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GTER

A Report Series

Gas Turbine Engineering Report - Performance

B Report Number

GTER 13846

C Issue

1

D Title

Industrial Trent 60: 50Hz DF WLE engine 56 pass-off performance results – Centrax/Gas de France

E Author(s)

L Leclerc

Yel Number

X 7524

F SUMMARY

A factory test was performed on the 9th October 2009 on ESN056. 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 ESN056 meets the customer guarantees and the PAT performance criteria. The key results are presented in the tables below.

	GAS WET				LIQUID WET			
	Engine 56 corrected	Guarantees	Diff.	STATUS	Engine 56 corrected	Guarantees	Diff.	STATUS
Electrical Power (kW)	58000	58000	0.0%	PASS	57999	58000	0.0%	PASS
Electrical Heat Rate (KJ/kWhr)	8763	9002	-2.7%	PASS	8739	9109	-4.1%	PASS

Engine 56 performance relative to contract guarantee

	GAS WET				LIQUID WET			
	Engine 56 corrected	PAT acceptance	Diff.	STATUS	Engine 56 corrected	PAT acceptance	Diff.	STATUS
Shaft Power (kW)	55283	53908	2.6%	PASS	55007	53965	1.9%	PASS
Shaft Heat Rate (KJ/kWhr)	8693	8975	-3.1%	PASS	8741	9107	-4.0%	PASS

Engine 56 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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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 9th October 2009 on ESN056. 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 ESN056 meets the customer guarantees and the PAT performance criteria. This report formally declares this performance, previously communicated in LGT3726.

2.0 Test data & results

ESN056's factory test took place in Test Cell 7 on 9 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	90156010	22	09/10/2009	14h18	285.8	58066
Liquid Wet	90156010	37	09/10/2009	16h26	286.2	58075

Emissions:

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

NOx recorded during the tests:

Gas Wet: NOx = 25.1 vppm

Liquid Wet: NOx = 43.0 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 18498BTU/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 torque meter 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)	8763	9002	-2.7%	PASS	8739	9109	-4.1%	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 56 corrected	PAT acceptance	Diff.	STATUS	Engine 56 corrected	PAT acceptance	Diff.	STATUS
Shaft Power (kW)	55283	53908	2.6%	PASS	55007	53965	1.9%	PASS
Shaft Heat Rate (KJ/kWhr)	8693	8975	-3.1%	PASS	8741	9107	-4.0%	PASS

Note : Negative heat rate margin means lower fuel consumption.

3.0 References

- | | |
|------------------------------------|---|
| 1. 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	22	37	
WS PRES	14.5764	14.5763	Ambient pressure (PSI)
WS TEMP	11.83	11.7283	Ambient temperature (C)
WS HUM	95.2654	95.4668	Relative Humidity (%)
TCELL	285.753	286.156	Average inlet temperature (K)
UPOWERV	58.0659	58.0751	Generator power (MW)
NL	3001.23	3001.47	LP Speed (RPM)
NI	6775.27	6776.82	IP Speed (RPM)
NH	10175.6	10175.4	HP Speed (RPM)
UT30V	589.676	591.414	T30 average
LMETHANE	96.4688	-	Gas Composition (% vol)
LETHANE	1.28687	-	
LPROPANE	0.081432	-	
LIBUTANE	0.005928	-	
LN BUTANE	0.005616	-	
LPENTANE	0	-	
LNPENTAN	0	-	
LC6PLUS	0.00155	-	
LNITRO	1.61302	-	
LCO2	0.537672	-	
LFT_0101	23755.8	-	Gas Fuel flow
LTE_0101	35.8818	-	Gas Fuel Temperature
ULIQT1	23.2573	23.2129	Diesel Temperature
FT0210	-	26538.9	Diesel fuel flow
FT0314	29760.6	31236.4	Water flow
UWIMSTI	16.9955	17.0174	Water temperature (C)
UTGTV	740.765	752.962	TGT average
NOx from lab (vppm)	25.1	43	
Diesel LCV from lab	-	18498	BTU/lb
Diesel LCV from lab	-	43026	kJ/kg

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Appendix B

09/10/2009 RRC T87 ITRENT DF WLE 056 GAS WET PERF															PAGE 1 of 1	
Emissions from jet pipe probes and cruciform rake (No.10)															Note:	
Measurements taken with M7000 CEMS															1) Emissions calculations by: COEMISV1.DLL (Version 1.0)	
Units: CO ₂ and O ₂ %, balance com															2) Emissions data handling by: COEMIS 2.EXE (Version 2.0)	
Fuel analysis: Mole%															3) Observe state changes in brackets	
Methane 95.247 Fuel net calorific value															4) Analyst: GEORGE ZON (CEMS), KURT NORMANDIN (EE)	
Ethane 1.447 Fuel molecular weight																
Propane 0.102 Relative humidity																
Butane 0.021 Ambient temperature															11.420 CHUMb	
Pentane 0.004 Barometric pressure															16.64 g/mol	
Hexane 0.002															94.60 %RH	
Carbon dioxide 0.552															11.75 °C	
Nitrogen 1.613															14.60 psia	
Time	CO DRY	CO ₂ DRY	O ₂ DRY	HE WET	NOx DRY	NO DRY	O ₂ adj. NOx	MW	SSS	T30	Probe	AFR	Effy	P30	FUEL	WATER
11:53:50	32.9	1.302	18.72	5.3	27.2	0.0	73.7	SI	30310103	334	1	138.62	99.840	136	3975	0
11:54:46	29.4	1.303	18.70	4.0	27.5	0.0	73.7	SI	30310103	334	2	138.46	99.862	136	3975	0
11:55:42	30.9	1.300	18.59	4.1	29.2	0.0	74.6	SI	30310103	334	3	130.60	99.865	136	3975	0
11:56:38	30.4	1.326	18.68	4.3	28.5	0.0	75.8	SI	30310103	334	4	138.01	99.859	136	3975	0
11:57:35	32.0	1.333	18.67	4.8	28.6	0.0	75.7	SI	30310103	334	5	135.26	99.851	136	3975	0
11:58:31	32.9	1.320	18.69	4.5	27.8	0.0	74.2	SI	30310103	334	6	136.61	99.848	136	3975	0
11:59:27	32.3	1.312	18.70	6.1	27.7	0.0	74.3	SI	30310103	334	7	137.44	99.836	136	3975	0
12:00:24	32.2	1.287	18.74	5.1	26.7	0.0	72.8	SI	30310103	334	8	140.06	99.842	136	3975	0
12:02:16	36.3	1.518	18.39	3.7	32.1	22.8	75.4	SI	30310103	334	10	118.61	99.863	136	3975	0
12:26:40	53.2	3.083	15.55	11.6	21.8	13.1	24.0	45	30310105	553	10	58.69	99.879	441	19127	22331
12:41:03	47.0	3.168	15.40	8.9	23.2	14.7	24.8	50	30310107	567	10	57.17	99.900	471	20884	24780
12:55:30	46.0	3.214	15.32	8.0	23.1	15.0	24.4	53	30310109	580	10	56.37	99.906	501	22712	28058
13:09:10	39.9	3.135	15.48	6.9	21.0	0.0	25.0	56	30310111	588	1	57.77	99.917	518	23802	29831
13:10:06	52.9	3.132	15.44	11.1	22.7	0.0	24.5	58	30310111	588	2	57.79	99.883	519	23802	29831
13:11:03	46.7	3.404	14.99	7.9	24.8	0.0	24.8	58	30310111	588	3	53.30	99.913	519	23802	29831
13:11:59	44.7	3.328	15.12	6.8	24.5	0.0	25.0	58	30310111	588	4	54.49	99.915	519	23802	29831
13:12:55	44.3	3.367	15.07	6.8	25.7	0.0	26.0	58	30310111	588	5	53.87	99.917	519	23802	29831
13:13:52	43.1	3.369	15.05	6.6	24.5	0.0	24.7	58	30310111	588	6	53.84	99.919	519	23802	29831
13:14:48	45.6	3.428	14.95	7.3	24.9	0.0	24.7	58	30310111	588	7	52.94	99.915	519	23802	29831
13:15:44	44.6	3.318	15.15	7.4	25.4	0.0	26.1	58	30310111	588	8	54.65	99.913	519	23802	29831
13:17:36	43.0	3.161	15.41	6.9	23.6	15.1	25.3	58	30310111	588	10	57.31	99.913	519	23802	29831
13:24:28	44.1	3.257	15.24	7.0	23.8	15.6	24.8	58	10393101	588	10	55.64	99.913	519	23760	29844
13:34:35	44.8	3.306	15.16	7.1	23.7	15.9	24.4	58	10393102	588	10	54.85	99.914	519	23760	29844
13:44:19	44.5	3.315	15.14	7.1	24.5	15.9	25.1	58	10393103	588	10	54.70	99.914	519	23760	29844
13:55:31	44.7	3.337	15.09	7.0	24.6	16.1	25.0	58	10393104	588	10	54.34	99.915	519	23722	23820
14:04:21	44.5	3.335	15.10	6.9	24.5	16.0	24.9	58	10393105	588	10	54.38	99.915	519	23722	23820
14:14:03	44.6	3.330	15.11	7.1	24.6	16.0	25.0	58	10393106	588	10	54.46	99.915	520	23760	29820
14:19:24	44.2	3.330	15.11	7.0	24.6	16.1	25.1	58	18393107	588	10	54.46	99.915	520	23760	29820

Table 1: Gas Wet emissions

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09/10/2009 RRC TB7 ITRENT DF WLE 056								PAGE 1 of 1								
Emissions from jet pipe probes and cruciform rake (No. 10)								NOTE:								
Measurements taken with M7000 CEMS								1) Emissions calculations by: COEMISV1.DLL (Version 1.0)								
Units: CO ₂ and O ₂ %, balance ppm								2) Emissions data handling by: COEMIS 2.EXE (Version 2.0)								
Fuel analysis: Mole%								3) Observe scale changes in graphs								
Methane								4) Analyst: GEORGE ZONI (CEMS), KURT NORMANDIN (CEMS, DE)								
Ethane								11420 CHU/lb								
Propane								16.64 g/mol								
Butane								95.20 %RH								
Pentane								12.95 °C								
Hexane								14.58 psia								
Carbon dioxide																
Nitrogen																
Time	CO DRY	CO ₂ DRY	O ₂ DRY	HC WET	NOx DRY	NO DRY	O ₂ adj. NOx	MW	SSS	T30	Probe	AFR	Effy	P30	FUEL	WATER
DIESEL/WET																
15:18:09	45.6	1.700	18.80	2.2	40.6	0.0	114.2	SI	30310118	338	1	105.86	99.961	136	4300	0
15:19:05	42.7	1.695	18.80	1.3	41.1	0.0	115.6	SI	30310118	338	2	106.20	99.874	136	4300	0
15:20:02	46.0	1.838	18.64	1.3	44.3	0.0	115.8	SI	30310118	338	3	97.92	99.076	136	4300	0
15:20:58	44.9	1.792	18.69	1.0	43.5	0.0	116.3	SI	30310118	338	4	100.45	99.077	136	4300	0
15:21:54	46.6	1.785	18.70	1.3	43.2	0.0	116.2	SI	30310118	338	5	100.64	99.870	136	4300	0
15:22:51	47.1	1.753	18.74	1.2	41.8	0.0	113.9	SI	30310118	338	6	102.69	99.867	136	4300	0
15:23:47	46.3	1.714	18.78	1.2	41.2	0.0	114.4	SI	30310118	338	7	104.99	99.866	136	4300	0
15:24:43	46.5	1.708	18.80	1.3	40.3	0.0	113.0	SI	30310118	338	8	105.36	99.865	136	4300	0
15:26:35	53.1	2.025	18.42	1.0	48.0	35.7	114.2	SI	30310118	338	10	88.90	99.872	136	4300	0
15:46:12	8.2	4.185	15.44	0.0	38.1	29.2	41.2	45	30310120	441	10	43.65	99.991	556	21462	23273
15:59:30	7.2	4.111	15.54	0.0	38.7	29.7	42.6	50	30310122	570	10	44.41	99.992	469	23375	25977
16:14:26	7.5	4.441	15.09	0.0	39.1	30.5	39.6	55	30310124	583	10	41.22	99.992	439	25323	30012
16:28:15	6.9	4.463	15.06	0.1	42.5	0.0	43.0	58	30310126	591	1	41.02	99.993	519	26480	31246
16:29:12	7.5	4.487	14.99	0.0	43.2	0.0	43.1	58	30310126	591	2	40.81	99.992	519	26480	31246
16:30:08	7.4	4.592	14.89	0.0	42.3	0.0	41.5	58	30310126	591	3	39.91	99.992	519	26480	31246
16:31:04	7.0	4.603	14.87	0.0	41.2	0.0	40.3	58	30310126	591	4	39.81	99.993	519	26480	31246
16:32:01	7.5	4.602	14.90	0.0	43.3	0.0	42.6	58	30310126	591	5	39.82	99.992	519	26480	31246
16:32:57	6.6	4.601	14.89	0.0	45.9	0.0	45.1	58	30310126	591	6	39.83	99.993	519	26480	31246
16:33:53	7.2	4.626	14.84	0.0	42.1	0.0	41.0	58	30310126	591	7	39.63	99.993	519	26480	31246
16:34:50	7.1	4.682	14.79	0.0	45.1	0.0	43.6	58	30310126	591	8	39.33	99.993	519	26480	31246
16:36:41	6.9	4.441	15.08	0.0	42.7	32.9	43.3	58	30310126	591	10	41.22	99.993	519	26480	31246

Table 2: Liquid Wet emissions

Title

Industrial Trent 60: 50Hz DF WLE engine 56 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: **56**

TEST DATE: **October 9, 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. **D26**
TEST BED I.D. **RH-1 2009-F-016**
SPECIFIC GRAVITY @ 60°F **0.8315** kg/L
CALORIFIC VALUE **18498** BTU/lb
VISCOSITY @ 0°C **5.41** cSt
VISCOSITY @ 30°C **2.60** cSt
WATER CONTENT **140** ppm

DATE OF FUEL ANALYSIS: **October 15, 2009**

Maryse Di Rosa

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

Sheet 2

Title

Industrial Trent 60: 50Hz DF WLE engine 56 pass-off performance results – Centrax/Gas de France

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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

Industrial Trent 60: 50Hz DF WLE engine 56 pass-off performance
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Appendix E:

Trent 60 DFWE Engine Serial Number 056 Build 1
Measured and Corrected Performance Data From Factory Test
Rolls-Royce Canada, Montreal, Test Bed #7, October 8, 2009

Experiment	90158010
Extract	22
Time	2:18 PM

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	kPa	100.50	100.50		99.42		99.42	
Ambient Temperature	C	12.60	12.60		11		11	
Relative Humidity	%	85.3	85.3		80		80	
Inlet Loss	mmH ₂ O	27	27		125		125	
Exhaust Loss	mmH ₂ O	305	305		125		125	
LP Speed	rpm	3000	3001		3000		3000	
Shaft Power	kWe	59640	59643	1.000	59003	59003	59003	
Gross Electrical Power	kWe		58068		58000	58000	58000	0.0%
Generator efficiency			97.36%		98.3%	96.3%		
Shaft Heatrate	kJ/kWe.hr	8796	8646	0.963	8791	8614	8849	
Gross Electrical Heatrate	kJ/kWe.hr	8936	8883		8973	8763	9002	-2.7%
Fuel Composition								
	vol%	95.4658	95.4658		92.4		92.4	
Methane								
Ethane		1.2860	1.2860		5.3		5.3	
Propane		0.0014	0.0014		1.6		1.6	
i-Butane		0.0056	0.0056		0.5		0.5	
n-Butane		0.0056	0.0056		0		0	
i-Pentane		0	0		0		0	
n-Pentane		0	0		0		0	
Hexane		0.0016	0.0016		0		0	
Nitrogen		1.6130	1.6130		0.2		0.2	
Carbon Dioxide		0.5377	0.5377		0		0	
LOV		47865.4			46997			
Fuel Temperature	C	38.9	38.9		50.0			
LPT Entry Temperature (TGT)	C	762.7	740.8	0.971	760.8	735.8	LIMIT 762.6C	
HPC Exit Temperature (T30)	K	861.0	862.8	1.002	858.8	860.8	LIMIT 876K	
NOx (Corrected to 15% O ₂ dry)	ppm	24.3	25.1		24.3			
Compressor Water Flow	kg/hr	13662	13498	0.985	14085	13569.7		
Compressor Water Temperature	C	17.0	17.0		15			

Table 1: Gas Wet referred to Guarantees

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Trent 60 DFWLE Engine Serial Number 056 Build1
Measured and Corrected Performance Data From Factory Test
Rolls-Royce Canada, Montreal, Test Bed #7, October 9, 2009

Experiment	90156010
Extract	22
Time	2:18 PM

Standard_DFWLE_ITRST638		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	100.50	100.50		101.33		101.325	
Ambient Temperature	C	12.60	12.60		25.0		25.0	
Relative Humidity	%	95.3	95.3		60		60	
Inlet Loss	mmH ₂ O	28	28		0		0	
Exhaust Loss	mmH ₂ O	308	308		0		0	
LP Speed	rpm	3000	3001		3000			
Shaft Power	kW	60359	59540	0.986	59590	55283	53608	-2.6%
Gross Electrical Power	kW		50086		56026	-		
Generator efficiency			87.38%		86.35%			
Shaft Heatrate	kJ/kWh.hr	8788	8648	0.984	8635	8693	8975	-3.1%
Gross Electrical Heatrate	kJ/kWh.hr	9027	8663		8953	-		
Fuel Composition								
	vol%							
Methane		95.4688	95.4688		95.527		95.527	
Ethane		1.3986	1.3986		2.004		2.004	
Propane		0.0614	0.0614		0.117		0.117	
i-Butane		0.0056	0.0056		0.000		0.000	
n-Butane		0.0056	0.0056		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		0.0016	0.0016		0.000		0.000	
Nitrogen		1.6130	1.6130		1.942		1.942	
Carbon Dioxide		0.5377	0.5377		0.340		0.340	
LOI		47865.4	47865.4		47825		47825	
Fuel Temperature	C	35.0	35.0		100.0		100.0	
LPT Entry Temperature (TGT)	C	785.8	740.8	0.967	773.2	746.0		
HPC Exit Temperature (T30)	K	862.8	862.8	1.000	878	876		
H ₂ O (Corrected to 15% O ₂ , dry)	ppm	24.3	25.1		24.3			
Compressor Water Flow	kg/hr	14218	13498	0.960	13484			
Compressor Water Temperature	C	17.0	17.0		15			

Table 2: Gas Wet referred to PAT

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Trent 60 DFWLE Engine Serial Number 056 Build1
Measured and Corrected Performance Data From Factory Test
Rolls-Royce Canada, Montreal, Test Bed #7, October 9, 2009

Experiment	90158010
Extract	37
Time	4:26 PM

Standard_DFWLE_ITRST#06		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	100.50	100.50		99.42		99.42	
Ambient Temperature	C	13.01	13.01		11		11	
Relative Humidity	%	95.5	95.5		80		50	
Inlet Loss	mm-H ₂ O	27	27		125		125	
Exhaust Loss	mm-H ₂ O	306	306		125		125	
LP Speed	rpm	3000	3001		3000		3000	
Shaft Power	kW	59650	59649	1.000	59003	59002	59003	
Gross Electrical Power	kWe		58075		58000	57999	58000	0.0%
Generator efficiency			97.36%		98.30%	98.30%		
Shaft Heatrate	kJ/MWh.hr	8517	8683	0.974	8822	8591	8564	
Gross Electrical Heatrate	kJ/MWh.hr	8159	8919	0.974	8974	8739	9109	-4.1%
Fuel Composition								
LCV		43026	43026		41900			
Fuel Temperature	C	23.2	23.2		16.0			
LPT Entry Temperature (TGT)	C	774.2	753.0	0.980	774.9	753.6	LIMIT 762.6C	
HPC Exit Temperature (T30)	K	881.7	864.8	1.003	858.4	861.3	LIMIT 876K	
NOx (Corrected to 15% O ₂ , dry)	ppm	42.0	43.0		42.0			
Compressor Water Flow	kg/hr	14905	14169	0.951	13024	12380.7		
Compressor Water Temperature	C	17.0	17.0		15			

Table 3: Liquid Wet referred to Guarantees

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Trent 60 DFWLE Engine Serial Number 056 Build 1
Measured and Corrected Performance Data From Factory Test
Rolls-Royce Canada, Montreal, Test Bed #7, October 9, 2009

Experiment	90156010
Extract	37
Time	4:26 PM

Standard_DFWLE_ITRST608		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	100.50	100.50		101.325		101.325	
Ambient Temperature	C	13.01	13.01		25.0		25.0	
Relative Humidity	%	95.5	95.5		60		60	
Inlet Loss	mmH ₂ O	28	27		0		0	
Exhaust Loss	mmH ₂ O	312	306		0		0	
LP Speed	rpm	3000	3001		3000			
Shaft Power	kW	50738	50549	0.992	50011	55007	53905	1.8%
Gross Electrical Power	kWe		58075		55067			
Generator efficiency			97.36%		98.36%			
Shaft Heatrate	kJ/kWh.hr	8907	8863	0.975	8965	8741	9107	-4.0%
Gross Electrical Heatrate	kJ/kWh.hr	9145	8919		9145			
Fuel Composition								
LCV		43026	43026		42500		42000	
Fuel Temperature	C	23.2	23.2		15.0		15.0	
LPT Entry Temperature (TGT)	C	779.2	753.0	0.9751	785.5	759.1		
HPC Exit Temperature (T30)	K	864.6	864.6	1.000	878	878		
NOx (Corrected to 15% O ₂ , dry)	ppm	42.0	43.0		42.0			
Compressor Water Flow	kg/hr	15290	14169	0.926	13796			
Compressor Water Temperature	C	17.0	17.0		15			

Table 4: Liquid Wet referred to PAT

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