat rate margin means lower fuel consumption

Note 2: The 0% margin against contract guarantee power shows the test was conducted at this power limit.

2.3 Results of referral to PAT reference conditions

Pass-off Test Acceptance:

Ambient conditions

Ambient Pressure	101.325 kPa
Ambient Temperature	25 °C
Ambient Relative Humidity	60%
Intake Total Pressure Loss	0 mm H2O
Exhaust Total Pressure Loss	0 mm H2O
Fuel Temperature	100 °C
Frequency	50Hz

Fuel properties:

eTrent North American Natural Gas Specification	
Component:	Value (mol %)
Methane	95.527
Ethane	2.064
Propane	0.117
I-Butane	0
N-Butane	0.01
Nitrogen	1.942
Carbon Dioxide	0.34
Fuel Temperature	373.15 K (212°F)

Diesel Fuel Specification	
Component:	Value
Carbon Atoms	12.9
Hydrogen Atoms	23.9
Cp (BTU/lbF)	0.4538
LHV (BTU/lb)	18315
Fuel Temperature	288.15 K

NOx control:

Gas	24.3
Diesel	42

Note: the reference temperature is 25°C, above the kink point, where the engine is operating on the T30 limiter.

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The results from the analysis of the factory test, shown in summary below, demonstrate that the engine meets PAT criteria.

	GAS WET				LIQUID WET			
	Engine 58 corrected	PAT acceptance	Diff.	STATUS	Engine 58 corrected	PAT acceptance	Diff.	STATUS
Shaft Power (kW)	56140	53908	4.1%	PASS	55998	53965	3.8%	PASS
Shaft Heat Rate (KJ/kWhr)	8724	8975	-2.8%	PASS	8718	9107	-4.3%	PASS

Note : Negative heat rate margin means lower fuel consumption.

3.0 References

- GTES 10760/2
H Ko, N Budeanu

Industrial Trent 60 WLE Dual Fuel – Customer Witness Test Procedure
4 September 2009

4.0 Appendices

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Appendix A: Raw data used for analysis

	GAS	DIESEL	
SCAN	18	41	
WS_PRES	14.7996	14.7765	Ambient pressure (PSI)
WS_TEMP	9.64	9.47	Ambient temperature (C)
WS_HUM	60.90	61.34	Relative Humidity (%)
TCELL	283.76	283.91	Average inlet temperature (K)
UPOWERV	58.071	58.062	Generator power (MW)
NL	3001	3001	LP Speed (RPM)
NI	6769	6767	IP Speed (RPM)
NH	10093	10076	HP Speed (RPM)
UT30V	581.1	582.1	T30 average
LMETHANE	96.3281	-	Gas Composition (% vol)
LETHANE	1.4	-	
LPROPANE	0.101099	-	
LIBUTANE	0.0078	-	
LNBTANE	0.008268	-	
LPENTANE	0	-	
LNPENTAN	0	-	
LC6PLUS	0.024186	-	
LNITRO	1.54581	-	
LCO2	0.604881	-	
LFT_0101	23859.3	-	Gas Fuel flow
LTE_0101	35.3	-	Gas Fuel Temperature
ULIQT	-	20.2	Diesel Temperature
FT0210	-	26417	Diesel fuel flow
FT0314	30078.7	31112.2	Water flow
UWIMSTI	13.8	14.1	Water temperature (C)
UTGTV	738.02	749.20	TGT average
NOx from lab (vppm)	26.0	41.7	
Diesel LCV from lab	-	18532	BTU/lb
Diesel LCV from lab	-	43105	kJ/kg

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Appendix B

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Emissions from jet pipe probes and cruciform rake (No.10)																	
Measurements taken with M7000 CEMS																	
Units: CO ₂ and O ₂ %, balance ppm																	
Fuel analysis: Mole%																	
Methane		96.411	Fuel net calorific value														
Ethane		1.351	Fuel molecular weight														
Propane		0.114	Relative humidity														
Butane		0.024	Ambient temperature		11432 CHU/lb												
Pentane		0.005	Barometric pressure		16.62 g/mol												
Hexane		0.002			62.10 %RH												
Carbon dioxide		0.595			9.10 °C												
Nitrogen		1.490			14.81 psia												
Note:																	
1) Emissions calculations by: COEMISV1.DLL (Version 1.0)																	
2) Emissions data handling by: COEMIS_2.EXE (Version 2.0)																	
3) Observe scale changes in graphs																	
4) Analyst: Kurt Normandin																	
Nox EFF=99.99%																	
Time	CO DRY	CO ₂ DRY	O ₂ DRY	HC WET	NOx DRY	NO DRY	O ₂ adj. NOx	MW	SSS	Probe	APR	Effy	FUEL	WATER	T30	P30	
GAS WET																	
10:25:27	35.0	1.306	18.61	5.7	29.1	0.0	74.8	51	30310001	1	138.21	99.830	4036	0	328	138	
10:26:24	34.3	1.311	18.59	4.9	28.8	0.0	73.7	51	30310001	2	137.69	99.840	4036	0	328	138	
10:27:20	36.9	1.384	18.48	5.3	29.5	0.0	72.1	51	30310001	3	130.28	99.836	4036	0	328	138	
10:28:16	36.3	1.343	18.55	5.5	29.6	0.0	74.2	51	30310001	4	134.32	99.832	4036	0	328	138	
10:29:13	36.2	1.345	18.55	5.3	29.2	0.0	73.5	51	30310001	5	134.13	99.834	4036	0	328	138	
10:30:09	34.7	1.337	18.55	4.3	28.8	0.0	72.5	51	30310001	6	134.97	99.846	4036	0	328	138	
10:31:05	35.8	1.313	18.61	6.2	28.1	0.0	72.3	51	30310001	7	137.44	99.824	4036	0	328	138	
10:32:02	34.6	1.298	18.63	5.0	28.0	0.0	72.7	51	30310001	8	139.09	99.836	4036	0	328	138	
10:33:54	39.3	1.493	18.32	4.0	31.6	22.4	72.2	51	30310001	10	120.72	99.850	4036	0	328	138	
10:57:09	189.4	2.189	17.04	39.6	16.9	5.1	25.9	14	30310002	10	81.87	99.495	9110	7700	433	248	
11:10:16	158.9	2.141	17.11	42.5	16.3	4.4	25.4	16	30310003	10	83.64	99.449	9522	8400	447	263	
11:28:22	52.4	2.895	15.78	10.2	21.0	12.7	24.2	45	30310004	10	62.51	99.878	19202	22531	545	443	
11:40:11	47.1	2.981	15.64	7.9	22.1	13.9	24.8	50	30310005	10	60.76	99.898	20954	25150	559	474	
11:54:19	44.6	3.088	15.44	7.0	22.6	14.7	24.5	55	30310006	10	58.71	99.908	22727	28392	572	505	
12:03:52	36.0	3.135	15.35	5.0	23.6	0.0	25.1	58	30310007	1	57.86	99.930	23780	30120	580	524	
12:04:48	52.7	3.174	15.26	8.6	23.4	0.0	24.5	58	30310007	2	57.12	99.894	23780	30120	580	524	
12:05:45	49.5	3.344	14.99	7.5	24.8	0.0	24.8	58	30310007	3	54.30	99.907	23780	30120	580	524	
12:06:41	51.5	3.249	15.17	9.0	24.0	0.0	24.7	58	30310007	4	55.83	99.893	23780	30120	580	524	
12:07:37	46.0	3.259	15.16	7.2	24.4	0.0	25.1	58	30310007	5	55.68	99.910	23780	30120	580	524	
12:08:34	42.6	3.232	15.19	5.7	24.1	0.0	24.9	58	30310007	6	56.15	99.920	23780	30120	580	524	
12:09:30	37.9	3.329	15.01	4.3	26.0	0.0	26.0	58	30310007	7	54.56	99.923	23780	30120	580	524	
12:10:26	37.5	3.268	15.12	4.6	26.2	0.0	26.8	58	30310007	8	55.55	99.931	23780	30120	580	524	
12:12:18	41.6	3.141	15.33	6.1	23.7	15.5	25.1	58	30310007	10	57.74	99.918	23780	30120	580	524	
12:24:51	42.4	3.149	15.32	5.9	23.5	15.6	24.8	58	10393001	10	57.59	99.917	23780	30120	580	524	
12:37:04	45.2	3.306	15.30	6.2	24.4	16.3	25.7	58	10393002	10	54.90	99.916	23780	30120	580	524	
12:44:18	43.5	3.232	15.41	6.3	24.2	16.1	26.0	58	10393003	10	56.15	99.916	23780	30120	580	524	
12:57:09	44.8	3.284	15.34	6.5	24.0	16.0	25.5	58	10393004	10	55.27	99.915	23780	30120	580	524	
13:04:00	45.7	3.333	15.24	6.7	24.8	16.2	25.9	58	10393005	10	54.48	99.915	23780	30120	580	524	
13:15:35	43.6	3.164	15.54	6.4	23.6	15.4	26.0	58	10393006	10	57.32	99.914	23780	30120	580	524	

Table 1: Gas Wet emissions

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Emissions from jet pipe probes and cruciform rake (No.10)

Measurements taken with M7000 CEMS

Units: CO₂ and O₂ %, balance ppm

Fuel analysis: Mole%

Methane	96.411	Fuel net calorific value
Ethane	1.352	Fuel molecular weight
Propane	0.114	Relative humidity
Butane	0.024	Ambient temperature
Pentane	0.005	Barometric pressure
Hexane	0.003	
Carbon dioxide	0.595	
Nitrogen	1.498	

Note:

- 1) Emissions calculations by: COEMISV1.DLL (Version 1.0)
- 2) Emissions data handling by: COEMIS_2.EXE (Version 2.0)
- 3) Observe scale changes in graphs
- 4) Analyst: Kurt Normander, Maryse Duroso

Time	CO DRY	CO ₂ DRY	O ₂ DRY	HC WET	NO _x DRY	NO DRY	O ₂ adj. NO _x	MW	SSS	Probe	AFR	Effy	FUEL	WATER	T30	P30
LIQUID WET																
16:09:53	51.4	1.229	18.79	2.1	44.6	0.0	124.4	51	30310024	1	104.17	99.849	4227	0	332	138
16:10:48	49.5	1.710	18.80	2.7	44.9	0.0	126.0	51	30310024	2	104.85	99.849	4227	0	332	138
16:11:44	51.9	1.828	18.67	2.4	46.9	0.0	123.8	51	30310024	3	98.54	99.854	4227	0	332	138
16:12:41	52.1	1.763	18.75	2.1	45.5	0.0	124.7	51	30310024	4	102.20	99.850	4227	0	332	138
16:13:37	53.8	1.763	18.75	1.7	45.4	0.0	125.0	51	30310024	5	102.19	99.847	4227	0	332	138
16:14:33	52.0	1.754	18.76	1.3	44.2	0.0	121.7	51	30310024	6	102.73	99.851	4227	0	332	138
16:15:30	51.1	1.725	18.79	1.7	43.8	0.0	122.7	51	30310024	7	104.42	99.852	4227	0	332	138
16:16:26	50.5	1.712	18.81	1.4	43.0	0.0	121.4	51	30310024	8	105.22	99.854	4227	0	332	138
16:18:18	58.1	1.921	18.51	1.2	49.6	36.6	122.2	51	30310024	10	91.39	99.856	4227	0	332	138
16:16:00	7.3	3.861	15.84	0.0	35.2	26.7	41.0	45	30310026	10	47.26	99.991	21350	23383	546	442
16:48:16	6.6	3.977	15.69	0.0	37.3	28.8	42.2	50	30310028	10	45.92	99.992	23150	26000	561	474
17:00:59	6.4	4.120	15.48	0.0	36.5	30.0	41.9	55	30310030	10	44.38	99.993	25150	29275	574	505
17:14:10	6.2	4.167	15.43	0.1	38.6	0.0	41.2	58	30310032	1	43.89	99.993	26450	31200	282	524
17:15:06	7.5	4.228	15.32	0.0	39.1	0.0	41.4	58	30310032	2	43.28	99.992	26450	31200	282	524
17:16:03	6.6	4.418	15.09	0.0	41.5	0.0	42.2	58	30310032	3	41.48	99.993	26450	31200	282	524
17:16:59	7.4	4.356	15.19	0.0	42.7	0.0	44.1	58	30310032	4	42.05	99.992	26450	31200	282	524
17:17:55	7.0	4.370	15.17	0.0	42.6	0.0	43.9	58	30310032	5	41.92	99.993	26450	31200	282	524
17:18:52	6.9	4.309	15.25	0.0	40.8	0.0	42.7	58	30310032	6	42.49	99.992	26450	31200	282	524
17:19:48	6.4	4.396	15.12	0.0	43.1	0.0	44.0	58	30310032	7	41.68	99.993	26450	31200	282	524
17:20:44	6.3	4.305	15.24	0.0	41.9	0.0	43.7	58	30310032	8	42.53	99.993	26450	31200	282	524
17:22:36	6.6	4.169	15.42	0.0	39.2	30.8	42.7	58	30310032	10	43.67	99.993	26450	31200	282	524

Table 2: Liquid Wet emissions

Title

Industrial Trent 60: 50Hz DF WLE engine 58 pass-off performance results – Centrax/Gas de France

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Appendix C: Diesel analysis

**Rolls-Royce****CERTIFICATE OF FUEL TESTING - DIESEL**

TO: **R. Inose, N. Budeanu**

ENGINE: **Ind. Trent Liquid Wet Performance Curve**

ESN: **58**

TEST DATE: **October 21, 2009**

This certifies that a representative fuel sample used in the performance testing of the above engine has been analyzed by the RRC Laboratory in accordance with the following ASTM methodology:

Calorific Value D 4809
Specific Gravity D 1250 - 80
Kinematic Viscosity D 445 - 96
Dissolved Water Content D 6308

The following results were obtained:

LABORATORY I.D. D29
TEST BED I.D. RH-1 2009-F-19
SPECIFIC GRAVITY @ 60°F 0.8232 kg/L
CALORIFIC VALUE 18532 BTU/lb
VISCOSITY @ 0°C 5.40 cSt
VISCOSITY @ 30°C 2.61 cSt
WATER CONTENT 86 ppm

DATE OF FUEL ANALYSIS: **October 22, 2009**


Maryse Di Rosa

RRC Form No. 540-611 Rev. 5 2005

Title

Industrial Trent 60: 50Hz DF WLE engine 58 pass-off performance
results – Centrax/Gas de France

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Appendix D: Ratio method presentation



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Trent 60 DF WLE Method to correct to Guarantee conditions or to PAT conditions

Louise Leclerc

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Private - Rolls-Royce Data

Site data correction

- ☐ In field the engine runs to a limiter (Power, T30 or TGT) or a defined parameter, eg. Power, depending on ambient conditions and/or needs of customer.
- ☐ To properly assess the performance of the engine, the data need to be corrected for ambient conditions and if necessary for TGT and T30 margin.
- ☐ Rolls-Royce standard way to analyse the performance of DF WLE engines is to use the « ratio Method » and to refer the data to a specific condition, e.g. the guarantee point, cf. diagram.
- ☐ The « ratio method » is done using eTrent.
- ☐ The procedure is different if the referral point is above or below the kink point, i.e. limited by Power or T30.

Private - Rolls-Royce Data

Ratio Method presentation

Slide 2

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The "Ratio Method" to guarantee conditions (below kink point)

- 1 - Run eTrent at same conditions as engine on test
 - Guarantee Expected Limit Parameter, GELP (measured generator power)
 - Same ambient conditions
 - Same installation losses
 - Same fuel
- 2 - Calculate the ratios of actual power, TGT, T30 and heatrate to eTrent predictions (power ratio will be 1.0 as eTrent was run to test power)
- 3 - Run eTrent at guarantee conditions and GELP at the guarantee condition (power of 58MW gross)
- 4 - Multiply TGT and T30 (absolute temperatures) from 3. by ratios from 2.
- 5 - If both corrected TGT and T30 are below the control limits:
 - Achievement of guaranteed power assured
 - Calculate heatrate at guarantee condition by Multiplying heatrate ratio from 2. to heatrate from 3.
- 6 - If either corrected TGT or corrected T30 are above the control limits (meaning the engine fails guarantee on Power):
 - Repeat 1 to 5 using TGT or T30 as the GELP to determine heatrate at guarantee conditions, and also power shortfall.

Private - Rolls-Royce Data

Ratio Method presentation

Slide 3

The "Ratio Method" to PAT conditions (above kink point)

- 1 - Run eTrent at same conditions as engine on test
 - Guarantee Expected Limit Parameter, GELP (measured T30)
 - Same ambient conditions
 - Same installation losses
 - Same fuel
- 2 - Calculate the ratios of actual shaft power and Heat rate to eTrent predictions (T30 ratio will be 1.0 as eTrent was run to test T30)
- 3 - Run eTrent at reference conditions and GELP at the reference condition (T30 limit - 876K)
- 4 - Multiply Shaft Power and Heat Rate from 3 to ratios from
- 5 - Compare Corrected Shaft Power and Heat Rate to PAT acceptance values.

Private - Rolls-Royce Data

Ratio Method presentation

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Appendix E:

Trent 60 DFWE Engine Serial Number 058 Build 1
Measured and Corrected Performance Data From Factory Test
Rolls-Royce Canada, Montreal, Test Bed #7, October 21, 2009

Experiment	90158010
Extract	18
Time	1:13 PM

Standard_DFWE_JTR606		Model at Test Conditions at test power	Engine Test Data	Ratio Engine to Model	Model at Guarantee Conditions (at Power Limit)	Engine Corrected to Guarantee Conditions	Project Guarantee	Difference to Project Guarantee
Ambient Pressure	kPa	102.04	102.04		99.42		99.42	
Ambient Temperature	°C	10.61	10.61		11		11	
Relative Humidity	%	60.9	60.9		60		60	
Inlet Loss	mmHg	28	28		125		125	
Exhaust Loss	mmHg	306	306		125		125	
LP Speed	rpm	3000	3001		3000		3000	
Shaft Power	kW	59046	59046	1.000	59003	59002	59003	
Gross Electrical Power	kW	58071	58071		58000	57999	58000	0.0%
Generator efficiency			97.36%		98.3%	98.3%		
Shaft Heatrate	kJ/kWh.hr	6766	6676	0.986	6761	6663	6648	
Gross Electrical Heatrate	kJ/kWh.hr	6024	6013		6013	6003	6002	-2.2%
Fuel Composition								
Methane	vol%	96.3281	96.3281		92.4		92.4	
Ethane		1.4000	1.4000		5.3		5.3	
Propane		0.1011	0.1011		1.8		1.8	
i-Butane		0.0076	0.0076		0.5		0.5	
n-Butane		0.0083	0.0083		0		0	
i-Pentane		0	0		0		0	
n-Pentane		0	0		0		0	
Hexane		0.0242	0.0242		0		0	
Nitrogen		1.5458	1.5458		0.2		0.2	
Carbon Dioxide		0.6046	0.6046		0		0	
LCV		47626.1			49397			
Fuel Temperature	°C	35.3	35.3		50.0			
LPT Inlet Temperature (T ₀₁)	°C	764.3	738.0	0.979	760.8	744.4	LIMIT 782.6°C	
HPC Exit Temperature (T ₃₀)	K	864.8	864.2	0.999	858.8	858.1	LIMIT 876K	
NO _x (Corrected to 15% O ₂ , dry)	ppm	24.3	28.0		24.3			
Compressor Water Flow	kg/hr	13835	13844	0.996	14068	13870.4		
Compressor Water Temperature	°C	13.8	13.8		15			

Table 1: Gas Wet referred to Guarantees

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Trent 60 DFWE Engine Serial Number 058 Build 1
Measured and Corrected Performance Data From Factory Test
Rolls-Royce Canada, Montreal, Test Bed #7, October 21, 2009

Experiment	90186010
Extract	15
Time	1:13 PM

Standard_DFWE.ITRST.005		Model at Test Conditions at Test T30	Engine Test Date	Ratio Engine to Model	Model at PAT Conditions (at T30 Limit)	Engine Corrected to PAT Conditions	PAT Limits	Difference to PAT Limits
Ambient Pressure	kPa	102.04	102.04		101.33		101.325	
Ambient Temperature	°C	10.61	10.61		25.0		25.0	
Relative Humidity	%	60.9	60.9		60		60	
Inlet Loss	mmH ₂ O	27	27		0		0	
Exhaust Loss	mmH ₂ O	304	304		0		0	
LP Speed	rpm	3000	3001		3000			
Shaft Power	kW	58443	58646	1.003	55950	56140	53908	4.1%
Gross Electrical Power	kW		58071		55026	-		
Generator efficiency			97.36%		98.35%			
Shaft Heatrate	kJ/kWh	8706	8676	0.987	8836	8734	8875	-2.8%
Gross Electrical Heatrate	kJ/kWh	8027	8913		8883	-		
Fuel Composition								
Methane	vol%	96.3281	96.3281		95.527		95.527	
Ethane		1.4000	1.4000		2.064		2.064	
Propane		0.1011	0.1011		0.117		0.117	
i-Butane		0.0078	0.0078		0.000		0.000	
n-Butane		0.0063	0.0063		0.010		0.010	
i-Pentane		0.0000	0.0000		0.000		0.000	
n-Pentane		0.0000	0.0000		0.000		0.000	
Hexane		0.0242	0.0242		0.000		0.000	
Nitrogen		1.5458	1.5458		1.942		1.942	
Carbon Dioxide		0.6048	0.6048		0.340		0.340	
LHV		47826.1	47826.1		47826		47825	
Fuel Temperature	°C	36.3	36.3		100.0		100.0	
LPT Entry Temperature (TGT)	°C	753.6	738.0	0.980	773.2	757.4		
HPC Exit Temperature (T30)	K	854.3	854.2	1.000	876	876		
MOx (Corrected to 15% O ₂ , dry)	ppm	24.3	25.0		24.3			
Compressor Water Flow	kg/hr	13772	13664	0.991	13484			
Compressor Water Temperature	°C	13.8	13.8		15			

Table 2: Gas Wet referred to PAT

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Trent 60 DFVLE Engine Serial Number 058 Build1
Measured and Corrected Performance Data From Factory Test
Rolls-Royce Canada, Montreal, Test Bed #7, October 21, 2009

Experiment	90158010
Extract	41
Time	5:12 PM

Standard_DFVLE_ITRST008		Model at Test Conditions at test power	Engine Test Data	Ratio Engine to Model	Model at Guarantee Conditions (at Power Limit)	Engine Corrected to Guarantee Conditions	Project Guarantee	Offariance to Project Guarantee
Ambient Pressure	kPa	101.88	101.88		99.42		99.42	
Ambient Temperature	C	10.79	10.79		11		11	
Relative humidity	%	61.3	61.3		80		80	
Inlet Loss	mmH ₂ O	27	27		125		125	
Exhaust Loss	mmH ₂ O	307	307		125		125	
LP Speed	rpm	3000	3001		3000		3000	
Shaft Power	kW	59638	59638	1.000	59000	59000	59000	
Gross Electrical Power	kW		58062		58000	58000	58000	0.0%
Generator efficiency			97.36%		98.30%	98.30%		
Shaft Heatrate	kJ/kWh.hr	8907	8901	0.972	8822	8678	8654	
Gross Electrical Heatrate	kJ/kWh.hr	9148	8896	0.972	8974	8727	8109	-4.2%
Fuel Composition								
LCV		43106	43106		41900			
Fuel Temperature	C	20.2	20.2		15.0			
LPT Entry Temperature (TOT)	C	765.0	749.2	0.985	774.0	758.9	LIMIT 782.6C	
HPC Exit Temperature (T30)	K	855.2	855.3	1.000	858.4	858.5	LIMIT 876K	
NOx (Corrected to 15% O ₂ , dry)	ppm	42.0	41.7		42.0			
Compressor Water Flow	kg/hr	14833	14112	0.951	13004	12981.3		
Compressor Water Temperature	C	14.1	14.1		15			

Table 3: Liquid Wet referred to Guarantees

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Trent 60 DF/WLE Engine Serial Number 058 Build 1
Measured and Corrected Performance Data From Factory Test
Rolls-Royce Canada, Montreal, Test Bed #7, October 21, 2009

Experiment	90155010
Extract	41
Time	5:12 PM

Standard DF/WLE JT8T605		Model at Test Conditions at test T30	Engine Test Data	Ratio Engine to Model	Model at PAT Conditions (at T30 Limit)	Engine Corrected to PAT Conditions	PAT Limits	Difference to PAT Limits
Ambient Pressure	kPa	101.68	101.68		101.325		101.325	
Ambient Temperature	°C	10.76	10.76		25.0		25.0	
Relative Humidity	%	61.3	61.3		80		80	
Inlet Loss	mmH ₂ O	28	28		0		0	
Exhaust Loss	mmH ₂ O	307	307		0		0	
IP Speed	rpm	3000	3001		3000			
Shaft Power air	MW	58050	58030	1.000	58011	55998	53805	3.8%
Gross Electrical Power air	kW		58082					
Generator efficiency			97.36%		98.35%			
Shaft Heatrate	kJ/kWh.hr	8907	8691	0.972	8966	8718	9107	-4.3%
Gross Electrical Heatrate	kJ/kWh.hr	9148	8836		9149			
Fuel Composition								
LHV		43105	43105		42600		42600	
Fuel Temperature	°C	20.2	20.2		15.0		15.0	
LPT Entry Temperature (T01)	°C	785.1	749.2	0.9647	785.5	768.3		
HPC Exit Temperature (T30)	K	855.3	855.3	1.000	878	876		
NO _x (Corrected to 15% O ₂ , dry)	ppm	42.0	41.7		42.0			
Compressor Water Flow	kg/hr	14637	14112	0.951	13796			
Compressor Water Temperature	°C	14.1	14.1		15			

Table 4: Liquid Wet referred to PAT

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