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GTER

A Report Series

Gas Turbine Engineering Report - PerformanceB Report Number
GTER 13847C Issue
1

D Title

Industrial Trent 60: 50Hz DF WLE engine 57 pass-off performance results – Centrax/Gas de France

E Author(s)

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F SUMMARY

A factory test was performed on the 16th October 2009 on ESN057. 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 ESN057 meets the customer guarantees and the PAT performance criteria. The key results are presented in the tables below.

	GAS WET				LIQUID WET			
	Engine 57 corrected	Guarantees	Diff.	STATUS	Engine 57 corrected	Guarantees	Diff.	STATUS
Electrical Power (kW)	58000	58000	0.0%	PASS	58000	58000	0.0%	PASS
Electrical Heat Rate (KJ/kWhr)	8793	9002	-2.3%	PASS	8745	9109	-4.0%	PASS

Engine 57 performance relative to contract guarantee

	GAS WET				LIQUID WET			
	Engine 57 corrected	PAT acceptance	Diff.	STATUS	Engine 57 corrected	PAT acceptance	Diff.	STATUS
Shaft Power (kW)	55646	53908	3.2%	PASS	55655	53965	3.1%	PASS
Shaft Heat Rate (KJ/kWhr)	8719	8975	-2.8%	PASS	8739	9107	-4.0%	PASS

Engine 57 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

Circulation:

Document Center
RRC Tech. Library

RRPG-Ansty

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Approved by:

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

J Ref. No.

K Date
27 Oct 2009L Dept. No.
32M File
X:/document/gter/r13846-01.doc

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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 16th October 2009 on ESN057. 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 ESN057 meets the customer guarantees and the PAT performance criteria. This report formally declares this performance, previously communicated in LGT3730.

2.0 Test data & results

ESN057's factory test took place in Test Cell 7 on 16 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	90157010	18	16/10/2009	11h47	278.1	58067
Liquid Wet	90157010	37	16/10/2009	15h52	282.4	58072

Emissions:

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

NOx recorded during the tests:

Gas Wet: NOx = 25.7 vppm

Liquid Wet: NOx = 41.8 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 18571 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 (%)	0.60%
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)	8793	9002	-2.3%	PASS	8745	9109	-4.0%	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 57 corrected	PAT acceptance	Diff.	STATUS	Engine 57 corrected	PAT acceptance	Diff.	STATUS
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Shaft Heat Rate (KJ/kWhr)	8719	8975	-2.8%	PASS	8739	9107	-4.0%	PASS

Note : Negative heat rate margin means lower fuel consumption.

3.0 References

- GTES 10760/2 Industrial Trent 60 WLE Dual Fuel – Customer Witness Test Procedure
H Ko, N Budeanu 4 September 2009

4.0 Appendices

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Appendix A: Raw data used for analysis

	GAS	DIESEL	
SCAN	18	37	
WS_PRES	14.7575	14.7386	Ambient pressure (PSI)
WS_TEMP	2.75139	6.44182	Ambient temperature (C)
WS_HUM	62.3999	45.9001	Relative Humidity (%)
TCELL	278.112	282.4	Average inlet temperature (K)
UPOWERV	58.0673	58.0724	Generator power (MW)
NL	3000.88	3001.06	LP Speed (RPM)
NI	6741.93	6783.31	IP Speed (RPM)
NH	10023.7	10059	HP Speed (RPM)
UT30V	569.573	580.346	T30 average
LMETHANE	96.5906	-	Gas Composition (% vol)
LETHANE	1.23812	-	
LPROPANE	0.075816	-	
LIBUTANE	0.004056	-	
LN BUTANE	0.003276	-	
LPENTANE	0	-	
LNPENTAN	0	-	
LC6PLUS	0.000713	-	
LNITRO	1.50673	-	
LCO2	0.579873	-	
LFT_0101	23644	-	Gas Fuel flow
LTE_0101	34.7818	-	Gas Fuel Temperature
ULIQT1	-	16.8239	Diesel Temperature
FT0210	-	26381	Diesel fuel flow
FT0314	29169.2	31962.5	Water flow
UWIMST1	16.0073	14.8339	Water temperature (C)
UTGTV	727.552	747.407	TGT average
NOx from lab (vppm)	25.7	41.8	
Diesel LCV from lab	-	18571	BTU/lb
Diesel LCV from lab	-	43196	kJ/kg

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Appendix B

October 16, 2009 RRC T87 Ind. Trent WLE DF Gas Wet Performance Curve

Emissions from jet pipe probes and stack probe (No.10)

Measurements taken with M7000 CEMS

Units: CO₂ and O₂ %, balance ppm

Fuel analysis: Mole%

Methane	98.838	Fuel net calorific value
Ethane	1.208	Fuel molecular weight
Propane	0.059	Relative humidity
Butane	0.007	Ambient temperature
Pentane	0.000	Barometric pressure
Hexane	0.000	
Carbon dioxide	0.590	
Nitrogen	1.510	

Note

- 1) Emissions calculations by: COEMSV1.DLL (Version 1.0)
- 2) Emissions data handling by: COEMIS_2.EXE (Version 2.0)
- 3) Observe scale changes in graphs
- 4) Analysis: G_Zone
- 5) Data Processing: G_Zone

Time	CO DRY	CO ₂ DRY	O ₂ DRY	HC WET	NO _x DRY	NO DRY	O ₂ adj. NO _x	SSS No.	MW	Fuel Inj.	Probe	AFR	Effy	T30	F30	Fuel	Water	W/F Ratio
9:33:34	38.0	1.308	18.72	7.2	30.0	0.0	81.3	78130001	51	F	1	137.86	99.808	322	140	4061	0	0.00
9:34:31	35.9	1.306	18.68	5.3	30.2	0.0	80.2	78130001	51	W+F	2	136.00	99.833	322	140	4061	0	0.00
9:35:27	38.1	1.401	18.57	5.3	31.2	0.0	78.9	78130001	51	W+F	3	128.69	99.834	322	140	4061	0	0.00
9:36:23	37.8	1.358	18.64	5.1	33.1	0.0	86.5	78130001	51	W+F	4	132.93	99.831	322	140	4061	0	0.00
9:37:20	39.0	1.347	18.66	6.9	31.1	0.0	81.9	78130001	51	W+F	5	133.80	99.812	322	140	4061	0	0.00
9:38:16	40.4	1.339	18.66	8.1	30.7	0.0	80.9	78130001	51	W+F	6	134.60	99.812	322	140	4061	0	0.00
9:39:12	41.7	1.323	18.70	9.2	30.0	0.0	80.4	78130001	51	W+F	7	136.22	99.783	322	140	4061	0	0.00
9:40:09	37.9	1.290	18.76	5.9	29.9	0.0	82.2	78130001	51	W+F	8	139.83	99.815	322	140	4061	0	0.00
9:42:01	43.4	1.495	18.42	5.2	33.2	23.0	79.2	78130001	51	W+F	10	120.45	99.829	322	140	4061	0	0.00
9:58:52	62.0	2.815	16.00	15.3	20.0	11.2	24.0	78130001	45	W+F	10	64.18	99.940	530	445	19012	21961	1.16
10:11:12	52.7	2.916	15.83	11.4	21.4	12.9	24.9	78130001	50	W+F	10	62.03	99.874	544	476	20748	24314	1.17
10:24:19	49.5	3.016	15.66	9.3	22.2	13.6	25.0	78130001	55	W+F	10	60.02	99.891	550	506	22493	27491	1.22
10:34:11	41.1	3.068	15.57	7.3	23.4	0.0	25.8	78130001	58	W+F	1	59.04	99.912	567	526	23594	29154	1.24
10:35:08	54.0	3.087	15.51	11.2	22.7	0.0	24.8	78130001	58	W+F	2	58.67	99.880	567	524	23594	29154	1.24
10:36:04	53.4	3.222	15.30	10.3	23.5	0.0	24.9	78130001	58	W+F	3	56.26	99.888	567	524	23594	29154	1.24
10:37:00	47.8	3.172	15.39	8.3	24.4	0.0	25.2	78130001	58	W+F	4	57.13	99.902	567	524	23594	29154	1.24
10:37:57	46.0	3.243	15.28	7.8	25.1	0.0	26.4	78130001	58	W+F	5	55.92	99.908	567	524	23594	29154	1.24
10:38:53	45.0	3.275	15.22	6.8	24.8	0.0	25.7	78130001	58	W+F	6	55.39	99.914	567	524	23594	29154	1.24
10:39:49	48.8	3.276	15.20	8.6	25.1	0.0	26.0	78130001	58	W+F	7	55.36	99.902	567	524	23594	29154	1.24
10:40:46	53.3	3.154	15.41	10.9	24.1	0.0	26.1	78130001	58	W+F	8	57.44	99.884	567	524	23594	29154	1.24
10:42:38	46.4	3.069	15.55	8.3	23.1	14.6	25.5	78130001	58	W+F	10	59.01	99.901	567	524	23594	29154	1.24
10:57:21	46.0	3.067	15.56	8.0	23.0	14.7	25.4	78130001	58	W+F	10	59.05	99.902	567	524	23615	29125	1.23
11:07:29	46.0	3.067	15.56	7.8	23.0	14.5	25.4	78130001	58	W+F	10	59.05	99.903	567	524	23650	29277	1.24
11:17:12	46.3	3.064	15.57	7.9	23.2	14.6	25.7	78130001	58	W+F	10	59.10	99.902	561	524	23650	29277	1.24
11:27:10	45.7	3.068	15.56	7.6	23.1	14.8	25.8	78130001	58	W+F	10	59.03	99.904	561	524	23650	29277	1.24
11:38:03	44.9	3.078	15.55	7.2	23.4	15.0	25.8	78130001	58	W+F	10	58.86	99.907	561	524	23650	29277	1.24
11:58:52	44.5	3.079	15.55	7.0	23.3	15.1	25.7	78130001	58	W+F	10	58.84	99.906	561	524	23650	29277	1.24

Table 1: Gas Wet emissions

Title

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October 16, 2009 RRC T/B #7 IND. TRENT WLE DF 057

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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 96.600

Ethane 1.220

Propane 0.070

Butane 0.006

Pentane 0.000

Hexane 0.006

Carbon dioxide 0.570

Nitrogen 1.500

Fuel net calorific value 11441

Fuel molecular weight 16.57

Relative humidity 46.70

Ambient temperature 5.92

Barometric pressure 14.70

Note:

1) Emissions calculations COEMISV1.DLL (Version 1.0)

2) Emissions data handling COEMIS_2.EXE (Version 2.0)

3) Observe scale changes in graphs

4) Analyst: M. Di Rosa

Time	CO DRY	CO ₂ DRY	O ₂ DRY	HC WET	NOx DRY	NO DRY	O ₂ adj. NOx	MW	SSS	Probe	AFR	Eff.	Diesel Flow	Water Flow	W/F Ratio	P30	T30
Liquid-Wet perf. curve																	
14:45:20	48.9	1.755	18.75	2.0	46.6	0.0	128.2	51	30310020	1	102.69	99.858	4270	-	-	137	333
14:46:16	47.7	1.766	18.74	1.4	47.8	0.0	130.6	51	30310020	2	102.05	99.866	4270	-	-	137	333
14:47:13	49.9	1.887	18.59	1.2	49.7	0.0	126.9	51	30310020	3	95.52	99.870	4270	-	-	137	333
14:48:09	49.4	1.817	18.66	1.2	46.9	0.0	130.2	51	30310020	4	99.16	99.866	4270	-	-	137	333
14:49:05	51.2	1.798	18.70	1.5	47.7	0.0	128.0	51	30310020	5	100.21	99.859	4270	-	-	137	333
14:50:02	51.2	1.774	18.74	1.3	47.2	0.0	128.9	51	30310020	6	101.57	99.858	4270	-	-	137	333
14:50:58	50.2	1.754	18.76	1.5	46.8	0.0	128.7	51	30310020	7	102.74	99.857	4270	-	-	137	333
14:51:54	48.1	1.728	18.79	1.2	45.4	0.0	127.0	51	30310020	8	104.25	99.863	4270	-	-	137	333
14:53:46	55.8	2.004	18.46	0.8	52.3	34.7	126.3	51	30310020	10	89.94	99.866	4270	-	-	137	333
15:13:18	7.7	3.836	15.87	0.0	35.3	27.1	41.4	45	30310022	10	47.57	99.991	21280	21550	1.04	442	545
15:25:29	6.8	3.854	15.72	0.0	37.1	28.6	42.2	50	30310024	10	46.19	99.992	23200	26400	1.10	472	557
15:40:49	6.8	4.100	15.51	0.0	37.5	29.4	41.1	55	30310026	10	44.59	99.992	25150	29800	1.15	504	572
15:53:39	6.1	4.164	15.43	0.0	38.7	0.0	41.8	58	30310028	1	43.92	99.993	26377	32094	1.19	522	581
15:54:35	7.0	4.208	15.33	0.0	37.8	0.0	40.1	58	30310028	2	43.48	99.992	26377	32094	1.19	522	581
15:55:31	7.4	4.373	15.14	0.0	39.5	0.0	40.5	58	30310028	3	41.89	99.992	26377	32094	1.19	522	581
15:56:28	6.8	4.276	15.28	0.0	38.3	0.0	40.2	58	30310028	4	42.81	99.993	26377	32094	1.19	522	581
15:57:24	7.1	4.366	15.13	0.0	41.2	0.0	42.1	58	30310028	5	41.77	99.992	26377	32094	1.19	522	581
15:58:20	6.5	4.429	15.08	0.0	41.6	0.0	42.2	58	30310028	6	41.38	99.993	26377	32094	1.19	522	581
15:59:17	6.6	4.400	15.09	0.0	40.7	0.0	41.3	58	30310028	7	41.64	99.993	26377	32094	1.19	522	581
16:00:13	6.6	4.305	15.23	0.0	40.6	0.0	42.2	58	30310028	8	42.53	99.993	26377	32094	1.19	522	581
16:02:05	6.4	4.175	15.40	0.0	38.1	29.8	40.9	58	30310028	10	43.82	99.993	26377	32094	1.19	522	581

Table 2: Liquid Wet emissions

Title

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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: **57**

TEST DATE: **October 16, 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. **D27**
TEST BED I.D. **RH-1 2009-F-017**
SPECIFIC GRAVITY @ 60°F **0.8231** kg/L
CALORIFIC VALUE **18571** BTU/lb
VISCOSITY @ 0°C **5.39** cSt
VISCOSITY @ 30°C **2.60** cSt
WATER CONTENT **87** ppm

DATE OF FUEL ANALYSIS: **October 19, 2009**

KURT NORMANDIN

RRC Form No. 540-011 Rev. 5 2005

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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

Title

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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

Slide 4

Title

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Appendix E:

Trent 60 DFWE Engine Serial Number 057 Build1

Measured and Corrected Performance Data From Factory Test

Rolls-Royce Canada, Montreal, Test Bed #7, October 16, 2009

Experiment	90157010
Extract	18
Time	11:47 AM

Standard_DFWE_ITRST608		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	hPa	101.75	101.70		99.42		99.42	
Ambient Temperature	°C	4.56	4.56		11		11	
Relative Humidity	%	60.0	62.4		80		80	
Inlet Loss	mmH ₂ O	26	26		125		125	
Exhaust Loss	mmH ₂ O	312	312		125		125	
LP Speed	rpm	3000	3001		3000		3000	
Shaft Power	kW	89542	89541	1.000	89003	89002	89003	
Gross Electrical Power	kW	89067	89067		89000	89000	89000	0.0%
Generator efficiency			97.36%		98.3%	98.3%		
Shaft Heatrate	kJ/kWh	8731	8614	0.987	8761	8643	8646	
Gross Electrical Heatrate	kJ/kWh	8685	8647		8913	8793	8900	-2.3%
Fuel Composition								
Methane	vol%	96.5906	96.5906		92.4		92.4	
Ethane		1.2381	1.2381		5.3		5.3	
Propane		0.0758	0.0758		1.6		1.6	
i-Butane		0.0041	0.0041		0.5		0.5	
n-Butane		0.0033	0.0033		0		0	
i-Pentane		0	0		0		0	
n-Pentane		0	0		0		0	
Hexane		0.0007	0.0007		0		0	
Nitrogen		1.9067	1.9067		0.2		0.2	
Carbon Dioxide		0.5799	0.5799		0		0	
LOI		47601.4			48307			
Fuel Temperature	°C	34.8	34.8		50.0			
LPT Entry Temperature (TGT)	°C	740.9	727.8	0.982	760.5	747.1	LIMIT 762.6°C	
HPC Exit Temperature (T30)	K	841.9	842.7	1.001	858.5	860.6	LIMIT 870K	
NOx (Corrected to 15% O ₂ , dry)	ppm	24.3	25.7		24.3			
Compressor Water Flow	kg/hr	13405	13291	0.987	14065	13852.5		
Compressor Water Temperature	°C	18.6	18.0		18			

Table 1: Gas Wet referred to Guarantees

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Trent 60 DFWE Engine Serial Number 057 Build1
Measured and Corrected Performance Data From Factory Test
Rolls-Royce Canada, Montreal, Test Bed #7, October 16, 2009

Experiment	90157010
Extract	18
Time	11:47 AM

Standard_DFWE_TTRST606		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	101.75	101.75		101.33		101.325	
Ambient Temperature	C	4.56	4.56		25.0		25.0	
Relative Humidity	%	60.0	62.4		60		60	
Inlet Loss	mmH ₂ O	28	28		0		0	
Exhaust Loss	mmH ₂ O	314	314		0		0	
LP Speed	rpm	3000	3001		3000			
Shaft Power	KW	55967	55841	0.996	55950	55646	53908	3.2%
Gross Electrical Power	KW		55067		55026	-		
Generator efficiency			97.38%		96.35%			
Shaft Heatrate	kJ/KW.hr	8725	8614	0.965	8835	8719	8575	-2.6%
Gross Electrical Heatrate	kJ/KW.hr	8964	8847		8913	-		
Fuel Composition								
Methane	vol%	95.5906	95.5906		95.527		95.527	
Ethane		1.2381	1.2381		2.064		2.064	
Propane		0.0756	0.0756		0.117		0.117	
Isobutane		0.0041	0.0041		0.000		0.000	
n-Butane		0.0033	0.0033		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		0.0007	0.0007		0.000		0.000	
Nitrogen		1.5067	1.5067		1.942		1.942	
Carbon Dioxide		0.5799	0.5799		0.340		0.340	
LOV		47501.4	47901.4		47820		47825	
Fuel Temperature	C	34.6	34.8		100.0		100.0	
LPT Entry Temperature (TGT)	C	742.2	727.6	0.980	773.2	758.0		
HPT Exit Temperature (T30)	K	842.8	842.7	1.000	876	876		
NOx (Corrected to 15% O ₂ , dry)	ppm	24.3	25.7		24.3			
Compressor Water Flow	kg/hr	13692	13231	0.966	13484			
Compressor Water Temperature	C	16.0	16.0		15			

Table 2: Gas Wet referred to PAT

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Trent 60 DFWE Engine Serial Number 057 Build1
Measured and Corrected Performance Data From Factory Test
Rolls-Royce Canada, Montreal, Test Bed #7, October 16, 2009

Experiment	90157010
Extract	37
Time	3:52 AM

Standard_DFWE_ITRST006		Model at Test Conditions at full 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	101.62	101.62		99.42		99.42	
Ambient Temperature	°C	9.25	9.25		11		11	
Relative Humidity	%	45.9	45.9		80		80	
Inlet Loss	mmH ₂ O	28	28		125		125	
Exhaust Loss	mmH ₂ O	311	311		125		125	
LP Speed	rpm	3000	3001		3000		3000	
Shaft Power	kW	59547	59548	1.000	59003	59002	59003	
Gross Electrical Power	kW		59072		59000	59000	59000	0.0%
Generator efficiency			97.36%		98.30%	98.30%	98.30%	
Shaft Heatrate	kJ/kWh.hr	8894	8896	0.974	8822	8595	8954	
Gross Electrical Heatrate	kJ/kWh.hr	9136	8901	0.974	8974	8745	9109	-4.0%
Fuel Composition								
LDV		43196	43196		41900			
Fuel Temperature	°C	16.8	16.8		15.0			
LPT Entry Temperature (TGT)	°C	761.8	747.4	0.980	774.9	760.3	LIMIT 762.6°C	
HPC Exit Temperature (T30)	K	882.5	853.5	1.001	858.4	859.4	LIMIT 874K	
NOx (Corrected to 15% O ₂ , dry)	ppm	42.6	41.8		42.0			
Compressor Water Flow	kg/hr	14992	14498	0.976	13024	12705.1		
Compressor Water Temperature	°C	14.8	14.8		15			

Table 3: Liquid Wet referred to Guarantees

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Trent 60 DFWE Engine Serial Number 057 Build1
Measured and Corrected Performance Data From Factory Test
Rolls-Royce Canada, Montreal, Test Bed #7, October 16, 2009

Experiment	90157010
Extract	37
Time	3:52 AM

Standard_DFWE_JTR57606		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	Differences to PAT Limits
Ambient Pressure	kPa	101.62	101.62		101.325		101.325	
Ambient Temperature	C	9.25	9.25		25.0		25.0	
Relative Humidity	%	45.9	45.9		60		60	
Inlet Loss	mmHg	28	28		0		0	
Exhaust Loss	mmHg	314	314		0		0	
LP Speed	rpm	3000	3001		3000			
Shaft Power	MW	80038	88540	0.904	56011	53655	53866	3.1%
Gross Electrical Power	MW		56072		56087	-		
Generator efficiency			97.36%		98.35%			
Shaft Heatrate	kJ/MWh hr	8891	6665	0.975	8966	8730	9107	-4.0%
Gross Electrical Heatrate	kJ/MWh hr	6132	8901		9149	-		
Fuel Composition								
LCV		43196	43196		43600		42600	
Fuel Temperature	C	15.8	16.8		15.0		15.0	
LPT Entry Temperature (TGT)	C	763.4	747.4	0.9846	766.5	769.2		
HFC Exit Temperature (T30)	K	853.5	853.5	1.000	879	878		
NOx (Corrected to 15% O2, dry)	ppm	42.0	41.8		42.0			
Compressor Water Flow	kg/hr	14885	14498	0.968	13796			
Compressor Water Temperature	C	14.8	14.8		15			

Table 4: Liquid Wet referred to PAT

Title:

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