BILLERICA (M.A296.01) - EQUIPMENT SUPPLY CONTRACT

APPENDIX B - TECHNICAL SPECIFICATIONS

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B1 COMMENTARY

Rolls-Royce scope of supply is limited to the gas turbine generating set and associated systems necessary for the safe operation of the gas turbine genset, as defined in the Appendix A - Scope of Work. Balance of plant, transformers and other equipment and services necessary as stated in the exclusions to complete the plant are not included. The design provided is based on use of equipment supply to Rolls-Royce standard design.

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B2 INTERFACE REQUIREMENTS

B2.1 FUEL GAS REQUIREMENTS

Connections to the Trent 60 Dual Fuel WLE Power Generation Package (Unit)are made to supply flange located on the exterior faces of the gas turbine modules, as shown on the general arrangement. Interconnection piping of the fuel gas system is the responsibility of the Customer

The customer shall provide the fuel gas compression and treatment system required to deliver fuel gas from the pipeline to the gas turbine skid edge interface within the Rolls-Royce fuel acceptability criteria, this includes removal of all potential contamination from the pipeline and gas compression process.

Fuel quality is directly related to the cost of repair and life of gas turbine components. Unacceptable fuel quality at entry to the gas turbine can result in detrimental effects to unit operability, performance, availability, emissions and life and therefore should be avoided.

Good fuel handling practice should always be followed to avoid contamination. As either a secondary measure or in cases where fuel contamination has occurred, fuel treatment should always be considered and put in place as necessary to meet the appropriate Rolls-Royce fuel acceptability criteria.

Equipment for fuel gas supply treatment, such as gas compressors and coalescers, are usually outside Rolls-Royce scope of supply.

In cases where liquid oil or other liquids are present in gas fuel, installation of purpose built coalescing units is recommended. Coalescing units should probably be sited where the gas is at its coldest, to maximize coalescer efficiency, and probably as close as possible to the gas fuel skid to minimize condensation in the pipe work following unit shutdown.

The Trent 60 Dual Fuel WLE Power Generation Package (Unit) Fuel Gas requirements are presented below.

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***Table B2.1-1*: Trent 60 WLE Fuel Gas Requirements**

<table>
<tr><td colspan="4">Where more than one gas fuel is to be used, where limits are outside these requirements, or where other fuel constituents are present, e.g. hydrogen (H_2), mercury (Hg), acetylene (C_2H_2), methanol (C_2H_3OH), ethanol (C_3H_5OH), benzene (C_6H_6), toluene (C_7H_8), heptane (C_7H_{16})… , dodecane ($C_{12}H_{26}$)… , heptadecane ($C_{17}H_{36}$) and so on, refer to Rolls-Royce.</td></tr>
<tr><td colspan="2">Gas fuel properties
(where standard conditions; 15°C (59°F) and 101.325kPa (14.696psia), apply to the fuel gas)</td><td>Units</td><td>Limits</td></tr>
<tr><td colspan="2">Lower Calorific, or Heating, Value (LCV or LHV)</td><td>kJ/ m^3 (Btu/SCF)
kJ/kg (Btu/lb)</td><td>29 000 (780) minimum
34 000 (14 600) minimum</td></tr>
<tr><td colspan="2">Wobbe Index {LCV / (√ SG)}</td><td>kJ/ m^3 (Btu/SCF)</td><td>34 500 (925) minimum
51 000 (1 370) maximum</td></tr>
<tr><td colspan="2">Wobbe Index variation to an agreed datum
(Minimum and maximum limits must also apply)</td><td>%</td><td>+/- 5 maximum</td></tr>
<tr><td colspan="2">Gas fuel constituents</td><td>Units</td><td>Limits</td></tr>
<tr><td colspan="2">Methane (CH_4)</td><td rowspan="8">% volume</td><td>65 minimum</td></tr>
<tr><td>Ethane (C_2H_6)</td><td rowspan="6">See Note A</td><td>13.0 maximum</td></tr>
<tr><td>Propane (C_3H_8)</td><td>7.0 maximum</td></tr>
<tr><td>Butane (C_4H_{10})</td><td>4.0 maximum</td></tr>
<tr><td>Pentane (C_5H_{12})</td><td>0.80 maximum</td></tr>
<tr><td>Hexane (C_6H_{14})</td><td>0.30 maximum</td></tr>
<tr><td colspan="2">Inert gases, including carbon dioxide (CO_2) and nitrogen (N_2) – see Note B</td><td>Consult Rolls-Royce for project specific inert gas limits</td></tr>
<tr><td colspan="2">Any form of sulfur, including hydrogen sulfide (H_2S) and sulfur dioxide (SO_2)
See Notes C, D, F, G and H</td><td colspan="2">All sulfur entering the gas turbine will affect unit life and will result in SOx emissions "sulfur-in = sulfur out".
Consult Rolls-Royce for expected unit life.</td></tr>
<tr><td colspan="2">Fuel contaminants / corrosive constituents</td><td>Units</td><td>Limits</td></tr>
<tr><td colspan="2">Oil – Concentration
Oil - Droplet size</td><td>ppm by weight
10^{-6} m (microns)</td><td>2 maximum
0.5 maximum</td></tr>
<tr><td colspan="4">No other liquids or hydrates are permissible – see Note I</td></tr>
<tr><td colspan="2">Particle size</td><td>10^{-6} m (microns)</td><td>20 maximum</td></tr>
<tr><td colspan="2">Sodium plus potassium
See Notes C, E, F G, H and J</td><td>ppm by weight</td><td>0.6 maximum</td></tr>
<tr><td colspan="2">Fuel supply</td><td>Units</td><td>Limits</td></tr>
<tr><td colspan="2">Fuel supply conditions (temperature and pressure) at entry to the gas fuel skid
See Notes A, B, K, L, M, N, O, P and Q</td><td colspan="2">Consult Rolls-Royce for project specific fuel supply conditions</td></tr>
<tr><td colspan="2">Fuel flow variation (at base load) see Note Q</td><td>%</td><td>+/-0.2 maximum</td></tr>
</table>

Note A: Higher levels and quantities of hydrocarbons, at a given pressure, increase the temperature required to maintain the fuel in the gaseous state. Accurate knowledge of fuel constituents, particularly heavier hydrocarbons is required to ensure the fuel remains fully gaseous.

Note B: In the majority of cases, the maximum acceptable level of inert gases is approximately 15% volume. However, the maximum acceptable level will depend on the balance of other fuel gas constituents and fuel supply conditions. Rolls-Royce shall be consulted for project specific inert gas limits.

Note C: Hot section gas turbine materials are susceptible to hot corrosion when certain contaminants such as sulfur, salts, and trace metals are ingested into the gas turbine. This is a metallurgical fact faced by all of the gas turbine industry. Rolls-Royce address this by applying specialised coating materials to components that are prone to hot corrosion caused by sulfur entering via the fuel.

Note D Typically sulfur enters the gas turbine via gas fuel in the form of hydrogen sulfide and/or sulfur dioxide. The sulfur level entering the gas turbine is critical for determining the rate of sulphidation of hot section components, which affects unit life. Typically when higher levels of sulfur enter the gas turbine the unit life is reduced.

Note E: Typically sodium and potassium enter the gas turbine via the intake air in the form of salts and in some cases via the fuel. The level of sodium plus potassium entering the gas turbine is critical for determining the rate of sulphidation of hot section components, i.e. the expected mid life refurbishment for maritime (salty air) applications compared to inland (non-salty air) is significantly lower for a given level of sulfur.

Note F: Information on air quality and where applicable water injection quality is important for prediction of mid life refurbishment. Further information is provided in the Rolls-Royce water injection acceptability criteria and in the Rolls-Royce definition of clean air.

Note G: Acceptable limits for sulfur and specified contaminants, such as trace metals, in fuel represent the total amounts permissible to enter the gas turbine. This includes intake air and where applicable injected water. All individual Rolls-Royce limits for fuel, injected water and air must be met.

Note H: Standard mid life refurbishment for gas fuel applications of 25 000 hours is based on applications where either of the following apply:

Clean environment; sulfur free, essentially non-salty air, i.e. ≤0.001wppm NaCl. Clean gas fuel, i.e. ≤0.027% volume H_2S+SO_2 with no other fuel contaminants.

Or

Salty but otherwise clean environment; sulfur free, salty air, i.e. ≤0.01wppm NaCl.
Clean gas fuel, i.e. ≤0.0005% volume H_2S+SO_2 with no other fuel contaminants.

Note I: The presence of oil, or any liquid hydrocarbons, in gaseous fuel entering the fuel system can cause large variations in heat input. In severe cases, where slugs of liquid accumulate, combustor damage can result. No accumulation or condensation of oil is permitted in the fuel system. Installation of purpose built coalescing units is recommended. Fuel temperature at entry to coalescing units is critical; coalescer suppliers should be consulted for the appropriate temperature range and advice.

Note J: The maximum limit for sodium plus potassium in the fuel applies to the <u>total</u> amount entering the gas turbine and is based on a fuel with an LCV (or LHV) of 43000kJ/kg.

Note K: Customer site-specific gas fuel supply conditions as stated in the contractual agreement apply. In cases where customer conditions have changed, such as fuel composition, Rolls-Royce shall be consulted to re-evaluate the gas fuel supply conditions.

Note L: The fuel supply at entry to the gas fuel skid must be maintained at a temperature that includes an allowance for cooling; between gas fuel skid edge and the fuel injector outlet.

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Note M: Water content, at a given pressure, will increase the temperature required to maintain the fuel in the gaseous state. Accurate knowledge of water content is required to ensure the fuel remains fully gaseous.

Note N: Fuel supply temperature must be controlled to ensure good operability of fuel system components such as fuel valves and to ensure that the fuel always remains fully gaseous.

Note O: Maximum fuel supply temperature is governed by certain components within the fuel delivery system that have maximum limits for which they are permitted to operate.

Note P: Maximum fuel supply pressure is governed by certain components within the fuel delivery system that have maximum limits for which they are permitted to operate.

Note Q: Fuel supply pressure fluctuations, at frequencies above 0.5 Hz, caused by pulsations in fuel supply should be avoided as they can cause cyclic oscillations of specific components. In extreme cases fuel supply pressure fluctuations can lead to component failure. The fuel pressure variation limit of +/-0.2% at base load equates to 200kJ/ s for Trent 60 WLE, which is the maximum fuel flow variation allowed for all operating conditions at 60Hz.

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B2.2 LIQUID FUEL REQUIREMENTS

Connections to the Trent 60 WLE Power Generation Package are made to flanges located on the liquid fuel skid, and supply flanges on the exterior face of the gas turbine module. Interconnection piping of the liquid fuel system is the responsibility of the Customer

Fuel quality is directly related to the cost of repair and life of gas turbine components. Unacceptable fuel quality can result in detrimental effects to unit operability, performance, availability, emissions and life and therefore should be avoided.

Poor fuel quality can be the result of purchasing fuel that does not meet the Rolls-Royce fuel acceptability criteria stated herein and/or a result of contamination, which can occur during transportation from the refinery to the site and/or during fuel storage and forwarding.

Applying good practice for handling liquid fuel is very important. A suitable reference document for Fuel management is ASTM-D4418 'Standard Practice for Receipt, Storage and Handling of Fuels for Gas Turbines'.

Fuel must not be transported or stored tanks constructed or containing the following materials; cadmium, copper, nickel or zinc. Storage tanks must also be constructed of corrosion resistant materials and lined to minimize contamination. For further information/advice consult Rolls-Royce.

Storage tank management should include regular drainage to remove any water and sludge, which is essential to prevent the growth of micro-organisms which can lead to blockage of fuel systems and corrosion problems.

Fuel storage tank inlets shall be located at the bottom of storage tanks. Refueling of tanks shall allow for settling time of 1 hour/foot before fuel can be drawn to for delivery into the gas turbine.

Good fuel handling practice, as stated above, should always be followed to avoid contamination. As either a secondary measure or in cases where fuel contamination has occurred, fuel treatment should always be considered and put in place as necessary to meet the appropriate Rolls-Royce fuel acceptability criteria.

Rolls-Royce must be consulted if any other contaminants other than those specified in Table 2.2 are present, e.g. arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, zinc...

Rolls-Royce should be consulted to agree any proposed fuel treatments.

Rolls-Royce should be consulted and for advice on test methods.

The Trent 60 WLE GenSet Liquid Fuel requirements are presented below:

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Table B2.2-1: Trent 60 WLE Liquid Fuel Requirements – Physical Properties

Physical properties Paramount to acceptability	Units	Minimum	Maximum	Test method(s) Latest standards apply (Rolls-Royce should be consulted and for advice on test methods.)
Fuels falling outside of these limits must be referred to Rolls-Royce for evaluation				
Aromatic Content	% volume	5	40	ASTM-D1319 / IP156 See Notes a and b
Consult Rolls-Royce where either the total aromatic content is over 25% volume or where control of smoke emissions is a requirement. Additional testing may be required.				
Carbon Residue on 10% bottoms (Conradson or Ramsbottom)	% weight	-	0.35	ASTM-D189 / ASTM-D524 / ASTM-D4530 / IP13 / IP14
Cloud point	Fuel temperature must be at least 5ºC above the cloud point throughout the gas turbine fuel delivery system.			ASTM-D2500 / IP219
Distillation data				
10% volume recovery	°C (°F)	-	250 (482)	ASTM-D86 / IP123
90% volume recovery			357 (675)	
Final Boiling Point			385 (725)	
Flash point	Fuel temperature must be at least 10ºC below the flash point throughout the gas turbine fuel delivery system.			ASTM-D56 / ASTM-D93 / ASTM-D3828 / IP34 / IP170 See Note c
Smoke point	Mm	17	-	ASTM-D1322 / IP57
Viscosity (Kinematic) – see Figure 1 and Note d	mm^2/ s (centistokes)	1	11	ASTM-D445 / IP71
Fuel supply	Units			
Fuel flow variation (at base load)	%	+/-0.2 maximum See Note e		

Note a: ASTM-D1319 is applicable to 5 to 99% volume aromatics. Samples containing dark-colored components that interfere in reading of the chromatographic bands cannot be analyzed. Rolls-Royce shall be consulted for advice.

Note b: Alternative test methods; ASTM-D5186, IP391 and IP436 can be used to measure % mass aromatic content. Results include both single and multi-ring aromatics and must be reported to Rolls-Royce to access acceptability.

Note c: ASTM-D56 is applicable to liquid fuels with a viscosity below 5.5mm2/ s (centistokes) at 40°C (104°F), or below 9.5mm2/s (cSt) at 25°C (77°F), and a flash point below 93°C (200°F).

Note d: Fuel preheating may be necessary to reduce viscosity and to remove wax from high cloud point fuels. Rolls-Royce should be consulted for advice.

Note e : Fuel supply pressure fluctuations, at frequencies above 0.5 Hz, caused by pulsations in fuel supply should be avoided as they can cause cyclic oscillations of specific components. In extreme cases fuel supply pressure fluctuations can lead to component failure. The fuel pressure variation limit of +/-0.2% at base load equates to 200kJ/ s for Trent 60 WLE, which is the maximum fuel flow variation allowed for all operating conditions at 60Hz.

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Figure 1: Viscosity (Kinematic)– Temperature characteristics for Industrial Gas Turbines

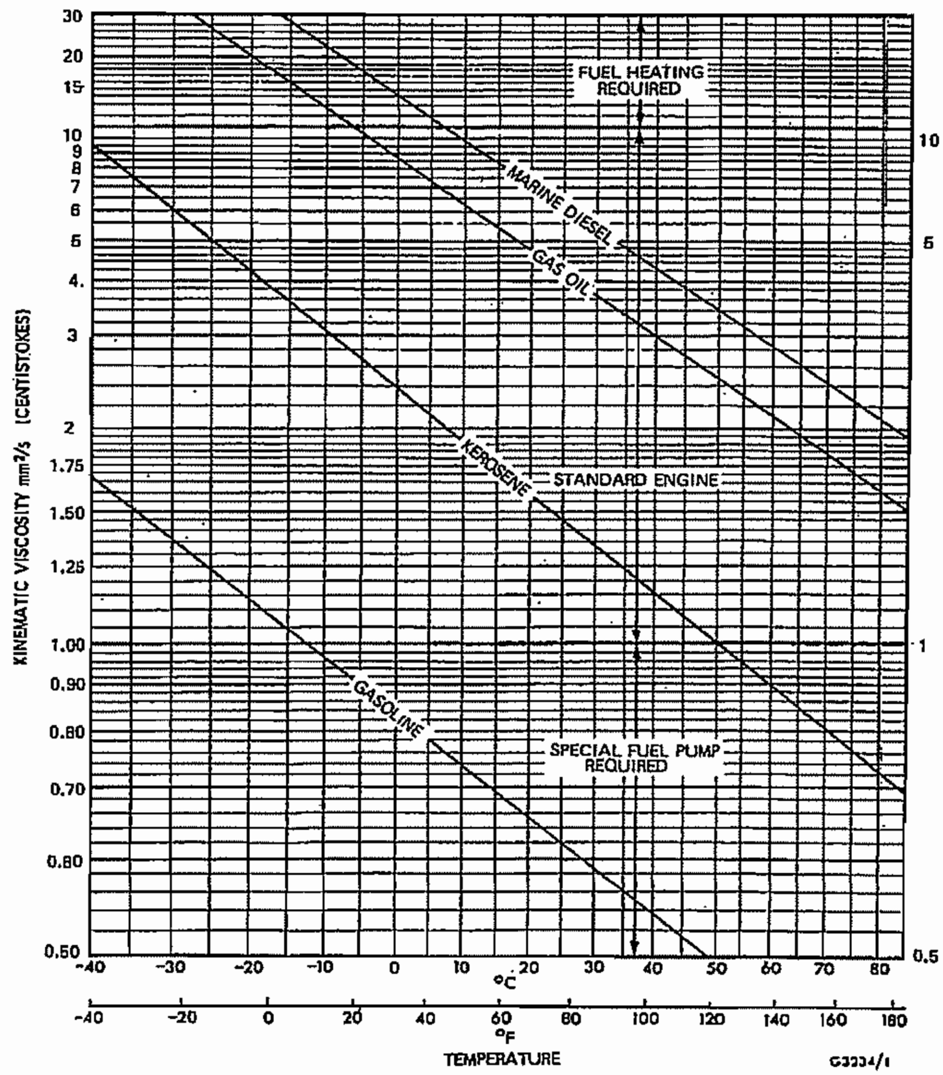

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Table B2.2-2: Trent 60 WLE Liquid Fuel Requirements – Fuel Cleanliness

Fuel cleanliness properties Paramount to acceptability	Units	Maximum	Test method(s) Latest standards apply (Rolls-Royce should be consulted and for advice on test methods.)
Fuels falling outside of these limits must be referred to Rolls-Royce for evaluation			
Ash	% weight	0.01	ASTM-D482 / IP4 See Note f
Trace metals - see Notes g, j, k, l and m			ASTM-D3605
Calcium	ppm by weight	0.5	
Lead		0.5	
Sodium plus potassium – see Note i		0.6	
Vanadium		0.5	
Rolls-Royce should be consulted to agree any proposed fuel treatments.			
Sulfur See Notes g, h, j, k, l and m	All sulfur entering the gas turbine will affect unit life and will result in SOx emissions "sulfur-in = sulfur out". **Consult Rolls-Royce for expected unit life.**		
	% weight	1.0	ASTM-D129 / ASTM-D1266 / ASTM-D1552 / ASTM-D2622 / ASTM-D4294 / IP61 / IP336 See Notes n and o
Free water and sediment	% volume	0.05	ASTM-D1796 / ASTM-D2709 See Note p
Particulates	mg/ litre	3.0	ASTM-D2276 / ASTM-D5452
	g/m^3		ASTM-D6217 / IP415
Particle size	10^{-6} m (microns)	40 maximum	
Rolls-Royce must be consulted if any other contaminants are present, e.g. arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, zinc....			

Note f: Both ASTM-D482 and IP4 are applicable to ash in the range of 0.001 to 0.180% from distillate and residual fuels, gas turbine fuels and other petroleum products, which are free from ash-forming additives, including certain phosphorus compounds.

Note g: Hot section gas turbine materials are susceptible to hot corrosion when certain contaminants such as sulfur, salts, and trace metals are ingested into the gas turbine. This is a metallurgical fact faced by all of the gas turbine industry. Rolls-Royce address this by applying specialised coating materials to components that are prone to hot corrosion caused by sulfur entering via the fuel.

Note h: Sulfur is present in all distillate fuels. The level sulfur level entering the gas turbine is critical for determining the rate of sulphidation of hot section components, which affects unit life. Typically when higher levels of sulfur enter the gas turbine the unit life is reduced.

Note i: Typically sodium and potassium enter the gas turbine via the intake air in the form of salts and in some cases via the fuel. The level of sodium plus potassium entering the gas turbine is critical for determining the rate of sulphidation of hot section components, i.e. the expected mid life refurbishment for maritime (salty air) applications compared to inland (non-salty air) is significantly lower for a given level of sulfur.

Note j: Information on air quality and where applicable water injection quality is important for prediction of mid life refurbishment. Further information is provided in the Rolls-Royce water injection acceptability criteria and in the Rolls-Royce definition of clean air.

Note k: Acceptable limits for sulfur and specified contaminants, such as trace metals, in fuel represent the total amounts permissible to enter the gas turbine. This includes intake air and where applicable injected water. All individual Rolls-Royce limits for fuel, injected water and air must be met.

Note l: Maximum limits and specified quantities of sulfur and contaminants are based on a fuel with a Lower Calorific Value (LCV) of 43 000kJ/kg (18500Btu/lb) and must be scaled as follows to account for changes in LCV. Hence where the specified maximum limit is 0.5wppm the following applies:
Acceptable limit = 0.5wppm x LCV (kJ/kg) / 43 000kJ/kg

Note m: Standard mid life refurbishment for liquid fuel applications of 16 000 hours is based on applications where either of the following apply:
Clean environment; sulfur free, essentially non-salty air, i.e. ≤0.001wppm NaCl.

Clean liquid fuel; i.e. ≤0.05% weight sulfur, ≤0.1wppm sodium, ≤0.1wppm potassium, ≤0.1wppm calcium, ≤0.1wppm magnesium) with no other fuel contaminants.

Or

Salty but otherwise clean environment; sulfur free, salty air, i.e. ≤0.01wppm NaCl.

Clean liquid fuel, i.e. ≤0.001% weight sulfur, ≤0.1wppm sodium, ≤0.1wppm potassium, ≤0.1wppm calcium, ≤0.1wppm magnesium) with no other fuel contaminants.

Note n: ASTM-D1266 covers the determination of total sulfur in liquid petroleum products in concentrations from 0.01 to 0.4 % weight and also includes a procedure that permits the determination of sulphur in concentrations as low as 5 mg/kg.

Note o: ASTM-D4294 covers the measurement of sulfur in hydrocarbons, such as Diesel, naphtha, kerosene, residuals, lubricating base oils, hydraulic oils, jet fuels, crude oils, gasoline (all unleaded), and other distillates. The applicable concentration range is 0.0150 to 5.00% weight sulfur.

Note p: ASTM-D2709 is applicable when fuel viscosity at 40°C is 1.0 to 4.1mm2/s and density is 770 to 900 kg/m3. ASTM-D1796 should be used for fuels with higher viscosity.

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Table B2.2-3: Trent 60 WLE Liquid Fuel Requirements – Physical Properties (Good Indicators)

<table>
<tr><th>Physical properties
Good indicators of acceptability</th><th>Units</th><th>Minimum</th><th>Maximum</th><th colspan="3">Test method(s)
Latest standards apply
(Rolls-Royce should be consulted and for advice on test methods.)</th></tr>
<tr><td colspan="7">Fuels falling outside of these limits must be referred to Rolls-Royce for evaluation</td></tr>
<tr><td>Copper corrosion</td><td>-</td><td>-</td><td>1</td><td colspan="3">ASTM-D130/ IP154</td></tr>
<tr><td>Density, SG and API - See Note n</td><td colspan="6"></td></tr>
<tr><td>Density at 15°C (59°F)
Or</td><td>kg/ m³
(lb/SCF)</td><td>600
(37.5)</td><td>880
(55.0)</td><td rowspan="3">ASTM-D1298</td><td rowspan="2">ASTM-D4052 / IP365</td><td>IP160</td></tr>
<tr><td>Specific gravity at 15.6/15.6°C (60/60°F)
Or</td><td>-</td><td>0.60</td><td>0.88</td><td>-</td></tr>
<tr><td>API at 15.6°C (60°F)</td><td>-</td><td>29.3</td><td>104</td><td>-</td><td>ASTM-D287</td></tr>
<tr><td>Lower Calorific Value</td><td>kJ/kg
(Btu/lb)</td><td>40 700
(17 500)</td><td>52 850
(22 720)</td><td colspan="3">ASTM-D4809</td></tr>
<tr><td>Lubricity, corrected wear scar diameter at 60°C (140°F)</td><td>10⁻⁶ m
(in)</td><td>-</td><td>460
(0.018)</td><td colspan="3">ISO-12156</td></tr>
<tr><td>Hydrogen content</td><td>% weight</td><td>12.5</td><td>-</td><td colspan="3">ASTM-D1018 / ASTM-D3343 / ASTM-D3701 / IP338</td></tr>
<tr><td>Neutralization number
Total acid number
Strong acid number
Strong base number</td><td>
mg KOH/ g
mg KOH/ g
mg KOH/ g</td><td>
-
-
-</td><td>
0.5
0.0
0.0</td><td colspan="3">ASTM-D974 / ASTM-D4739 / IP139</td></tr>
<tr><td>Olefin Content</td><td>% volume</td><td>-</td><td>5.0</td><td colspan="3">ASTM-D1319 / IP156</td></tr>
</table>

Note n: Customer fuel specifications should include Density, Specific Gravity or API Gravity. Information on all three properties is not required, but in cases where more than one property is stated they should all conform to the specified limits.

B2.3 WATER INJECTION REQUIREMENTS

Connections to the Trent 60 WLE Power Generation Package are made to supply and return flanges located on the water injection skid, and supply flanges on the exterior face of the gas turbine module. Interconnection piping of the water injection system is the responsibility of the Customer

Water quality employed for water injection applications is directly related to the cost of repair and life of gas turbine components. Unacceptable water quality at entry to the gas turbine can result in detrimental effects to unit operability, performance, availability and life and therefore should be avoided.

Good water treatment practice, on-line monitoring and periodic sampling should always be followed to produce and maintain acceptable water quality. Contamination shall be avoided.

Water shall not be allowed to come into contact with components constructed of, or containing copper and/or zinc.

Equipment for water treatment is outside Rolls-Royce scope of supply.

The Trent 60 GenSet WLE Water acceptability requirements are presented below.

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Table B2.3-1: **Water acceptability criteria at entry to the gas turbine.**

Acceptable water shall be prepared and controlled in accordance with ASTM-D1193 as Type IIIA or Type IVA and shall meet the requirements specified below – see Notes a and b				
Appearance	Clear and colorless			
Water temperature	Conditions shall be such that no ice or steam forms			
Parameter	**Units**	**Minimum**	**Maximum**	**Test method(s)** ***Note* c**
Acidity *Notes d, e, f and g*	pH	6.0	8.0	ASTM-D5128 OR ASTM-D5464
Conductivity at 25°C *Notes d, e, f, h, i, j and k*	µS/cm	-	1.0	ASTM-D5391
Silica *Note l*	wppm	-	0.05	ASTM-D859 OR ASTM-D4517
Calcium plus magnesium *Notes m and l*	wppm	-	0.08	ASTM-D3919
Sodium *Notes m and l*	wppm	-	0.1	
Potassium *Notes m and l*	wppm	-	0.1	
Total metals (to include sodium, potassium, calcium and magnesium) *Notes n and l*	wppm	-	0.30	ASTM-D3919 PLUS ASTM-D4190
Chlorides *Note l*	wppm	-	0.2	ASTM-D4327
Total sulphates, sulphides and phosphates *Note l*	wppm	-	1.0	ASTM-D4327 PLUS ASTM-D4658
Filtration *Notes d, k and o*	µm	10 nominal 40 absolute		
Consult Rolls-Royce if any other constituents/contaminants are present. Refer to Note n.				

Note a: All limits for parameters specified in ASTM-D1193 that are not included in the Rolls-Royce specific requirements, Table 1.1, shall be met.

Note b: Where parameters are specified in both ASTM-D1193 and the Rolls-Royce specific requirements, Table 1.1, the limits stated in Table 1.1 have precedence.

Note c: There are numerous tests for measuring water quality parameters, which are often addressed by international standards such as American Society for Testing and Materials (ASTM). Updates to such test methods and the applicability of test range to the defined limit/s is important. Rolls-Royce shall be consulted for advice.

Note d: On-line monitoring is available for measurement of pH (ASTM-D5128), measurement of conductivity (ASTM-D4519) and measurement of particulates. Consult Rolls-Royce for further advice.

Note e: Both pH and conductivity measurements are indicative of acceptable water quality.

Note f: In cases where levels are outside the stated limits, Rolls-Royce shall be consulted.

Note g: ASTM D5128 and ASTM D5464 are standard test methods for pH measurement of water of low conductivity or on-line and sample analysis respectively. Both methods are applicable to water with conductivity lower than 100μS/cm over the pH range of 3 to 11.

Note h: Conductivity levels of 1.0≥1.5μS/cm at 25°C are permissible if all other limits in Table 1.1 are met and confirmed by appropriate sampling results.

Note i: S = Siemen, 1 Siemen = 1 mho, mho was the old unit.

Note j: c (centi) = 0.01 = 10-2, cm = centimetre.

Note k: μ (micro) = 0.000 001 = 10-6, μS = microSeimen, μm = micrometer (micron).

Note l: Limits stated in wppm (weight parts per million) are based on all other individual wppm limits also being met.

Note m: Limits stated must also be converted into the "effective fuel equivalent". The total effective amounts entering the gas turbine from all potential sources, water, air and fuel shall be related to the limits stated in the applicable Rolls-Royce fuel acceptability criteria. Consult Rolls-Royce for further advice.

Note n: Rolls-Royce shall be consulted when metals, elements and compounds in addition to the those specifically stated in Table 1.1 are present. Details shall be reported to Rolls-Royce.

Note o: Nominal means that the filter will trap at least 98.7% of particles over the stated nominal value, which equates to a Beta ratio of 75, i.e. 1 particle in 75 will pass through the filter. Absolute means that the filter will trap at least 99.5% of particles over the stated absolute value, which equates to a Beta ratio of 200.

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B2.4 AMBIENT AIR QUALITY REQUIREMENTS

Rolls-Royce defines the Ambient Air Quality requirements as presented below. Ambient air quality falling outside of these limits, or where other constituents or contaminants are present, needs to be referred to Rolls-Royce for evaluation.

***Table B2.4-1*: Post filtration air contaminant limits for entry into the gas turbine enclosure/intake.**

Air contaminants	Units *See Note A*	Rolls-Royce air contaminant limits *See Note B*
Total chloride salts (intake)	ppmw in air	0.001 maximum
Total chloride salts (enclosure)		0.01 maximum
Particulate matter	mg/m^3	0.05 maximum
	microns	10 maximum (PM10)

***Table B2.4-2*: Definition of Clean Dry Ambient Air Quality**

Air constituents/contaminants	Units *See Note A*	Rolls-Royce acceptable range for clean dry air *See Notes B, C and D*
Nitrogen (N_2)	% Volume	77.5 to 78.5
Oxygen (O_2)	% Volume	20.5 to 21.5
Argon (Ar)	% Volume	0.5 to 1.5
Carbon dioxide (CO_2)	% Volume	0 to 0.5
Neon (Ne)	% Volume (ppmv)	0 to 0.002 (0 to 20)
Ozone (O_3)	% Volume (ppmv)	0 to 0.000 8 (0 to 8)
Helium (He)	% Volume (ppmv)	0 to 0.000 5 (0 to 5)
Methane (CH_4)	% Volume (ppmv)	0 to 0.000 2 (0 to 2)
Krypton (Kr)	% Volume (ppmv)	0 to 0.000 15 (0 to 1.5)
Hydrogen (H_2)	% Volume (ppmv)	0 to 0.000 1 (0 to 1)
Nitrous oxide (N_2O)	% Volume (ppmv)	0 to 0.000 1 (0 to 1)
Carbon monoxide (CO)	% Volume (ppmv)	0 to 0.000 1 (0 to 1)
Xenon (Xe)	% Volume (ppmv)	0 to 0.000 01 (0 to 0.1)
Nitrogen dioxide (NO_2)	% Volume (ppmv)	0 to 0.000 01 (0 to 0.1)
Ammonia (NH_3)	% Volume (ppmv)	0 to 0.000 001 (0 to 0.01)
Sulfur dioxide (SO_2) plus Hydrogen sulfide (H_2S)	% Volume (ppmv)	0 to 0.000 002 (0 to 0.02)
Total sulfur (includes SO_2 plus H_2S)	ppmw	0 to 0.02
Total metals (includes metal content of salts, NaCl, KCl ...)	ppmw	0 to 0.005
Total chlorides (includes chloride content of salts)	ppmw	0 to 0.006

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Note A: parts per million by weight (ppmw) = 1×10^{-6}

m^3 assumes standard temperature, 15°C (59°F) and atmospheric pressure of 101.325 kPa (14.696 psia).

micron = μm = 1×10^{-6} m

Note B: Hot section gas turbine materials are susceptible to hot corrosion when certain contaminants such as sulfur, salts, trace metals are ingested into the gas turbine. Appropriate filtration and materials selection typically accommodate these requirements to ensure expected unit life, performance, operability, reliability, availability and emissions.

Note C: Gaseous air contaminants, cannot be removed by filtration so in cases where gaseous contaminants are present their expected effect and potential mitigation shall be agreed with Rolls-Royce.

Note D: Unit life, performance, operability, reliability, availability and emissions as agreed with Rolls-Royce are on the basis of the defined customer site ambient air conditions.

Note E: All air contaminants/constituents that exceed the defined limits in Tables A and B will not be addressed by the Rolls-Royce standard package. In such cases expected unit life, performance, operability, reliability, availability and emissions will not be ensured unless specific mitigation is agreed with Rolls-Royce.

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B2.5 COMPRESSED AIR REQUIREMENTS

Connections to the Trent 60 Power Generation Package are made to supply flanges located on the exterior faces of the gas turbine module, water injection skid, liquid fuel injection skid and , as shown on the general arrangement. Interconnecting pipework from M313 to Compressor Wash Cart is supplied with the Compressor Wash Cart

The Trent 60 Power Generation Package requires a compressed instrument air supply to the self-cleaning combustion air inlet filter, fuel gas manifold vent valves, water wash system and other pneumatically operated equipment. The attached utility consumption information is forwarded to indicate the likely duty required, but will depend on local site conditions.

The instrument air supply is required to provide continuous supply for the Pulse Clean Combustion Filter for anti icing purposes during icing conditions.

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B2.6 COOLING WATER REQUIREMENTS

Connections to the Trent 60 Power Generation Package are made to supply and return flanges located on the exterior faces of the gas turbine and AC generator modules, as shown on the general arrangement.

The Trent 60 Power Generation Package requires cooling water circulation to the gas turbine lube oil cooler, gas turbine hydraulic system cooler, oil mist cooler and AC generator lube oil cooler. The attached utility consumption information is forwarded to indicate the duty required, but will depend on local site conditions. The Fin-Fan coolers are included in Rolls-Royce Scope of Supply, interconnection piping and first fills are to be provided by the Customer.

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B2.7 GAS TURBINE COMPRESSOR WATER WASH REQUIREMENTS

Connections to the Water Wash Cart are made to supply fill point located on the tank of the water wash cart.

Interconnecting pipework from gas turbine module connection M 313 to Compressor Wash Cart is supplied with the Compressor Wash Cart

The Trent 60 Power Generation Package requires water, detergent and, for temperate and arctic applications, anti-freeze, to be stored externally and pumped into the holding tanks of the gas turbine compressor water wash cart.

***Table B2.7-1*: Trent GenSet Gas Turbine Compressor Water Wash Requirements**

Item	Specification
Expected wash frequency	On Condition as required, site-specific
Solution demand per unfired wash	Water 123 liters (32.5 US gal) Anti-freeze 47 liters (12.5 US gal) Cleaning fluid 19 liters (5.0 US gal)

***Table B2.7-2*: Water Quality Required for Unfired Wash**

Item	Property
Total dissolved solids	< 10 ppmw
Acidity	5 < pH < 7.5
Silica	< 3 ppmw
Specific conductance	< 11 micro-mhos/cm

***Table B2.7-3*: Recommended Wash Fluids**

GROUP 'A' (no anti-freeze added)	GROUP 'B' (anti-freeze added)
Ardrox 6343	Castrol ICD 177 pre-mixed [1]
Ardrox 6345	[1] Ready-to-use solution can be used down to -32 °C (-26°F). No mixing required.
Ardrox 6366(Turboclean)	
Ardrox 6367(Turboclean)	
RMC G21	Ardrox6373 (Turboclean 2 Wintergrade)[2]
Techniclean GT (ZOK 27)	[2] Ready-to-use solution can be used down to -20°C (-4°F). No mixing required
Techniclean GT-2(Castrol ICD 177)	
Fyrewash F3	

***Table B2.7-4*: Recommended Anti-Freeze Fluids**

Anti-Freeze Fluid	Anti-Freeze Specifications	Quantities
Methyl Alcohol (MA)	MA to (British Standards) BS506 or 0-M-232G Grade A (US Standard)	20% vol. Max, for a min. temp. -15°C (5°F)
Isopropyl Alcohol (IPA)	IPA to (British Standards) BS1595 or TT–1735a and 3 Grade B (US Standard)	35% vol. max, for a min. temp. -15°C (5°F)
Ethylene Glycol (EG)	EG to (British Standards) BS2713 – US Standard not available	40% vol. Max, for a min. temp. -35°C (-31°F)

***Table B2.7-5*: Unfired Wash Mixture Ratios**

Mixing Proportions for Group 'A' Cleaning Fluids (Except R-MC CS)

Ambient Temperature Range	Alternative Cleaning Fluid (CF) Mixture Ratios		
Above +5°C (+41°F)	CF 20% Demin.Water 80%		
-5°C < T < 5°C (23°F < T < 41°F)	CF 20% Demin.Water 70% MA 10%	CF 20% Demin.Water 70% EG 10%	CF 20% Demin.Water 60% IPA 20%
-15°C < T < -5°C (5°F < T < 23°F)	CF 20% Demin.Water 60% MA 20%	CF 20% Demin.Water 55% EG 25%	CF 20% Demin.Water 45% IPA 35%
	MA Methyl Alcohol	EG Ethylene Glycol	IPA Isopropyl Alcohol

***Table B2.7-6*: Unfired Wash Mixture Ratios**

Mixing Proportions for Group 'A' R-MC CS Cleaning Fluid

Ambient Temperature Range	Alternative Cleaning Fluid (CF) Mixture Ratios		
Above +5 °C (+41 °F)	R-MC CS 14% WATER 86%		
-5°C < T < 5°C (23°F < T < 41°F)	R-MC CS 14% WATER 75% MA 11%	R-MC CS 14% WATER 74% EG 12%	R-MC CS 14% WATER 63% IPA 23%
-15°C < T < -5°C (5°F < T < 23°F)	R-MC CS 14% WATER 63% MA 23%	R-MC CS 14% WATER 60% EG 26%	R-MC CS 14% WATER 48% IPA 38%
	MA Methyl Alcohol	EG Ethylene Glycol	IPA Isopropyl Alcohol

***Table B2.7-7*: Rinse Fluid Mixture Ratios for Unfired Wash**

Mixing Proportions for Group 'A' Rinsing Fluids (Except R-MC CS)

Ambient Temperature Range	Alternative Rinse Water & Anti-Freeze Ratios		
Above +5 °C (+41 °F)	WATER 100%		
-5°C < T < 5°C (23°F < T < 41°F)	WATER 90% MA 10%	WATER 85% EG 15%	WATER 75% IPA 25%
-15°C < T < -5°C (5°F < T < 23°F)	WATER 75% MA 25%	WATER 70% EG 30%	WATER 55% IPA 45%
	MA Methyl Alcohol	EG · Ethylene Glycol	IPA Isopropyl Alcohol

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B2.8 OIL & GREASE REQUIREMENTS

Connections to the Trent 60 Power Generation Package are made to supply and return flanges located on the exterior faces of the gas turbine modules and inside the AC generator enclosure for AC generator lube oil system, as shown on the general arrangement. The Trent 60 Power Generation Package requires synthetic oil for the gas turbine oil systems and mineral oil for the AC generator lube oil system.

Table B2.8-1: Trent GenSet Oil Specification

Item	Specification		
Service	Gas Turbine Lube Oil System	Gas Turbine Control Oil System	AC Generator Lube Oil Systems
Type	Synthetic Oil	Synthetic Oil	Mineral Oil
First Fill	1100 liters	530 liters	1664 liters
Approved for use with Industrial Trent	ROYCO Turbine Oil 500 Mobil Jet Oil II Mobil Jet Oil 254 Exxon Turbo Oil 2197		ISO VG32

B2.8.1 Greases

General greases required for electrical motors, fans, valves, actuator and damper spindles, door hinges and so forth.

B2.9 DRAINS AND VENTS REQUIREMENTS

B2.9.1 Vents

Connections to the Trent 60 Power Generation Package are made to connections located on the exterior faces of the gas turbine, AC generator modules and auxiliary skids, as shown on the general arrangement. Connection to Vents is the responsibility of the Customer. Vent lines must have a continuous vertical rise (no traps or low points) and must be routed to a safe area.

B2.9.2 Drains

Connections to the Trent 60 Power Generation Package are made to connections located on the exterior faces of the gas turbine, AC generator modules and auxiliary skids, as shown on the general arrangement. Connection to Drains is responsibility of the Customer

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B2.10 ELECTRICAL / C&I CABLING REQUIREMENTS

Cabling at site between the undrilled gland plates, incoming, outgoing and earthing terminals of the Trent 60 Power Generation Modules is the responsibility of the Customer. The attached utility consumption information is forwarded to indicate the duty required, but will depend on local site conditions.

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B2.11 GROUND (EARTHING) LOCATIONS

Connection to Earthing location on gas turbine module, AC Generator Module and auxiliary skids at site between the grounding pads of the Trent 60 Power Generation Modules is the responsibility of the Customer.

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B2.12 HV (13.8 KV) ELECTRICAL TIE-IN

B2.12.1.1 Generator Electrical Tie-in Location

The generator tie-ins are located opposite each other on either side of the enclosure. The Line cubicle is on the left side and the Neutral cubicle on the other.

Connection to HV (13.8 kV) in the AC Generator Module Line and Neutral Cubicles is the responsibility of the Customer.

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B2.13 CONTROL SYSTEM INTERFACE REQUIREMENTS

A dual Ethernet LAN is used for the onward link between the HMI system and the Customer's Station Control System (SCS). The following discrete signals will interface to the Station Control System.

From Station Control System to Genset Control System:

- Start
- Stop
- Base selection
- Peak selection
- Fast loading
- Normal loading
- Droop mode
- Speed / load raise
- Speed / load lower
- Voltage raise
- Voltage lower
- Synch reset

From Genset Control System to Station Control System:

- Ready to start
- Load limit
- Unit running
- Failure to auto synch
- Failure to start
- Breaker closed
- Start in progress

The following signals need to be hardwired into the on base control system:

- From Station Control System to Genset Control System:
  - Plant emergency shut down
  - Trip generator breaker
- From Genset Control System to Station Control System:
  - GenSet trip

In addition an RS-232 serial port will allow access to GenSet sensors and status information for the purpose of data logging and trend monitoring.

Additional programming for communication or hardware for communication with the Station Control System is in additional to the base scope of supply.

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B2.14 CONTROL PANELS

B2.14.1 Package Control System & Engine Management System

The Genset control system is mounted on the gas turbine baseplate. All on-skid instrumentation is pre-wired into the control system. Connection to control system panels, nodes and HMI's of the Trent 60 Power Generation Modules is the responsibility of the Customer.

B2.14.2 Human-Machine Interface (HMI)

Human-Machine Interface's (HMI) that are linked to the package through a dual redundant network connection remotely controls the GenSet Package. The HMI's are free-issued for installation in a general purpose, control room environment. As part of the Appendix A - Scope of Work, Rolls-Royce will provide two (2) HMI units. One shall be mounted in the local control room and the second may be remotely mounted connected via an Ethernet line.

B2.14.3 Generator Control and Protection panel (GCPP)

The Generator Control and Protection panel (GCPP) is free-issued for installation in a general purpose, control room environment.

- Swingrack configuration w/Rittal cabinets having front access doors.
- Overall panel dimensions: 1600mm (63") wide, 852mm (33") deep, 2200mm (86") high

B2.14.4 Control Nodes

The MCC (by others) is controlled and monitored via a motor control system interface module (MCS) linked to the PCS through a dual redundant network connection. The MCS is free-issued for mounting in the MCC during installation.

The GCPP is controlled and monitored via a generator control interface module (GCS) linked to the PCS through a dual redundant network connection. The GCS is free-issued for mounting in the GCPP during installation.

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B2.15 CIVIL REQUIREMENTS

Please refer to Bolting and Grouting Drawings.

The supply of foundation bolts and all civil is by the Customer.

Machinery Grout may be dry pack or wet type (supplied by Customer)

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B2.16 EXHAUST INTERFACE REQUIREMENTS

Not Used

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B2.17 CODES AND STANDARDS

B2.17.1 The following represents the list of Codes and Standards to which the TRENT 60 WLE Dual Fuel has been designed:

- 98/37/EC The Supply of Machinery (Safety) Regulations
- 97/23/EC Pressure Equipment Directive (PED)
- 94/9/EC ATEX Directive (Electrical/Mechanical)
- 89/336/EEC The Electromagnetic Compatibility Regulations
- 73/23/EEC Low Voltage Equipment
- 93/465/EEC Rules for CE Marking
- ASME VIII Div 1 U-Stamped Pressure Vessel
- ASME B31.3 and BS EN 13480 Process Piping
- ASME B16.5 Pipe Flanges and Fittings
- ASME V Non-Destructive Testing
- ASME 1X/BS EN 25817/PED Welding Piping/Weld Acceptance
- AWS D1.1/BS 5950 Structural Design Fabrication
- Material Traceability Certification to Section 3.1 of EN-10204
- Hazardous Area Classification North America Class 1 Div 2
- Institute of Petroleum Model Code of Safe Practice Part 15
- Fire Codes – NFPA 72 / NFPA 12

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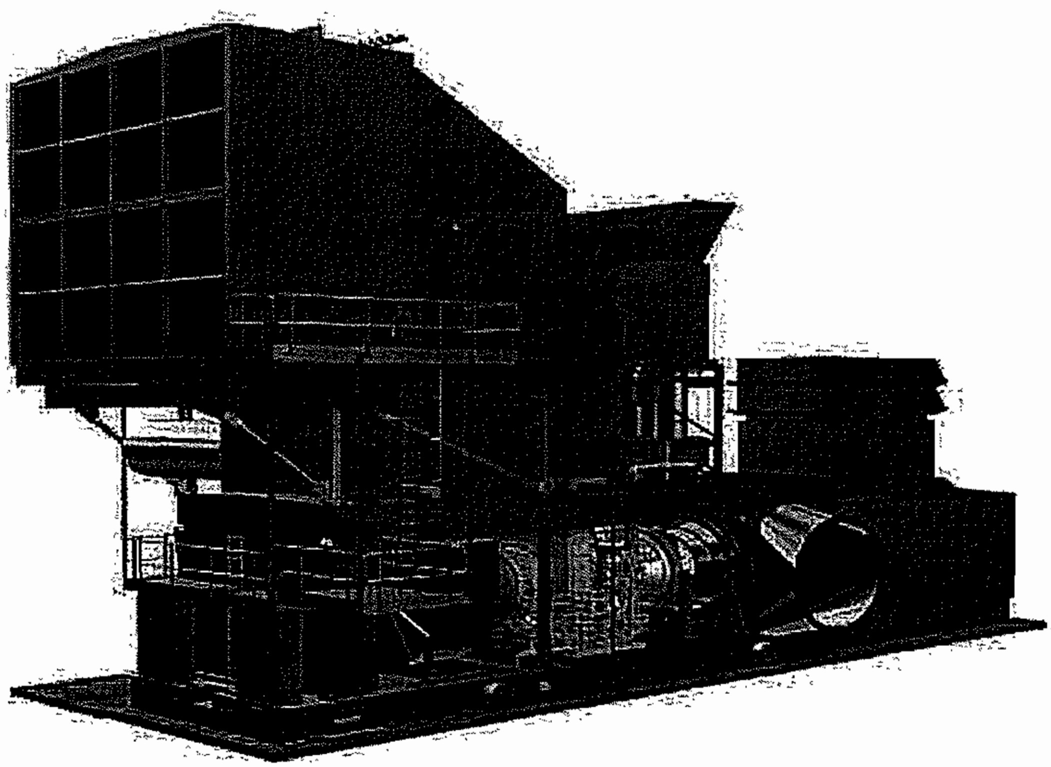
B3 FUNCTIONAL SPECIFICATION

The data contained in this section represents the functional specification of the Rolls-Royce baseline Trent 60 WLE Dual Fuel Power Generation Set. Rolls-Royce scope of supply is limited to the gas turbine generating set and associated systems necessary for the safe operation of the gas turbine genset, as defined in the Appendix A - Scope of Work.

B3.1 TRENT GENSET

B3.1.1.1 The Trent GenSet



The Trent 60 Power Generation Package will provide a complete generating system. All components and subsystems have been carefully selected and optimized to form a compact plant, housed within enclosures, and designed to comply with environmental requirements.

The package is designed for quick installation and easy maintenance in the field. Since most of the systems are mounted on the base they can be tested in the factory shop before shipment to the field.

The Trent 60 Power Generation Package encompasses the following major components:

- Gas Turbine Module - This module houses the gas turbine, the turbine thrust bearing, inlet air scroll, exhaust transition duct and diffuser volute, engine mounting and removal arrangement, fuel distribution system, fire protection and gas detection devices. The front compartment of this module houses the major gas turbine auxiliary systems. These include gas turbine synthetic lubricating oil, hydraulic control oil, and hydraulic start oil systems.

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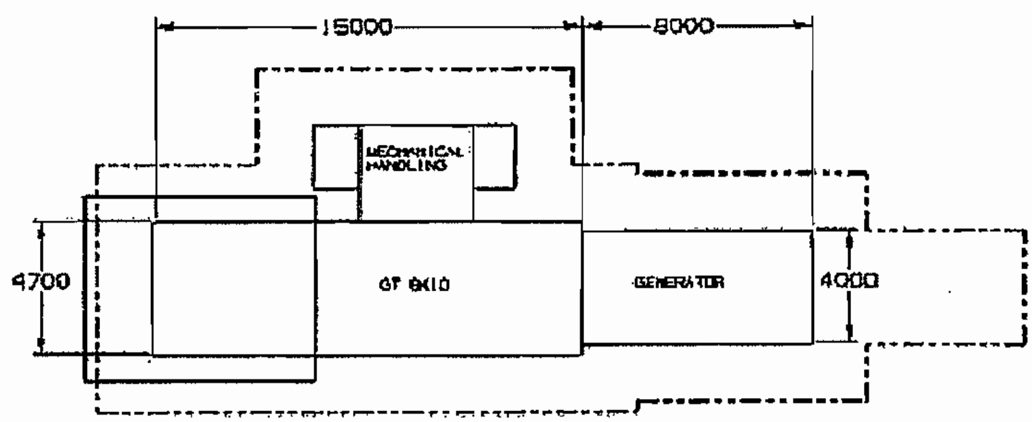
- AC Generator Module - The AC Generator Package is self-contained and encompasses the AC generator and exciter and the AC generator mineral lube oil system and lineside cubicles. It is mounted on its own base plate that is separately mounted in line with the gas turbine base.
- Control System - Located in the front of the gas turbine baseplate are two control cabinets. These control cabinets include the engine management system, package control system, fire and gas system and safety related systems. The AC generator control and protection panel together with the remote HMI's, allowing complete Trent Power Generation Package control, are mounted in the remote control room.
- Air Inlet System - The inlet air filtration system is supported by the gas turbine enclosure. Air for both the turbine and enclosure purging is filtered by self-cleaning pulse type filter elements. The system includes all necessary ductwork and silencing.
- CO_2 bottles are rack mounted in weatherproof enclosures and set onto prepared foundations, and provide extinguishant protection to the gas turbine and AC Generator enclosures.
- The fuel forwarding skid (liquid only) are set onto prepared foundations, and provide fuel to the gas turbine.
- The water injection skid is set onto prepared foundations, and provides water to the gas turbine for emissions control.

Each of these modules provides a distinct series of functions that in combination enable the Trent 60 Power Generation Package to operate.

B3.1.1.2 *Footprint*

The compact footprint allows for installation of the Trent 60 Power Generation Package into numerous configurations of site layout, to suit the tightest of locations.

Figure B3.1-1: Trent 60 Power Generation Package Footprint



B3.1.2 Major Plant Equipment Summary

A brief review of each major component of the Trent 60 Power Generation Package follows:

B3.1.2.1 Trent 60 GenSet

B3.1.2.1.1 Gas Turbine

The industrial Trent 60 gas turbine is a three spool design has evolved from the successful family of RB211 aero and industrial engines. The prime mover consists of three basic elements:

The axial flow compressor sections - There are three separate sections of compression in the Trent 60 gas turbine. Each compressor section operates at its own optimum speed and is driven by its own corresponding turbine section. The inlet to the LP compressor of the gas turbine includes a set of variable geometry stators to control airflow into the engine. The inlet to the IP compressor also contains three rows of variable geometry stator blades.

The turbine sections - Three independently operating turbine sections match with their front end compressor sections. The HP and IP turbine rotors are free to operate at their optimum speeds to achieve the best engine efficiency. The LP rotor acts as the main power turbine driving the LP compressor and the AC generator.

Combustion System - Fuel is injected into the combustors from the fuel manifolds in a controlled manner by the Engine Management System (EMS).

These three elements are combined into a single assembly that is shipped complete, with rotors in place, for installation in the gas turbine enclosure.

B3.1.2.1.2 AC Generator and Exciter

The OAC AC generator and brushless exciter design. The AC generator is mounted on its own baseplate along with the AC Generator mineral lube oil system. The AC generator package is complete with an acoustic enclosure including a fire protection system.

B3.1.2.1.3 Enclosures

The enclosure walls are fabricated from steel plate, backed by insulation and a perforated liner, providing attenuation of the noise generated within the enclosure by the machinery.

The enclosures are weatherproof structures with easy access to the equipment and systems installed. Routine maintenance, inspection and cleaning can be performed within the enclosure.

The enclosures are completely wired and have power socket outlets; AC powered lamps provide normal lighting. Emergency exit hardware is provided on all exterior doors.

B3.1.2.1.4 Inlet Air System

The air inlet system consists of a top mounted, self-cleaning inlet filter, with Evaporative Cooler System, supported by 2 legs and the gas turbine enclosure, which will deliver filtered air to the Trent 60 gas turbine and the enclosure via ductwork and an inlet silencer. The gas turbine inlet air is guided into the engine by a radial intake scroll which is mounted within the gas turbine module. The air filter will use compressed air supplied by others for periodic cleaning of the air filter cartridges when the pressure drop across the air filter exceeds a certain set point.

B3.1.2.1.5 Gas Turbine Enclosure Ventilation Systems

The gas turbine enclosure ventilation air system performs two main functions. The primary function is to cool and ventilate the gas turbine enclosure to maintain the enclosure temperature within acceptable limits. However, the ventilation air system also dilutes any concentrations of fuel gases that may occur.

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An induced draft system draws filtered air through the gas turbine enclosure via a separate stream of air drawn through the gas turbine combustion air filter.

B3.1.2.1.6 Gas Turbine Exhaust system

The gas turbine exhaust system discharges the combustion exhaust gas to atmosphere or via a heat recovery unit. The exhaust gas outlets are vertical from the module and terminate at the volute flange. The remainder is in the Customers scope.

B3.1.2.1.7 Gas Turbine Fuel System

A self-contained gas turbine fuel system located to the side of the gas turbine inside the enclosure. Fuel forwarding skids and the water injection skid will be located outside of the gas turbine base. The fuel system controls and regulates the flow and pressure of fuel supplied to the gas turbine fuel manifolds.

B3.1.2.1.8 Gas Turbine Synthetic Oil Systems

A self-contained gas turbine synthetic oil skid is housed forward of the air intake plenum inside the gas turbine enclosure. The skid provides three functions: gas turbine starting hydraulic oil, gas turbine lube oil and gas turbine control oil.

The hydraulic start system provides oil to power and cool the on-engine mounted gas turbine hydraulic starter motor that accelerates the HP spool of the gas turbine to purge speed. The system also provides compressor rotation for purging after an aborted start and during the unfired compressor water wash cycle.

The gas turbine lube oil system provides synthetic oil from the common synthetic oil reservoir with the starting oil to lubricate and cool the three gas turbine bearings, internal gearbox and external gearbox.

The gas turbine hydraulic control oil system provides control oil to the LP compressor bleed valve actuators, LP and IP compressor inlet guide vane actuators and LP and IP thrust piston actuators. As above this oil is supplied from the common synthetic oil reservoir

B3.1.2.1.9 AC Generator Mineral Lube Oil System

The system provides lube oil to the two AC generator rotor support bearings including a DC motor driven emergency pump to supply oil in the event of AC power loss and a rotor jacking oil system to assist manual rotation drive train.

B3.1.2.1.10 Cooling Water System

The Modules are provided with plate type water to oil heat exchangers for use as oil coolers. The baseplate mounted heat exchangers are designed to provide the cooling needs of the gas turbine synthetic oil systems and AC generator mineral lube oil system described above.

B3.1.2.1.11 Gas Turbine Compressor Mobile Water Wash Cart

The gas turbine compressor water wash system is located on a mobile cart that can be moved or stored.

The system provides a means of removing contaminants deposited on the rotating and stationary blades of the gas turbine compressor by injecting cleaning chemicals into the blade path via nozzles located in the inlet scroll.

The wash cycle is executed unfired, i.e. cranking the gas turbine using hydraulic start system.

The system comprises one tank storing a mixture of de-mineralised water, detergent and anti-freeze. Delivery is via pressurizing the tank with compressed air.

B3.1.2.1.12 Fire Protection System

A high pressure CO_2 fire protection system is provided for the gas turbine enclosure. A fire in either of these areas will initiate the fire protection system in that area only and shut down the package.

A two shot system is provided for the gas turbine and AC Generator enclosures.

The fire protection system will give visual indication of actuation at the fire control panel, with repeat alarm facility to the main plant control system.

B3.1.2.1.13 Control Systems

The control and protection systems permanently monitor the operating conditions of the plant. The control system adjusts plant parameters according to the operating conditions.

The Human Machine Interface (HMI) is a single point of access to view operation, maintenance and historical data.

The Engine Management System (EMS) provides direct control of the Gas Turbine. The Generator Control and Protection Panel (GCPP) will facilitate manual and duplex auto synchronizing, voltage regulation, generator protection and metering and breaker control. The Plant Control System (PCS) provides control over all Gas Turbine auxiliary systems and interfaces with the HMI, EMS, GCPP, and customer control systems.

The EMS and PCS are contained in cabinets mounted on the gas turbine baseplate forward of the enclosure, the GCPP is mounted in the control room.

B3.1.2.1.14 Start Time

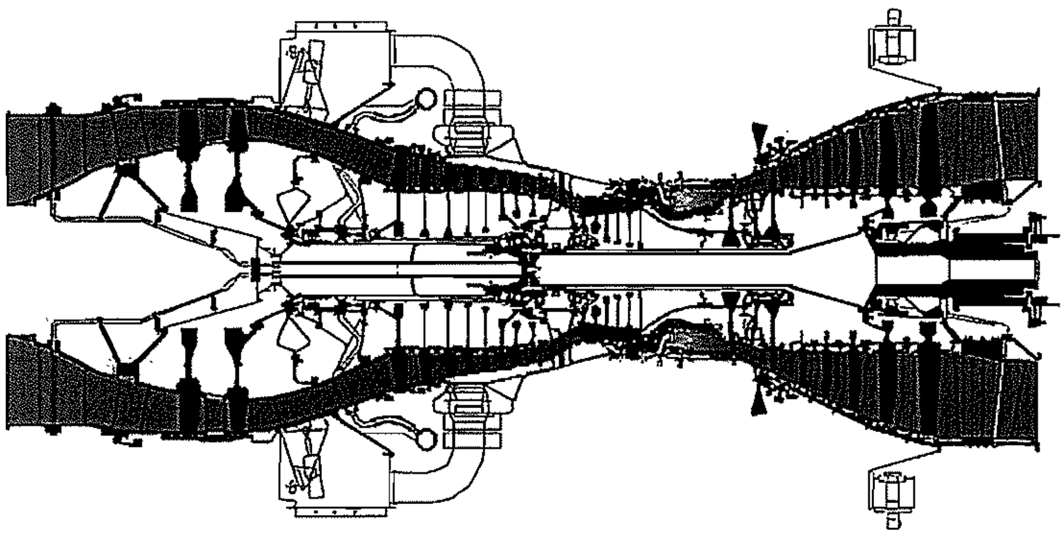
The start-up sequence time, for a simple cycle Trent 60 Power Generation Package is 9 minutes 46 seconds from pressing the start button to reaching full baseload. This includes an allowance for 2 minutes exhaust system purge.

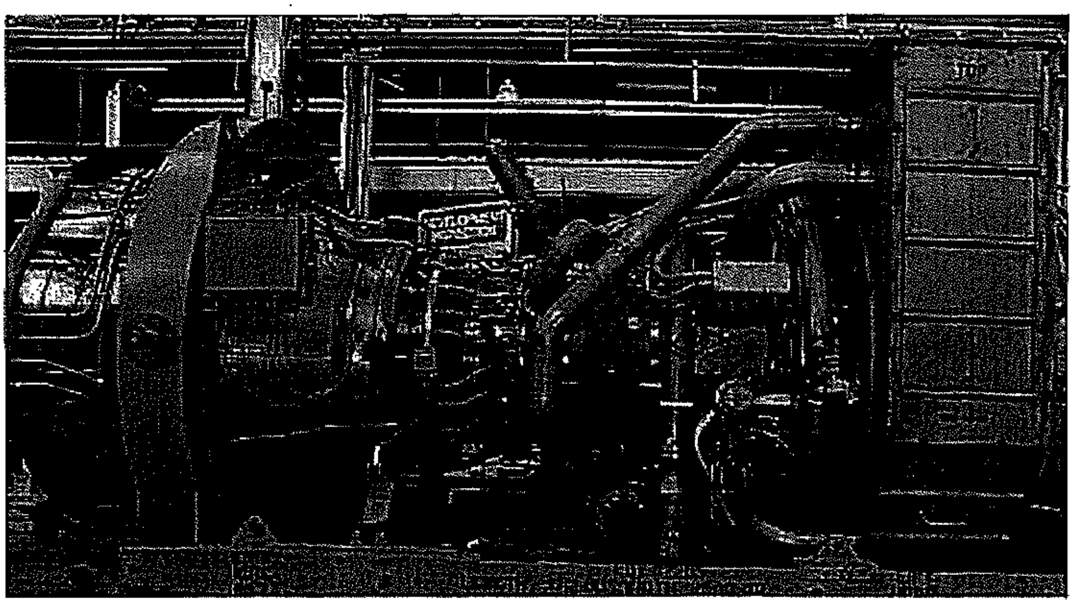
B3.2 TRENT 60 - GAS TURBINE

B3.2.1 Technical Description

B3.2.2 Overview

Figure B1: Trent 60 WLE Gas Turbine





The Rolls-Royce Industrial Trent 60 Gas turbine is a modular constructed engine. The mechanical arrangement uses three co-axially independent running shafts contained within a carcass of axially joined circular cases / modules.

The low pressure shaft (LP) comprises a two stage LP compressor driven by a five stage LP turbine. The intermediate pressure shaft (IP) comprises an eight stage IP compressor driven by a single stage IP turbine. The high pressure shaft (HP) includes a six stage HP compressor driven by a single stage HP turbine.

The HP & IP shaft assemblies are mechanically independent and rotate at their own optimum speeds once the unit is brought on line. The LP shaft speed rotates at a constant 3000 rpm for 50 Hz applications.

The eight engine modules are as follows:

- Module 01 - LP compressor module
- Module 02 - Inter compressor duct (ICD) and IP compressor module
- Module 03 - Internal gearbox (IGB) and inter-compressor case module
- Module 04 - HP system module
- Module 05 - IP turbine module
- Module 06 - External gearbox module
- Module 07 - Non-modular parts
- Module 08 - LP turbine module

Each module is pre-balanced to provide complete interchangability, enabling major assembly changes to be effected on site. Module 07 comprises the ancillary parts such as pipes and cables not included in the other modules, and cannot be changed as a unit.

On engine start, air is drawn through the LP compressor by rotation of the HP compressor via the starter motor and enters into the IP compressors before entering the combustion chambers.

Fuel is injected into the annular combustor system from on-engine fuel manifolds, in a controlled manner by the Engine Management System (EMS). The fuel is mixed with the air flow and is then ignited. Ignition is achieved by two high energy igniter plugs, mounted within the 04 module

The resultant increase in temperature expands and accelerates the hot combustion gas from the combustor to rotate the turbine sections. Each turbine system extracts energy from the gas stream to drive its respective compressor system. The LP turbine is directly connected to an output shaft coupled directly to the AC generator as well as the LP compressor.

After passing through the turbines the hot gas exits to atmosphere via the exhaust stack or into a waste heat recovery boiler in the case of co-generation or combined cycle applications.

Operation and control of the engine, the supply of fuel and oil, and all auxiliary systems is split between the Package Control System (PCS) and the Engine Management System (EMS), such that the overall control system is 'seamless' with minimum overlap between systems.

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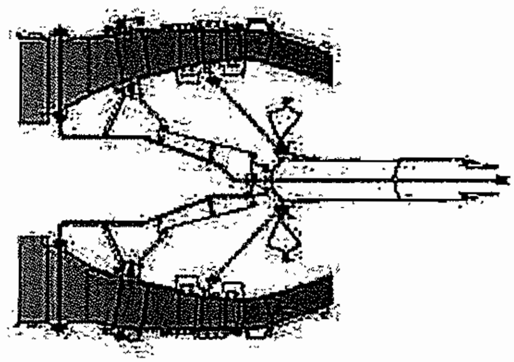
B3.2.2.1 *Module 01 - LP Compressor*

Figure B3.2-1: *LP* ***Compressor Module***



The LP compressor module comprises an annular duct casing of inner and outer walls which are joined by six equally spaced radial support vanes. Two of the vanes are utilised to convey an oil feed pipe for the central engine bearings and a scavenge pipe to drain any residual oil from the transfer tube support assembly area.

Immediately behind the radial vanes is a ring of Variable Inlet Guide Vanes (VIGV's) within the LP VIGV casing assembly, which is in turn secured to the LP compressor rotor case.

The VIGV's are linked via levers to a 'unison' ring. The ring is attached to three hydraulic ram actuators. Two of the three actuators are fitted with positional transducers (LVDT's) which indicate ram position to the control system.

Within the LP compressor rotor case, a two-stage rotor assembly straddles a single stator stage. The outer LP compressor casing is split to permit access to the stator vanes.

Located within the module is a static support tube assembly. The static support is attached at the outer end to the inner rear retaining ring of the LP compressor VIGV assembly. Fitted to the inner end of the static support is an oil transfer tube support assembly which in turn mates, via a seal ring, to the central oil tube within the LP compressor shaft.

The rear end of the central oil tube terminates at an oil distributor assembly, fitted with an oil filter, in the front end of the LP turbine shaft.

The rotor is attached to, and supported by, a drive arm secured to the second stage disc to connect, by a curvic coupling, to the forward end of the LP compressor shaft. The rear end of the LP compressor shaft is coupled to the forward end of the LP turbine shaft.

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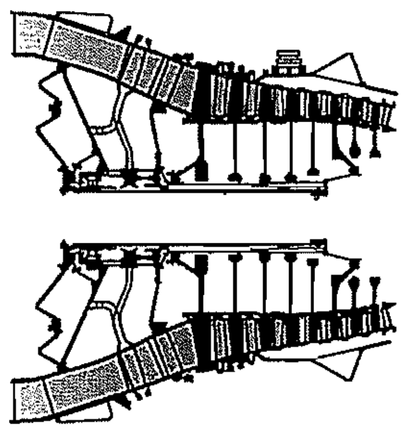
B3.2.2.2 Module 02 - ICD and IP Compressor

Figure B3.2-2: ICD and IP Compressor Module



The Inter Compressor Duct (ICD) provides a low loss transition between the LP compressor delivery and the inlet to the IP compressor.

The ICD contains a row of LP compressor outlet guide vanes, to straighten the air flow prior to it passing the LP bleed aperture doors, a row of ICD outlet guide vanes and the IP compressor variable first stage vanes (VIGV's).

The hollow centers of most of the ICD outlet vanes are used as service vanes to provide access for the following:

- LP and IP electronics
- Front bearing housing oil feed
- Front bearing housing oil scavenge
- Front bearing housing vent
- LP thrust compensation air
- IP thrust compensation air

The LP compressor and the IP compressor front bearings are also housed in the ICD, as are the trim, LP and IP speed probes for control and monitoring of the IP and LP compressor shaft speeds.

Surrounding the ICD are 18 hydraulic actuator operated bleed doors. They are required to bleed off air flow from the constant speed LP compressor when operating at less than 80% power, down to no load, synchronous idle speed.

The IP compressor consists of eight stages of stator and rotor blades. The first two stator stages are variable stator vanes (VSV's).

The single row of VIGV's and double row of VSV's are supported in inner and outer bushes and linked via levers to individual 'Unison' rings.

All 'Unison' rings are linked by control rods and bellcranks, which in turn are attached to two operating actuators.

Signals from the ECS cause the IP VSV control unit to direct hydraulic oil to move the hydraulically operated actuator rams to either extend or retract, thus moving the 'Unison' rings, causing the angle of all the VIGV's and VSV's to move simultaneously in response to airflow requirements.

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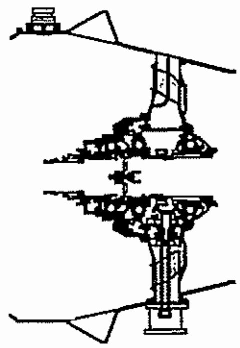
The IP compressor rotating assembly comprises a fully welded drum supported at the front end by a stub shaft secured to the first stage rotor disc which mates with the rear bearing in the ICD bearing housing. The rear of the IP compressor rotating assembly is supported on a conical drive shaft assembly, from the sixth stage rotor disc curvic coupling, by the IP location bearing mounted at the forward end of the inter-case hub.

The rear part of the conical drive shaft assembly mates with the forward end of the IP turbine shaft helical spline coupling, locked in position by a spring loaded plunger assembly.

B3.2.2.3 *Module 03 - IGB and Inter-Compressor Case*

Figure B3.2-3: Internal gearbox and inter-compressor case module



The inter-compressor case forms the transition between the IP and HP compressors and is a one piece structural casting which connects the IP compressor directly to the HP compressor inlet.

Ten struts, through which pass the internal gearbox service pipes, secondary air system bleeds and a radial drive shaft for the external gearbox, connect the hub to the outer case.

The hub of the casing supports the starter radial drive bevel gear and shaft, the HP compressor shaft front bearing and its associated bearing support, oil / air seal, retaining nut and lock washer to the rear. Attached to the front of the hub are the LP and IP compressor shafts location bearings, their associated bearing support, oil / air seal, retaining nut and lock washers.

Attached to the rear of the vanes is the location ring for the 04 module bell mouth and the HP first stage rotor air seal and air baffle plate.

Four IP8 blow-off valves (two port and two starboard) are located at the front of the outer case, while the IP8 off-take, to the air cooler, is located at the lower rear of the outer case.

B3.2.2.4 *Module 04 - HP System*

The HP module, which is common to the aero Trent 800, comprises the HP compressor system, the HP turbine system and the combustion structure.

The HP compressor comprises a six stage rotor and stator assembly. The rotor assembly is a two portion drum, with stages one to four welded together and bolted to stages five and six, which are also welded.

The static stator assembly consists of five stages of stator (the sixth OGV stage is part of the OGV assembly) located in a casing consisting of circular rings bolted together. Thermal insulation strips are located in the rings above stator stages one, two, four and five. No insulation is fitted above stage three as this is where excess HP3 air is removed via the HP bleed valves above the stage three stator. The ring areas above the rotors have abradable linings fitted for sealing purposes. The HP6 start up and emissions control valve is located in the rear locating cone assembly.

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The combustion structure is an integral part of the 04-module structure that supports and contains the annular combustion system. There are twenty-four (24) gas burners fed from a gas manifold through the top of each burner; water is injected through the side of each burner and then atomized prior to delivery. This is fed from a flexible supply pipe utilising the existing aero fuel pigtails. Two common high-energy ignitors also form part of the combustion system.

The HP compressor rotor is supported at the front, through a curvic coupling arrangement to a HP drive shaft supported by a location bearing mounted in the rear of the inter-case assembly. The rear is supported via the compressor rotor drum and mini-disc to bolt to the front of the single stage HP turbine disc. The rear of the HP turbine disc is secured to a rear drive shaft assembly which is located by a roller bearing within the HP / IP turbine bearing support.

Fitted to the rear of the combustor structure, a case assembly supports the HP turbine nozzle vane assemblies structure. A further case assembly secured to the rear of the OGV case houses the static members of the HP turbine front air seals and pre-swirl nozzle segments. It also secures the inner platforms of the HP NGV's. The combustor nozzle rear flanges are also secured to these two case assemblies.

B3.2.2.5 *Module 05 - IP Turbine*

Figure B3.2-4: IP Turbine Module

The IP turbine module houses the IP turbine NGV's, the IP turbine rotor assembly, the LP first stage NGV's and the HP / IP bearing housing assembly.

The HP / IP bearing housing support assembly is attached to the outer case by thirteen (13) struts which pass through the hollow IP turbine NGV's. Oil and air service pipes also pass through other IP turbine NGV's into the HP / IP bearing chamber area.

The HP and IP turbine bearing housing extends rearwards from the hub of the support housing. Secured to the rear of the housing is a sealing ring assembly, containing an oil jet and strainer, the HP and IP bearings, bearing retainers and air seal fitments.

The single stage axial IP turbine disc extends rearwards and is secured between a stub shaft and the IP turbine main drive shaft. The stub shaft is supported by the IP roller bearing. The main IP turbine drive shaft runs forward through to the inter-case bearing support assembly ending in a helical spline coupling that forms the interface with the IP compressor conical drive shaft.

Bolted to the casing and projecting into the LP first stage turbine NGV's are seventeen (17) thermocouples spaced around the casing. Further vane groups have provision for overheat detectors and borescope ports.

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The outer case connects to the 04 module combustion structure and the 08 module LP turbine case.

B3.2.2.6 *Module 06 - External Gearbox*

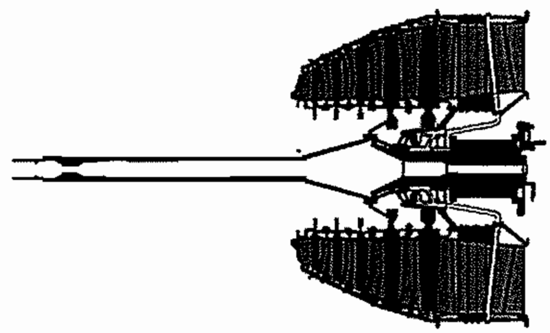
The external gearbox is flange mounted directly beneath the 03 module, to mate with the radial drive shaft. The front of the gearbox is also bracket mounted to the 03 module outer case.

The main lubrication oil pump and the starter / clutch assembly drive shafts are spline connected to the internal components of the gearbox and then 'V' band clamped to the mounting flanges at either side of the external gearbox. The oil pump is on the port side and the starter / clutch is on the starboard side.

The gearbox also houses speed probes and a manual rotation feature.

B3.2.2.7 *Module 08 - LP Turbine*

Figure B3.2-5: LP Turbine Module



The LP turbine case is conical in section and contains the stage two to five NGV's turbine segments. The LP turbine drum comprises five stages of disc and blading bolted together. The stage four disc acts as a drive arm and provides the attachment joint for the LP turbine shaft assembly.

The LP turbine shaft assembly comprises a rear stubshaft, to which the number 4 disc is directly attached, and a forward LP shaft, which runs forward within the IP turbine shaft to connect to the LP compressor shaft within the 03 module inter-case bearing housing. The LP turbine rear stubshaft, supported within the LP turbine roller bearing housing by the bearing, mates with a power take off hub which attaches to the generator coupling.

The 16 vane LP turbine bearing support structure attached to the rear of the LP turbine also provides access for cooling air and the bearing oil feed and scavenge pipes.

Also secured to the front of the rear LP turbine flange is the conical spring assembly and rear engine mounting ring

B3.2.3 ***Technical Data***

Item	Specification	
Gas turbine type	Industrial aero derivative	
Gas turbine component modules	01	LP compressor
	02	ICD and IP compressor
	03	IGB and inter-compressor case

Item	Specification		
	04	HP system	
	05	IP turbine	
	06	External gearbox	
	07	Ancillary pipes, cables	
	08	LP turbine	
Number of shafts	Three (3)		
Direction of rotation	Clockwise facing inlet		
Shaft speed			
	LP	3600 rpm	
	IP	6575 rpm	
	HP	9950 rpm	
Shaft natural frequencies – modes 1, 2, 3			
	LP	30, 36, 54 Hz	
	IP	29, 110, 137 Hz	
	HP	148, 172, 222 Hz	
Shaft inertia	LP	386 kg/m^2 (9,167 lb ft^2)	
	IP	61.9 kg/m^2 (1,462 lb ft^2)	
	HP	19.1 kg/m^2 (454 lb ft^2)	
Compressor type	Axial flow		
Compression ratio	35:1		
Number of compression stages	LP	Two (2) stages	
	IP	Eight (8) stages	
	HP	Six (6) stages	
Compressor materials		Blade	Disc
	LP	Titanium	
	IP	Titanium	
	HP (1,2)	Titanium	
	HP (3, 4, 5, 6)	Nickel	
Variable inlet guide vanes / stator vanes	LP compressor	One (1) stage VIGV	
	IP compressor	One (1) stage VIGV Two (2) stages VSV	
Compressor bleed system	LP	Exit	18 bleed doors
	IP	Stage 8 exit	4 bleed valves
	HP	Stage 3 exit	3 bleed valves

Item	Specification		
Combustion system	Trent 60 WLE - Water-Injected Low Emissions (WLE)		
Combustors	Trent 60 WLE - One (1), Aero Derivative Annular		
Igniters per combustor	Two (2)		
Igniter type	Electric		
Combustor material	Nickel		
Injector Type / Zones	Trent 60 WLE – Twenty four (24) aero injector for gas / water		
Method of ignition detection	Thermocouple (rate of temperature rise)		
	HP compressor speed		
Turbine type	Axial flow		
Number of turbine stages	LP	Five (5) stages	
	IP	One (1) stage	
	HP	One (1) stage	
Turbine materials		Blade	Disc
	HPT	Nickel SC	Nickel
	IPT	Nickel SC	Nickel
	LPT1	Nickel	Nickel
	LPT2-5	Nickel	Nickel
Bearings	Five (5) cylindrical rolling element bearings		
	Three (3) Ball rolling element bearings		
Vibration monitors	Natural crystal accelerometers		
Vibration monitoring locations	One (1) above front bearing housing		
	One (1) above center bearing housing		
	One (1) above rear bearing housing		
Vibration alarm/trip level	21 / 28 mm/s		
Starter system	Hydraulic		
Exhaust area	1.838 m^3 (65 ft^3)		

B3.3 TRENT 60 - AC GENERATOR AND EXCITER

B3.3.1 AC Generator

The AC Generator is a synchronous two (2) pole, single end drive, Open Air Cooled OAC) cylindrical rotor machine. The rotor is supported by two endframe mounted bearings. It has a brushless excitation system and a permanent magnet pilot exciter.

The typical rated output of the AC Generator is 58.00 MW, 68.235 MVA at ISO conditions, in accordance with IEC 34.3, as appropriate and defined in the technical data section.

The stator and rotor are built with class "F" insulation materials but operation is limited to Class "B" temperature rises on a total temperature basis.

B3.3.1.1 Stator Frame and Core

The stator frame is fabricated from mild steel plate to form a rigid structure that carries the stator core and supports the bearing end frames.

The core is built up from segmental laminations of low loss, high permeability, high silicon content electrical steel.

The laminations of the core are located by means of dovetail key bars, bolted to suitably placed members of the stator frame.

All laminations are deburred and coated with insulating varnish to minimize inter-laminar contact and restrict eddy current losses.

Radial ventilation ducts are formed at intervals along the core by "H" section steel spacers. On each side of the spacer is a thicker lamination to prevent core distortion. The spacers extend to the end of the slot teeth to increase tooth rigidity.

The core is hydraulically pressed at predetermined stages during the building operation to ensure uniform compaction, the pressure being carefully monitored.

The finished core is clamped between heavy steel end plates which are located by keys inserted in slots in the key bar lands whilst the core is under pressure. Substantial non-magnetic tooth supports transmit the pressure from the endplates to the stator teeth.

B3.3.1.2 Stator Winding

The stator winding is of the two-layer diamond type, half coils being used for ease of handling during manufacture and winding.

In order to minimize eddy current losses each conductor is subdivided into appropriately sized laminations which are insulated from each other by a resin impregnated woven glass braid and fully transposed to minimize circulating currents.

The insulation system is based on a resin rich mica glass tape which, when processed, results in a high performance insulation capable of continuous operation at temperatures up to 155°C (311°F) (Class "F").

The insulation possesses high dielectric strength and low internal loss and can meet all current specifications. The resin system is thermosetting so that the resulting insulated coil sides are dimensionally stable. Additionally, it is highly resistant to most of the common electrical machine contaminants such as hydrocarbons, acids, alkalis and tropical molds.

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The insulated copper laminations are cut to length, stacked together and the coil ends formed into the required end winding shape on a jig. They are then clamped tightly together, taped with an initial layer of tape and hot pressed to consolidate the conductor stack. Following this, the main insulation is applied and pressed to size. The amount of compression is carefully controlled to ensure correct resin flow and produce a consistent high standard of void free insulation.

Each finished half coil is subjected to dimensional checks to ensure that a correct fit in the stator slot is achieved.

To prevent corona discharge in the slot and resultant insulation damage, the surface of the coil in contact with the core is made conductive by the application of a graphite impregnated polyester tape. A silicon carbide impregnated polyester tape is applied to the coil surface immediately outside the slot to control the voltage gradient in this region.

The half coils are placed in the stator slots in two layers and wedged securely in position by synthetic resin bonded wedges prior to connection of the endwinding.

In order to withstand the forces which could arise in the event of an accidental short circuit, the endwinding is securely braced to insulated brackets supported from the stator frame. Spacer blocks are fitted between adjacent coil sides to produce a strong arch bound, yet resilient, composite structure.

Finally, the completed stator is "baked" in an oven to fully cure the insulation.

Resistance temperature detectors are embedded in the windings at selected points, and anti-condensation heaters are fitted into the stator frame.

Graded high voltage tests are carried out at stages during manufacture of the coils and assembly of the winding. This ensures a high standard of insulation and also that any faults are detected at the earliest possible stage.

B3.3.1.3 *Terminal Arrangement*

The stator terminals are in the form of three epoxy resin bushings brought out on either side of the stator frame at the exciter end of the AC Generator.

The line and neutral ends of the stator winding are terminated in individual line and neutral cubicles.

B3.3.1.4 *Rotor Construction*

The rotor is manufactured from an integral forging of nickel chromium molybdenum alloy steel which is de-gassed and vacuum poured to obtain a uniform material which has excellent tensile properties.

The manufacture of the forging is closely supervised by the forgemaster to an agreed quality control procedure, including checks for freedom from porosity and for mechanical and thermal stability.

Axial slots, to carry the winding and for ventilation, are milled on the periphery of the body of the rotor.

Axial grooves are milled along the top of both winding and ventilation slots to hold the slot closing wedges. At the exciter end, a hole is bored along the axis of the shaft to take the leads from the excitation system to the rotor winding.

The connections to the rotor winding are brought out from the bore by radial connections.

B3.3.1.5 *Rotor Winding*

The rotor winding is manufactured from high conductivity copper silver alloy strip which is pre-formed before winding.

The pre-formed coils are inserted into the slots, each turn being insulated from the next. The class "F" insulation system is moisture resistant, shockproof and capable of withstanding the high mechanical forces to which it will be subjected.

After completion of the winding, the conductors are heated electrically and pressed to the correct depth using pressing rings.

The aluminum alloy wedges are inserted and fully interconnected at the ends to form the complete damper winding. The rotor endwinding is braced with packing blocks between the conductors, after which the rotor endcaps are fitted. The endcaps, which retain the rotor endwinding, are manufactured from austenitic non-magnetic manganese chromium steel which is cold expanded during manufacture to produce the high mechanical strength required.

The endcaps are shrink fitted to spigots at each end of the rotor body.

All completed rotors are tested in the Company's rotor overspeed test facility, which is equipped with comprehensive monitoring equipment.

The rotor is first given a low speed balance and is over sped to 20% above its normal operating speed for two minutes. The rotor is then heated to its maximum operating temperature, check balanced and the overspeed test repeated. Finally, the balance at normal running speed is checked.

Balance adjustment planes are provided in the rotor body itself, in the ventilating fan rings, and in the main exciter diode carrier fan hub.

Following overspeed testing, the rotor is subjected to high voltage tests to prove the integrity of the insulation system.

B3.3.1.6 *Bearings*

The rotor is supported by two hydrodynamic, white metal lined, cylindrical profile bearings.

The spherically seated bearing bushes are split on the horizontal center line for ease of inspection and removal. The two halves are bolted and doweled together.

The stator has a stiffened and reinforced stator frame to support the bearing arrangement. A detachable solid ribbed steel plate, split on the bearing horizontal centerline incorporates the lower half bearing housing. The upper half bearing is bolted and doweled to the bottom half housing.

The endframe is completed by a steel plate bolted on as the upper part of the endplate. This is arranged in sections capable of easy removal to give access to the bearing assembly.

The bearings are fitted with pressurized seals to prevent ingress of oil mist into the stator and enclosure. The pressurized air is derived from the downstream side of the AC Generator fan and is taken to the seals via flexible pipes.

RTD's in the bearing metal provide bearing temperature sensing.

The bearings have connections for both lubrication mineral oil during operation and high pressure jacking oil. Jacking oil is required when slow turning of the shaft line is required for maintenance. The oil supply pipework is stainless steel, and the drainage pipework is carbon steel.

B3.3.2 BRUSHLESS EXCITATION SYSTEM

The AC Generator excitation system is located at the non-drive end of the AC Generator module.

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The brushless exciter consists of a three phase, rotating armature, alternating current AC Generator, with a shaft mounted fused rotating rectifier. The field winding is stationary. The brushless concept enables the exciter output to be connected to the AC Generator field without the use of commutators, brush-gear or slip-rings.

The exciter armature is overhung from the AC Generator rotor.

The armature core is built up from insulated circular laminations of electrical steel. These are clamped between substantial fabricated end-rings securely keyed and shrunk onto the exciter shaft.

The armature windings are composed of heavy pre-formed copper bar type coils retained in the slot by dovetail wedges. The end-windings are retained by fully cured glass fiber bands.

The armature output is three phase, the three terminals being connected to a three phase, full wave rectifier bridge (the rotating rectifier).

A fuse is connected in series with each diode of the rotating rectifier to ensure that any arm of the bridge containing a short circuit diode becomes open circuit, thus averting a short circuit on the exciter winding.

The rating of the rotating rectifier and armature is such that full load rotor current can be supplied with one arm of the three phase bridge inoperative. A failure would be identified by the continuous monitoring system, so that the unit could be shut down and the fault corrected at the first convenient opportunity.

The exciter field magnet is formed from copper strip wound field coils that are resin bonded to laminated pole bricks, which are bolted to the magnet frame. The frame is made from heavy rolled steel plate.

A pilot exciter is used to provide the excitation power to the automatic voltage regulator (AVR). This method provides an inherent 'fault clearance' facility. The pilot exciter is mounted on the AC Generator shaft and is a permanent magnet, single phase, revolving field, alternating current generator.

B3.3.3 Line and Neutral Cubicle

The AC Generator module is provided with separate line and neutral cubicles located on either side of the AC Generator enclosure. The cubicles can be handed as required to suit the site requirements. The cubicles provide the main primary protection devices for the AC Generator.

B3.3.3.1 The Line Cubicle

The line cubicle can be arranged for either bus duct or cable exit and accommodates the following:

- Current transformers for protection and metering;
- Voltage transformers for protection and metering;
- Surge arrestors;
- Surge capacitors.

B3.3.3.2 The Neutral Cubicle

The generator star point is made in the neutral cubicle. Also included are the following:

- Neutral earthing transformer;
- Secondary loading resistor;
- Current transformers for protection and metering;

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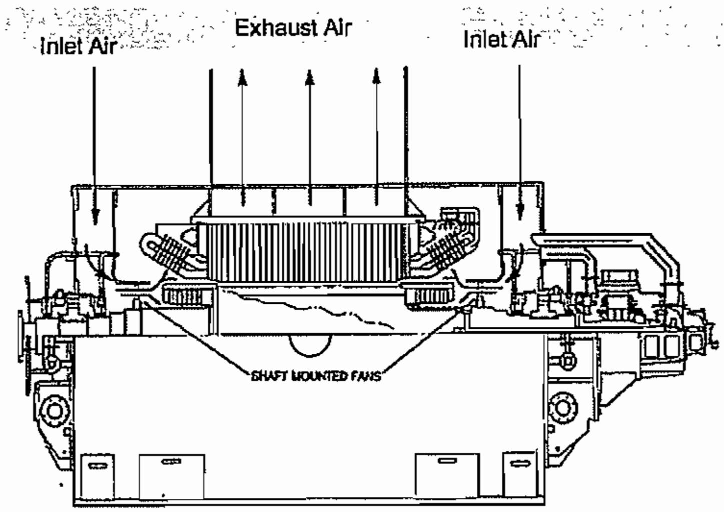
- Insulated boss for connection to the main station earth.

B3.3.4 AC Generator – Open Air Cooled (OAC)

Figure B3.3-1: AC Generator Internal Cooling Path



B3.3.5 Air Filtration

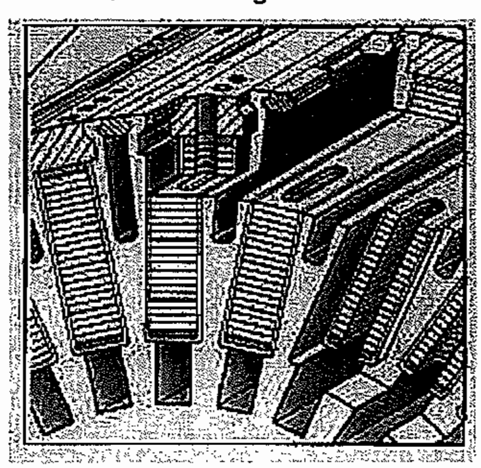
Air is drawn into the AC Generator through a filtration unit mounted on top of the weatherproof enclosure.

The filtration unit is equipped with air intake louvers, behind which are replaceable media filter pads, supported in retaining frames, and air inlet silencers. A hood protects the air intake from water and snow ingress during shut down.

The exhaust air is ducted from the machine through the outlet ducting of the air filtration unit.

B3.3.5.1 Cooling Air Circuit

Figure B3.3-2: Interslot Cooling and Subslot Cooling Paths



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Cooling air is forced around the machine by means of two axial flow fans mounted on the rotor shaft. These fans draw air in at each end of the machine and direct it through the cooling circuit.

The stator core has radial ventilating ducts at intervals along its length to ensure optimum cooling of the stator winding and core. This is achieved by ducting air to pressure chambers at the back of the core where it flows radially inwards. The air then mixes with air from the rotor and direct from the fans before exhausting radially outwards through the core.

The rotor is cooled by air flowing under the rotor endcaps, past the endwindings and through axial cooling slots (interslots) between the winding slots. Exhaust ducts in the closing wedges of the interslots allow the air to escape at the center of the rotor in line with the exhaust aperture in the stator frame.

In addition to the interslots, the rotor also incorporates cooling slots beneath the winding slots (subslots). The cooling air escapes from the subslots through radial exhaust ducts along the length of the winding.

The exhaust air leaves the machine through a silenced outlet duct built into the package. Stainless steel gravity closing louvers at the outlet inhibit the ingress of rain or snow whilst the machine is shut down.

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B3.3.6 Technical Data (60Hz)

Attachments

- AC Generator Technical Data (WE07269)
- AC Generator Curves (WE07296)
- Excitation Model, including PSS (G15008-Q0050-75)

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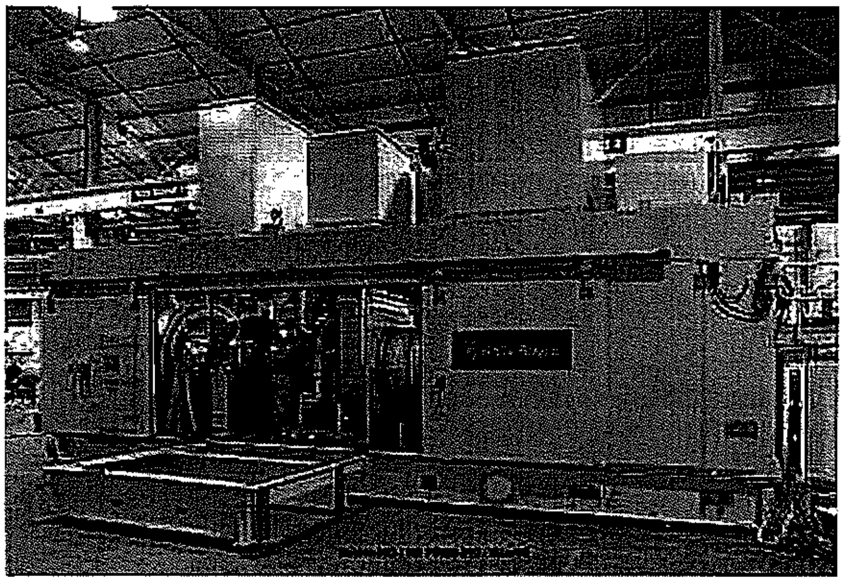
B3.4 TRENT 60 - POWER GENERATION PACKAGES

B3.4.1 Gas Turbine Module

Figure B3.4-1: Gas Turbine Skid



B3.4.1.1.1 Gas Turbine Enclosure

The gas turbine enclosure is a fabricated structural panel and weatherproof acoustic enclosure designed to house the gas turbine. Incorporated into the enclosure are the fire protection system and normal and emergency lighting. The combustion air inlet and exhaust system, ventilation air inlet system and ventilation air exhaust system interconnect through the roof of the enclosure.

The enclosure provides an environment for cooling the turbine casing and purging air. The electrical system within the gas turbine enclosure is designed to IEC 60079-10 Zone 2.

The rear section of the compartment contains the exhaust diffuser. The engine is removed horizontally through sliding doors in the side of the gas turbine enclosure. All equipment necessary to remove the engine from the enclosure and place it in the shipping skid at the side of the enclosure is included with the package.

B3.4.1.1.2 Gas Turbine Mounting Arrangements

The Trent 60 Gas turbine is mounted inside the gas turbine compartment of the gas turbine enclosure.

The Trent 60 Gas turbine is supported from a single location on the IP compressor support cone at the front, and at the rear from two locations on the cold ring.

The front mount is a pivoting strut at bottom dead center. It supports a portion of the weight but does not restrain the gas turbine laterally or hold the cold ring (at the rear of the gas turbine) at the horizontal centerline. The trunnions restrain the gas turbine axially and vertically. This ensures repeatable engine alignment during engine change-out, and eliminates the requirement for further alignment checks after the initial engine installation during commissioning.

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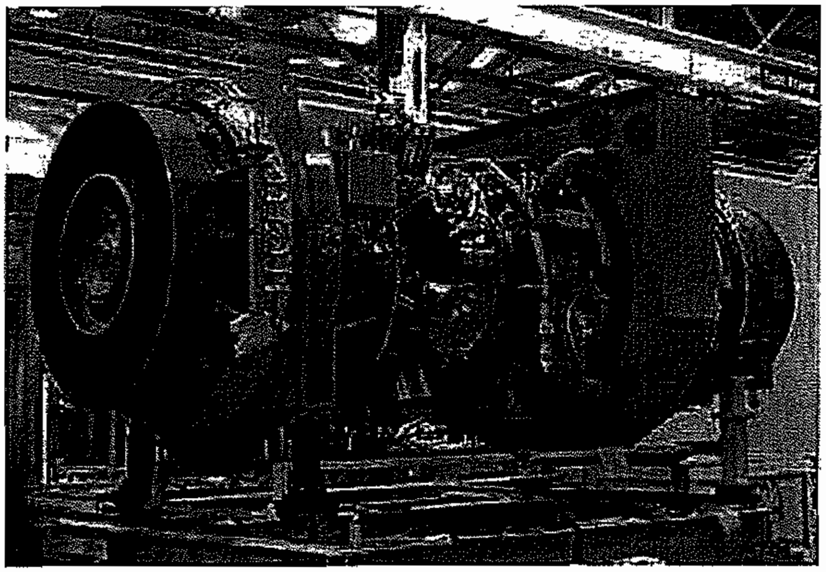
B3.4.1.1.3 Gas Turbine Mechanical Handling

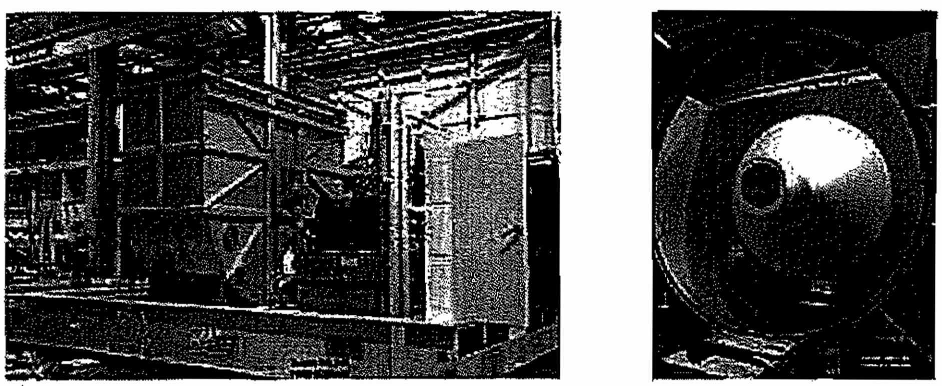
Figure B3.4-2: Gas Turbine Mechanical Handling



The gas turbine removal is achieved via a rail system mounted within the enclosure, and out-board shipping and mechanical handling skid which is placed alongside the enclosure during the operation.

B3.4.1.1.4 Radial Intake Plenum

Figure B3.4-3: Radial Intake Plenum



The radial intake plenum is located in the gas turbine enclosure immediately forward of the Trent 60 gas turbine.

It provides a stabilization zone for the filtered combustion air delivered through the combustion air intake silencer and ducting. Air flows between the inlet scroll and center body, with minimal airflow distortion and swirl, and then into the low-pressure compressor.

The inlet scroll is also the mounting point for two rings, each of twenty compressor water wash nozzles which direct cleaning fluid into the first stages of gas turbine compressor blading. The inboard ring is used for unfired.

The center body is supported from the plenum wall and joins onto the gas turbine inlet case via an extension piece and transition flange.

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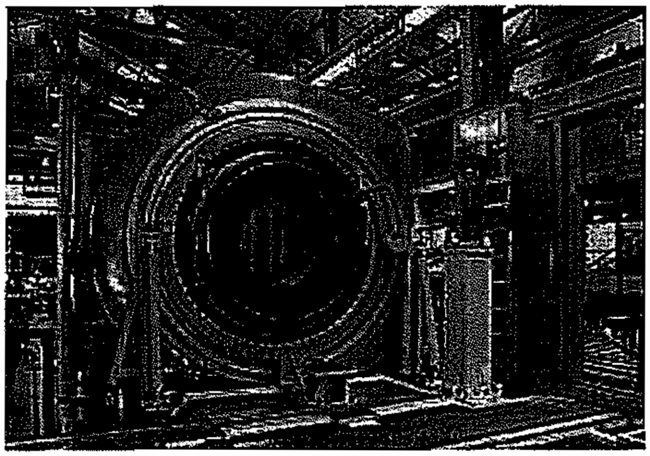
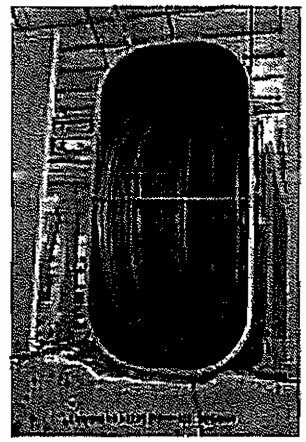
A 15 mm gap between the extension piece and transition flange allows for thermal growth of the gas turbine.

B3.4.1.1.5 *Exhaust Assembly*

Figure B3.4-4: Exhaust Assembly





The exhaust assembly is located behind the Trent 60 gas turbine inside the gas turbine enclosure. It consists of a radial dump diffuser designed for maximum pressure recovery. The diffuser can discharge vertically or horizontally, parallel to the ground, on the left or right side of the package.

B3.4.1.2 *Gas Turbine Module Technical Data*

Item	Specification
Baseframe	Carbon steel sections
Outer skin	Carbon steel sheet
External and internal paint system	Inorganic zinc primer Two layers epoxy / acrylic polyurethane topcoat
External color	Light gray
Internal color	White
Insulation	50-100mm bats
Inner skin	1.5 mm perforated galvanized sheet
Lighting – gas turbine compartment	Incandescent globe lights
Lighting – mechanical auxiliaries room	Incandescent globe lights
Heating – gas turbine compartment	2 off 3 phase 4 kW forced air heaters

B3.4.2 ***AC Generator Module***

B3.4.2.1 *AC Generator Module Technical Data*

Item	Specification
Baseframe	Carbon steel sections

B3.4.3 ***GenSet Design Conditions***

Item	Specification
Design ambient temperature range	-4°F to +104 °F
Design wind load	100 mph / 120 mph gusts
Design rain fall	4.9 in/hr
Design snow load	30 lb/m^2
Design seismic level (UBC) [for the ground mounted equipment.]	Zone 3
Elevation	0 to +3280 ft asl

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B3.5 TRENT 60 - AUXILIARY SYSTEMS

B3.5.1 Self-Cleaning Combustion Air Intake Filter

The self-cleaning combustion air intake filter is mounted on a steel support structure above the radial air intake plenum of the gas turbine enclosure. It is connected to the combustion air intake silencer and ducting.

The filter provides a stream of clean air for combustion within the gas turbine, which is drawn into the combustion air intake silencer and ducting by the gas turbine compressor.

The air flows through the filter element chamber. The filtered air exits the clean air plenum and enters the ducting / silencer assembly. The system uses a single stage high inertial separation filter with a single pad.

When the filter loads with dirt during turbine operation, the differential pressure across the elements increases. Instrumentation provided with the filter senses this pressure and at a preset point initiates an automatic cleaning sequence. A reverse air pulse is sequentially injected into each filter element. The shock wave from this momentary reverse pulse of compressed air is used to knock any build up of debris from each individual cartridge. This operation does not affect the overall flow of air to the gas turbine.

Pulsing continues sequentially across the bank of cartridges until the differential pressure measurement decreases to a lower preset value. The re-ingestion of debris is minimized as the dust is sucked into the dust chute and ejected from the filter house by a secondary fan. The build up of ice is prevented via continuous pulsing of compressed air. Relative humidity and temperature sensors are located adjacent to the filter cartridges. For combined relative humidity > 85% and ambient temperature < 5°C the package control system demands continuous compressed air pulsing.

The filter house comes complete with access doors and inspection hatch to both the dirty air plenum for filter change out and clean air plenum for inspection, ladders and internal lighting. Filter replacement would be at planned time intervals based on individual site environmental conditions.

B3.5.2 Gas Turbine Enclosure Ventilation Air System

The gas turbine enclosure ventilation air system performs several distinct functions. The primary function is to cool and ventilate the gas turbine enclosure and to prevent the creation of potentially explosive atmospheres within the gas turbine enclosure in the event of a fuel gas leak.

Ambient air is drawn through the gas turbine enclosure utilizing an induced draft system.

Extensive computer modeling techniques (CFD) have been employed to optimize that the gas turbine enclosure and ventilation air system to ensure there will be no regions greater than 0.1% of the gas turbine enclosure volume where fuel gas concentrations are greater than 50% of the lower explosive limit (LEL).

Finally, a separate bleed air system exists for the compressor bleed air exhaust including a silencer. During start-up, part-load operation and shutdown, it is necessary to bleed off excess airflow from the gas turbine compressors to maintain smooth airflow and to improve part load efficiency.

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B3.5.2.1 *Gas Turbine Enclosure Ventilation Air Intake*

The gas turbine enclosure ventilation air is drawn from the same filter house as the main combustion air. Separation barriers are supplied between the combustion and ventilation air. The ventilation air inlet provides a clean, stable, directed flow of cooling air into the gas turbine enclosure. The ventilation air system includes a silencer system. The filters for the ventilation system are the same type as used for the combustion filter assembly, and are ducted separately into the gas turbine enclosure.

The ventilation system is of an induced ventilation design, creating a negative pressure within the gas turbine enclosure. Ventilation air is drawn into the gas turbine enclosure by two of the three fans, located in the ventilation exhaust system.

The inlet air enters the gas turbine enclosure above the auxiliary room in front of the radial inlet plenum. This air then passes around the radial inlet plenum and flows over the gas turbine casing. The gas turbine enclosure interior is designed to force air over the fuel distribution area to ensure the necessary air dilution properties. The ventilation inlet duct is equipped with a fire damper, operated pneumatically by the release of fire extinguishant CO_2.

B3.5.2.2 *Ventilation Air Exhaust System*

The ventilation exhaust system is comprised of fire dampers, silencer, extraction fans and ducting. It is located in front of the gas turbine exhaust assembly area of the gas turbine enclosure.

The bleed air exhaust is collected in the inter-compressor duct and passes, via insulated ducting and expansion joints, outside the enclosure and through the bleed exhaust silencer.

Operationally, the system is engaged as part of the start sequence. The gas turbine enclosure is ventilated to assure a safe environment prior to engine light off. Upon shutdown, the vent system continues in operation for 30 minutes after fuel gas shut off during gas turbine run down.

Two aspirated gas sensors are located in the gas turbine enclosure ventilation exhaust duct.

B3.5.3 *Gas Turbine Bleed Air System*

As the Trent 60 gas turbine LP spool rotates at a constant synchronous speed, the IP and HP spool speeds vary with power output. A compressor bleed air system is required to blow off excess air from the compressors to maintain smooth airflow between spools during start-up, operation at part load and shutdown.

The bleed air system works in conjunction with the variable inlet guide vanes and variable stator vanes.

Air is bled through eighteen (18) valves after the LP compressor (the LPC exit), is dumped to the inter-compressor duct (ICD) and into the bleed air exhaust structure.

Air is bled through four (4) valves after the IP compressor (the IP8 exit). This air is of the correct pressure to be used for sealing and pressurizing within the Trent 60 gas turbine. The flow is dumped into the ICD, but during normal operation part of the flow is reused within the gas turbine.

Air is bled through three (3) valves after the HP compressor (the IP3 exit), during start-up and shutdown, the flow is dumped into the ICD.

Each compressor bleed system is controlled and operated independently.

B3.5.4 *Fuel and Emission Control Systems*

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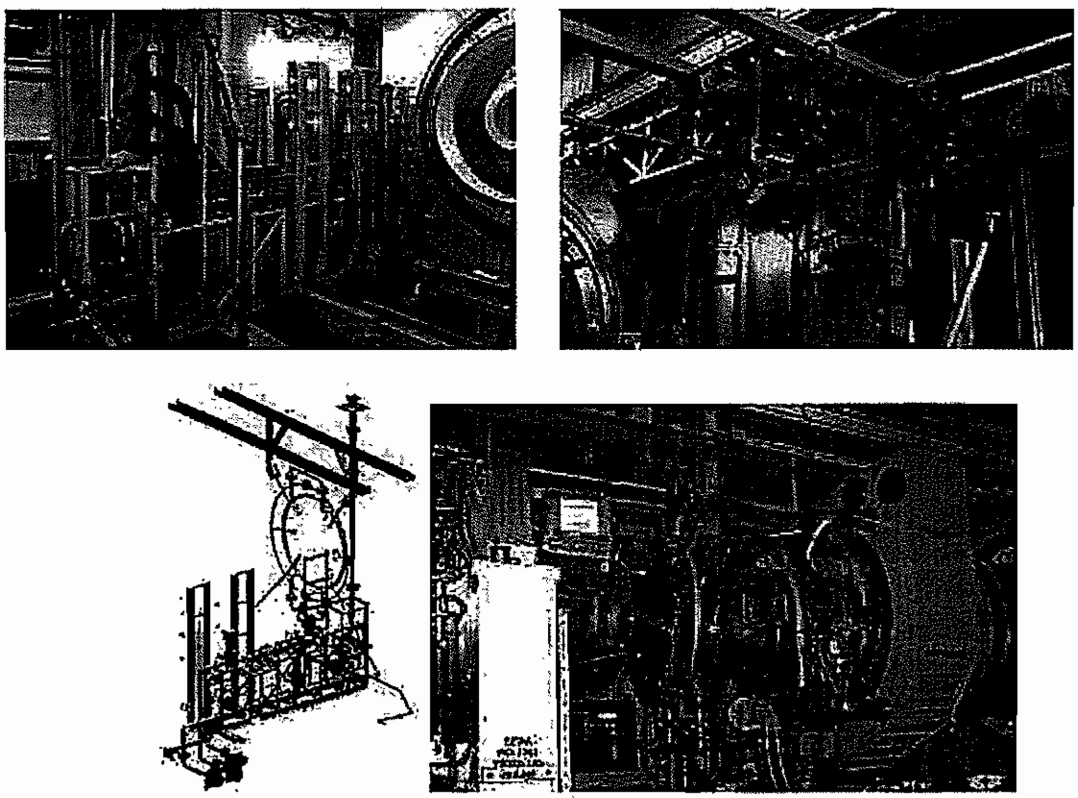
A self-contained fuel control skid is mounted alongside the gas turbine inside the enclosure. The fuel forwarding skids and the water injection skid will be located outside of the gas turbine enclosure. The electronic Engine Management System (EMS) controls the fuel flow demand to each of the manifolds in order to govern the engine output speed, power and emissions, using inputs from the engine and operator control panel.

During engine shutdowns and load sheds gas is vented via the vent valves through a combined vent pipe to ambient. A flow switch is located in the vent to detect any gas leaks through these vent valves during normal running conditions.

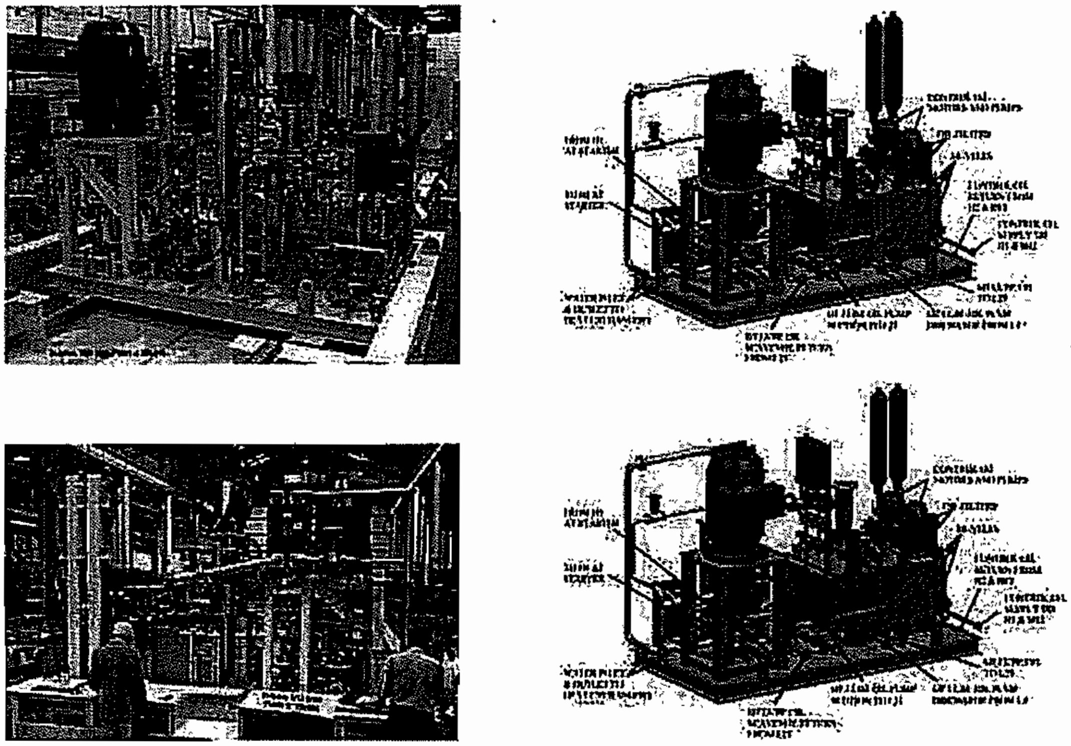
Figure B3.5-1: Dual Fuel System



B3.5.5 Gas Turbine Oil Systems

The combined gas turbine lube oil, hydraulic control and hydraulic start system is located on the main skid in front of the main air radial inlet plenum, the system is depicted below and described in the following sections.

Figure B3.5-2: Gas Turbine Oil Systems



B3.5.5.1 *Gas Turbine Synthetic Lube Oil System.*

The system provides synthetic oil from a common lube oil and starting oil tank to lubricate and cool the three gas turbine bearings, internal gearbox and external gearbox.

Synthetic oil is directed through a simplex filter and into a manifold for distribution. Oil is scavenged from the bearings via a simplex filter and is routed to a fin/fan cooler heat exchanger before returning to the oil tank. Air from the oil tank is vented to atmosphere after passing through a mist eliminator where the final oil is recovered and drained back to the oil tank. This tank is equipped with external fill facilities, heater, a breather/coalescer system and an oil consumption monitor.

B3.5.5.2 *Electro-Hydraulic Oil Starting System*

The system provides oil to power and cool the on-engine mounted hydraulic starter motor that accelerates the HP spool of the gas turbine to purge speed. It then maintains that speed until purging is complete and ignition successful. It then assists the gas turbine to accelerate to self-sustaining speed.

The system also provides compressor rotation for purging after an aborted start and during the unfired compressor water wash cycle.

The system is supplied from the common oil tank shared with the lubricating oil system. The system is pressurized by one electric motor driving two separate pumps in tandem on a common shaft, discharging into a common supply header. The main pump powers the hydraulic motor. The charging pump pressurizes the system on start up, provides cooling oil to the hydraulic motor and compensates for bleed flow to the heat exchanger.

Hydraulic oil returns from the starter motor via a return header to maintain system pressure. A hot shuttle valve acts as a cross-port relief, ensuring that neither the supply header nor the return header is over pressurized. The tank is provided with an oil mist separator and vent.

B3.5.5.3 Gas Turbine Hydraulic Control Oil System

The system provides control oil to the LP compressor bleed valve actuators, LP and IP compressor inlet guide vane actuators and LP and IP thrust piston actuators.

Oil is supplied from a separate section of the oil tank. The system is pressurized by one of two 100% electric motor driven (one running, one stand-by) variable displacement pumps. The pumps are automatically adjusted to maintain constant pressure. Flow is directed through a duplex filter and into a manifold for distribution.

Oil is returned via a common line with the gas turbine hydraulic start system to the tank.

B3.5.5.4 Gas Turbine Oil Systems Technical Data

B3.5.5.4.1 Gas Turbine Synthetic Lube Oil System.

Item	Specification
Recommended lube oil grade	See interface list
Tank capacity - Combined with Starting Oil System	1330 liters (Gross)
Average residence time of oil in tank	8 minutes
Tank heater	2 X 1.5 kW element, thermostatically controlled
System material	Stainless steel throughout Filters are CS with SS internals
Supply pumps	One (1) off shaft driven
Scavenge pumps	Eight (8) off shaft driven
Normal supply pump discharge pressure	16.55 bara
Maximum system pressure	24.13 bara – Safety Valve Crack 29.30 bara – Valve Full Open
Normal oil supply flow	78 l/min
System filtration level	β3 = 200 (3 micron)
Filter differential pressure alarm	140 kPad
Lube oil heat exchanger	One plate type oil to water cooler
Minimum oil temperature @ start up	15ºC
Oil cooler bypass temperature	54ºC – Thermostatic control valve is in mixing mode
Air / oil separator capacity	43.5 l/min

B3.5.5.4.2 Electro-Hydraulic Starting System

Item	Specification
Recommended hydraulic oil grade (same as control oil)	See interface list
Tank capacity	Same as lube oil

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Item	Specification
System material	Stainless steel, Filters and PSV are Carbon Steel
Electric motor	One (1) off 250 KW, AC 3 phase
Main pump	One (1) off variable displacement piston type
Charging pump	One(1) off fixed displacement type
Hydraulic motor cooling oil circuit	Bleed off from charge pump.
Clutch type	Centrifugal over-running, automatic engaging
Normal main pump discharge pressure	350 bar
Maximum system pressure	413 bar
Maximum oil flow to starter motor	517 l/min
Normal cooling oil flow to starter motor	18 l/min
Starter motor cut out speed	4500 rpm
Maximum starter motor speed	4650 rpm
System filtration level	10 micron absolute
Filter differential pressure alarm	1 bar
Heat exchanger	One (1) off water cooled, plate type
Maximum tank oil temperature	65 °C
Min tank temperature @ start	15 °C

B3.5.5.4.3 *Gas Turbine Hydraulic Control Oil System*

Item	Specification
Recommended hydraulic oil grade	See interface list
Tank capacity	587 Liters
System material	Stainless steel, Filters and PSV are Carbon Steel
Electric motor	Two (2) off 22 kW AC 3 phase
Main pump	Two (2) off variable displacement piston type
Normal pump discharge pressure	76 bar
Maximum system pressure	79.3 bar
Normal oil flow	0.221 l/min
Accumulators	Two (2) off bladder type, nitrogen charged
System filtration level	$\beta 3 = 200$ (3 micron)
Tank Heater	1 X 1.5 kW Element, Thermostatically Controlled
Maximum operating temperature	65°C
Minimum operating temperature	55°C

B3.5.6 AC Generator Lube Oil System

A self-contained lubricating oil system is located as part of the AC generator module. The system is depicted below and described in the following sections

The system provides lube oil to the two rotor support bearings.

The system is supplied from a dedicated lube oil tank. Oil is supplied from one shaft driven pump and one AC motor driven standby pump. Oil is delivered via a heat exchanger, with a thermostatically controlled bypass to the bearings through a simplex filter. The tank is fitted with an oil heater for low ambient temperature operation and an oil vapor extractor on the vent line.

Rotor jacking oil is also supplied from an AC motor driven pump and provides high pressure oil for lifting the rotor during GT maintenance which requires turning of the shaft line.

A DC Emergency pump is included. This pump will supply oil to the bearings in the event of a complete loss of AC power.

B3.5.6.1 AC Generator Lube Oil System Technical Data

Item	Specification
Recommended lube oil	ISO VG32 lubricating oil
Lub oil tank capacity	2079 Liters
Tank heater	2 X 2 kW thermostatically controlled
System material	Oil tank – carbon steel Lube oil piping stainless steel.
Supply pumps	One (1) off shaft driven One (1) off 7.5 kW AC motor driven standby pump One (1) off AC Jacking oil pump One (1) off DC Emergency pump
Normal supply pump discharge pressure	1.5 Bar
Maximum system pressure	12 Bar
Normal oil supply flow	180 l/min
System filtration level	10 Micron
Filter differential pressure alarm	1.4 Bar
Lube oil heat exchanger	One (1) off water cooled, plate and frame type
Lube oil supply temperature (Normal)	55 to 65 °C
Maximum lube oil supply temperature	70°C Alarm 77°C Shutdown
Minimum tank oil temperature	10 °C
Oil cooler bypass temperature (Start)	54 °C

B3.5.7 Gas Turbine Compressor Mobile Water Wash Cart

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The gas turbine compressor water wash system is located on a mobile cart that can be moved between units.

The system provides a means of removing contaminants deposited on the rotating and stationary blades of the gas turbine compressor by injecting cleaning chemicals into the blade path via nozzles located in the inlet scroll.

The wash cycle is executed unfired, i.e. barring using the gas turbine hydraulic start system.

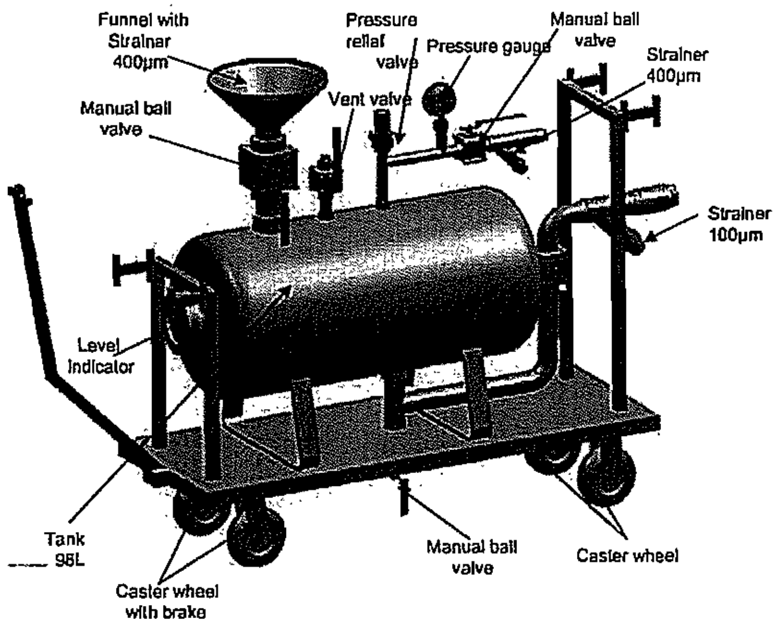

Figure B1: Gas Turbine Compressor Mobile Water Wash Cart

The mobile water wash cart comprises one tank storing a mixture of de-mineralized water, detergent and anti-freeze, pressure relief valve (set at 9 bar g), vent valve, pressure indicator, level gauge, Strainer one (1) x 100µm and two (2) x 400µm), 2 x 5 m hose with quick release coupling (self sealed), as illustrated above.

Each gas turbine module has the required piping, solenoid valve with pneumatic actuator and manual drain valves to supply the fluid from the cart to gas turbine intake.

Delivery is via pressurizing the tank using compressed air supplied by others.

B3.5.7.1 *Gas Turbine Compressor Mobile Water Wash Cart Data*

Item	Specification	
Wash / Rinse Tank capacity	95 Liters	25 Gallons
Normal flow	90 Liters / Min	23.8 Gallons / Min
System filtration level	100 µ	

Unfired Compressor Water Wash Cycle

Item	Time	Volume
Engine cool down	30 mins	

Item	Time	Volume
Inject detergent solution	1 min	41 Liters
Soak	25 mins	
Inject rinse solution	1 mins	41 Liters
Soak	25 mins	
Inject rinse solution	1 min	41 Liters
Drain down	25 mins	
Dry out	15 mins	
Total cycle	2 hr 3 mins	

B3.5.8 Package Fire and Gas Protection System

The GenSet fire and gas system incorporates a full fire detection system, gas detection system and CO_2 fire suppression system for the zones of the GenSet - the gas turbine. The control panel is located on skid and requires a separate 24 VDC power supply battery backed for 24 hours. The CO_2 bottles are housed in a rack outside the gas turbine enclosure.

If any one flame detector or rate of rise heat detector is activated, the gas turbine is automatically tripped, the gas supply closed and residual gas vented, the enclosure ventilation fans tripped, and an audible siren and a visual beacon light warn of impending CO_2 discharge inside the enclosure. After an adjustable 20 second delay, CO_2 is discharged to extinguish the fire by oxygen starvation.

If re-ignition is detected, a second discharge is activated.

Two gas sensors are located in the gas turbine enclosure ventilation stacks. Activation of a single gas sensor at a 5% level will cause an alarm and a second enclosure ventilation fan to be started to increase ventilation. Activation of a single sensor at a 10% level will cause the gas turbine to be automatically tripped, the fuel gas supply closed and residual fuel gas vented.

Manual pull stations adjacent to all enclosure access doors allow manual CO_2 discharge. Positive deactivation systems are provided for personnel protection during access to the enclosure for housekeeping / maintenance.

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B3.6 TRENT 60 - CONTROL SYSTEMS

B3.6.1 Control System Overview

The control and protection systems permanently monitor the operating conditions of the plant. The control system adjusts plant parameters according to the operating conditions. The protection system prevents a status liable to present a risk to the plant. The control system is mounted on skid to minimize the number of interconnects and facilitate factory wiring checks. Off skid or inter-skid signals are routed over dual redundant ControlNet to reduce on site wiring time, allowing flexibility in the location of the MCC, GCPP, etc.

The Human Machine Interface (HMI) is a single point of access to view operation, maintenance and historical data. Access to the different functions is secured with passwords. The HMI communicates with the control system over dual redundant Ethernet and may be placed on skid, off skid, or at an additional remote location. It allows to toggle the display of Rolls-Royce or Customer standard tagging, units of measurement and language. The primary operating HMI will be located in the control room. Communication between the HMI's and the control systems utilizes the OPC protocol for data collation. This facility can also be made available for DCS communications with the control system.

The Engine Management System (EMS) provides direct control of the Gas Turbine. The Generator Control Panel (GCP) will facilitate manual and auto synchronizing, voltage regulation, generator protection and metering and breaker control. The Package Control System (PCS) provides control over all Gas Turbine auxiliary systems and interfaces with the HMI, EMS, GCPP, and customer control systems.

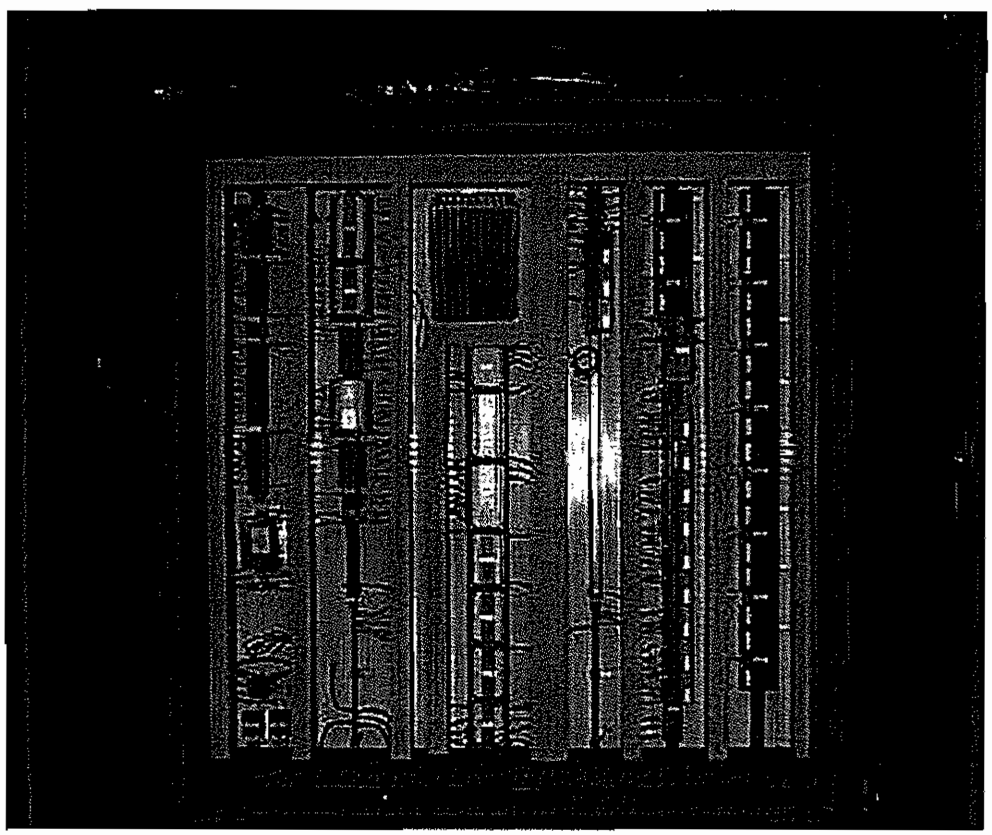

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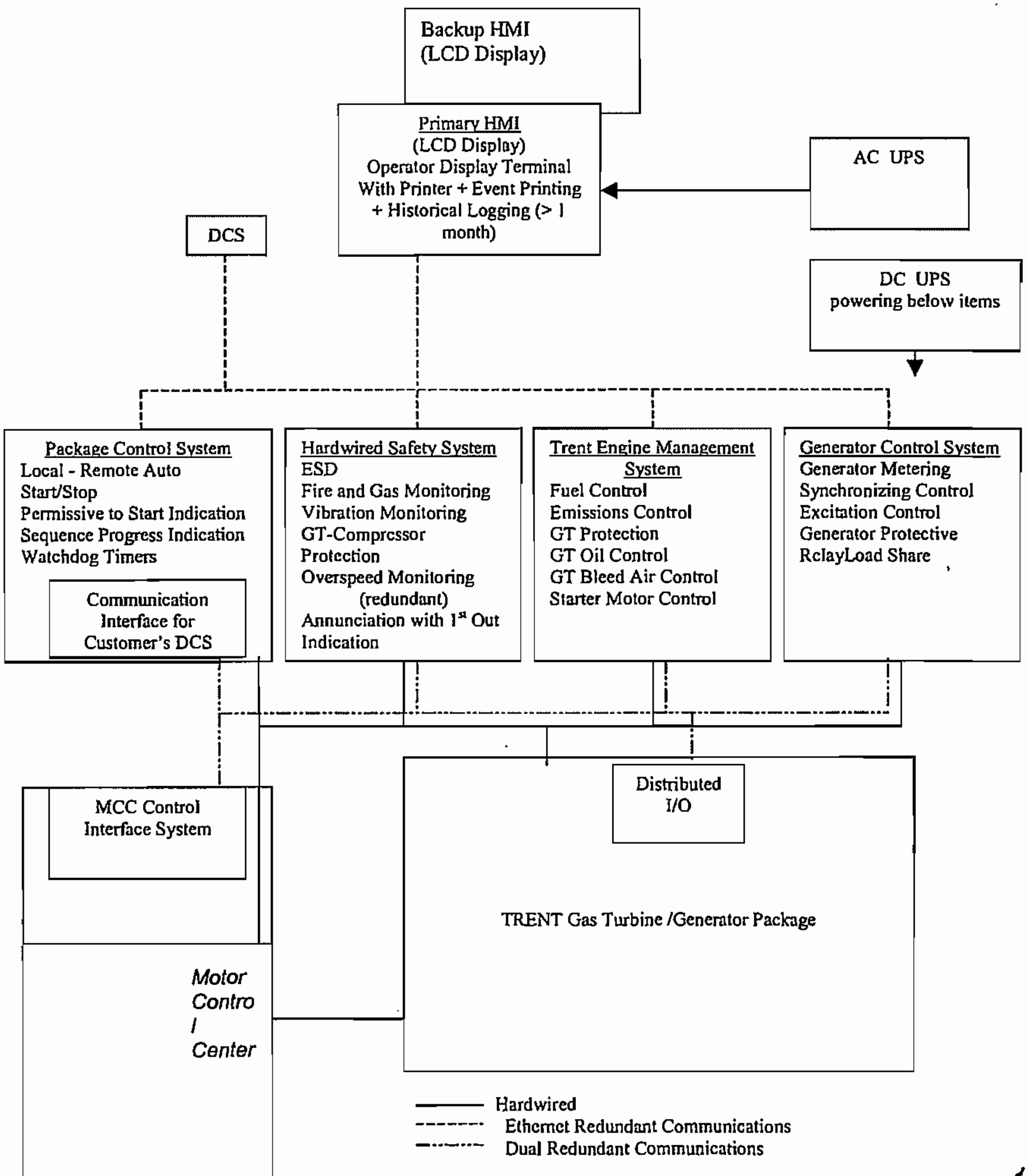
Figure B3.6-1: Block Diagram of Control System



B3.6.2 HMI System

B3.6.2.1 Functions

The operator and maintenance information system would be used for central graphic operator displays and long-term historical information such as trending of analog parameters and eventlogging. It also is used to print events on occurrence and is able to print periodic reports of station operating conditions. High speed trip data capture (pre & past) is available.

The generator unit can be controlled by moving the cursor on the display and changing the setpoint signals.

B3.6.2.2 Graphic Displays

This system provides optimal information to the operator by means of the following CRT displays on the system. They can be easily selected from a menu.

- Multiple units overview
- Unit Overview
- Unit Permissives/Timers
- Start sequence
- Generator Overview
- Vibration
- Lube Oil Systems
- Valve Mimic
- Event History
- Alarm/Shutdown Summary
- Alarm/Shutdown Annunciators
- Transmitter Failure
- Historical Trending
- Reporting (Standard)
- Calibration Screens

B3.6.2.2.1 CBOS 210 Development Software License

The CBOS 210 software is based on Windows NT software package and it includes the following:

- Development software, Intellution, for changes in graphic and data base
- Microsoft Excel™
- SNAG-IT - Screen Printouts
- FT DDE Server
- Windows NT
- Flexnet FT55 driver
- Historical Trending

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B3.6.2.3 *Computer*

A Pentium PC, 1.8 GHz, 1GB RAM, 40.0 GB hard disk or better is proposed for this application, communications card. Including 1.44 FD, CD-ROM Drive, 2 parallel and 2 serial ports.

B3.6.2.4 *Printer*

One Inkjet color (high end) printer which is PC compatible and high resolution.

B3.6.2.5 *Monitors*

The color industrial monitor is 17" diagonal screen, LCD super XGA.

B3.6.2.6 *Construction*

The HMI part of the system will be mounted in PCS, with an additional remote desktop HMI provided for mounting in the remote control room.

B3.6.2.7 *Communications Modem*

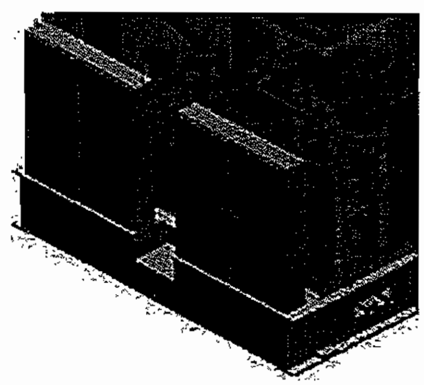
One (1) RS-232 telephone dial-up modem is supplied which is beneficial to both the customer and Rolls-Royce for remote system interrogation for troubleshooting and diagnostics.

B3.6.2.8 *Communications Protocols*

The system that would be used as the facility monitoring unit has the capability of developing several different industrial type communications protocols in software for communications between unlike systems.

B3.6.3 ***Package Control System***

Figure B1: Package Control and Engine Management System



The PCS provides overall supervisory control of the gas turbine and generator and sequence control of the GenSet auxiliary plant.

Extensive use is made of distributed I/O mounted on the turbine generator package. Communication between the PCS and its distributed I/O is via dual redundant ControlNet communication.

The PCS performs the following functions:

- Mode of operation selection logic (i.e. base, etc.);
- Start sequence initiation, start auxiliary systems, verify auxiliary systems, initiate purge sequences, and initiate EMS start;

- Scheduled shutdown initiation, cool down and coast down sequences for auxiliary systems;
- Interface with plant controls, data logging and Trend monitoring system;
- Initiation of generator synchronization;

The PCS controls the following auxiliary systems:

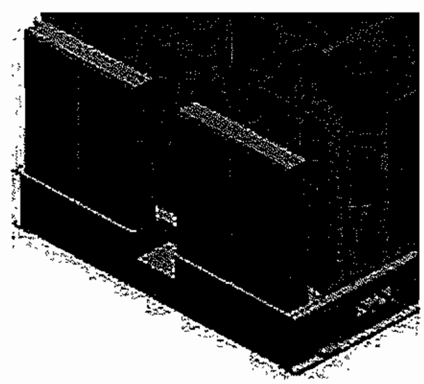
- Gas fuel system;
- Liquid fuel system;
- Water injection system;
- Hydraulic start system;
- Gas turbine lube oil;
- Hydraulic control oil system;
- Gas turbine enclosure cooling;
- Gas turbine bleed air cooling;

The PCS interfaces with the following auxiliary systems:

- Vibration
- Fire and Gas
- Generator and auxiliary monitoring and protection;

B3.6.4 Engine Management System

Figure B1: Package Control and Engine Management System



The PCS will interface with the engine via the Engine Management System (EMS) to provide start / stop type control and will directly control all other equipment in the generating set. The EMS provides closed loop and sequence control of the gas turbine directly. The PCS/EMS interface is a dual redundant ControlNet link.

The EMS performs the following functions:

- Fuel/Water system control and metering;
- Engine auto start control sequence;
- Low pressure (LP) compressor and intermediate pressure (IP) compressor inlet variable stator vane control;
- Compressor bleed valve control;

- IP / LP turbine tip clearance control;
- LP / IP shafts thrust piston control;
- Engine transient control;
- Flame out detection;
- Engine shutdown control;
- Engine protection shutdown control;
- Engine safe operating limit control / protection;
- Emission control;
- Shaft shear protection;
- LP / IP shaft overspeed protection.
- Loading and unloading rate control;

In the droop mode, load sharing with a parallel generator is accomplished. One unit is typically selected as the isochronous master frequency reference (i.e. 50 Hz ± 5%) and with the companion units operating in droop load share mode. The controls will function to load share both active and reactive loads.

The governor will operate with the synchroniser automatically for breaker closure or may respond to manual control. Provisions are available to accommodate transferring of operating mode, from isochronous to droop, after paralleling with companion units.industrial type communications protocols in software for communications between unlike systems.

B3.6.5 AC Generator Control and Protection System

The GCPP houses the AVR, synchronizing, metering and protection for the AC Generator.

The following equipment is located in the panel:

- AVR;
- Excitation controls;
- Auto synchronizer;
- Check synchronizer;
- Synchronizing control;
- Synchroscope;
- Metering equipment.

The following generator/transformer protection facilities are provided:

- Reverse power;
- Field;
- Negative phase sequence;
- Neutral displacement;
- Voltage dependant overcurrent;
- Undervoltage;
- Over frequency;
- Under frequency;
- AC Generator differential;

- AC Generator/Busbar differential;
- AC Generator hand lockout;
- Voltage balance.

The PCS/AC Generator control interface is via remote I/O and is located in an enclosure (called the GCI – Generator Control Interface) mounted adjacent to the GCPP and hardwired to the GCPP. The PCS interfaces to the GCI to receive the information.

These facilities are provided by a multilink SR489 multifunction relay. The PCS/AC Generator instrumentation interface is via dual redundant ControlNet.

B3.6.6 Control System For Gas Turbine Generator Unit

B3.6.6.1 Display of Permissive Conditions

The start permissive conditions recognized by the PCS and displayed on the Human Machine Interface (HMI) are shown below and will prevent the unit start until all conditions are permissive. The HMI is the primary operator interface and the "Permissive to Start" page is one of the pages of information as described below.

- Gas Turbine not rolling
- Fuel valve closed
- Engine Management System (EMS) preset
- Auxiliaries available
- Lube oil reservoir's levels and temperatures permissive
- Unit selector switch
- Control power normal
- No alarm
- No shutdown
- Generator permissive
- Station permissive

B3.6.6.2 Display of Sequence Progress

The sequence progress display is provided on the HMI. On incomplete sequence, the last step will be locked in for trouble shooting purposes.

- Unit starting
- Generator lube oil pump on
- Generator lube oil pressure Satisfied
- Gas Turbine (GT) oil pump on
- GT oil pressure satisfied
- GT hydraulic starter motor on
- GT purging
- GT acceleration, three stages
- GT warm-up
- GT loaded

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B3.6.6.3 *Display of Status Condition*

The following status conditions are indicated via the HMI

- Unit starting
- Starter on
- Ignitors on
- Fuel vent valves closed
- Fuel shutoff valve closed
- Fuel control valve open
- GT warmed-up
- Loaded
- GT minimum speed setting
- GT maximum speed setting
- GT maximum horsepower
- Unit stopping
- Post lube
- Aux lube pump on
- Enclosure fans on

B3.6.6.4 *PUSHBUTTONS*

- Start
- Normal stop
- Emergency stop (guarded)
- Lamp test
- Acknowledge annunciator
- Increase (GT speed set point)
- Decrease (GT speed set point)
- Manual starter control
- Aux. Lube pump return to primary

B3.6.6.5 *SELECTOR SWITCHES*

- Main control mode [4 position, key operated], (Off – Manual starter – local auto – remote auto)
- Speed mode (idle – manual – auto)

B3.6.6.6 *CLOCKS / COUNTERS*

- Engine hourmeter (0-99,999)
- Start attempt counter
- Successful starts

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B3.6.6.7 *Temperature Monitoring System*

Both RTD's (resistive temperature detectors) and thermocouples are used for temperature sensing. Temperature monitoring is via the FT55 system with individual setpoints for each channel.

The following temperature points are monitored and displayed on the HMI:

- GT Lube oil reservoir (RTD)
- GT fuel gas (RTD)
- GT hydraulic starter (RTD)
- GT auto ignition (TC)
- GT IP & LP turbine inlet (TC)
- GT exhaust differential (TC)
- GT compressor discharge (TC)
- GT lube oil supply (RTD)
- GT lube oil scavenge (RTD)
- GT IPT turbine front/rear disc. bearings (TC)
- GT LP turbine exit (TC)
- GT HP compressor delivery (TC)
- Generator bearings (RTD) journal
- Generator starter winding (RTD), exciter bearing drain, (RTD)
- Lube oil supply (RTD)
- Lube oil reservoir (RTD)

B3.6.6.8 *Vibration Monitoring System*

The vibration monitoring system consists of individual monitoring channels for each accelerometer and radial vibration sensor, location (x,y) and each axial displacement probe. The GT channels are monitoring accelerometer probes and displaying velocity (mm/sec). Alarm occurs if gap voltage or relative shaft position exceeds pre-set levels. The monitored vibration points are:

- GT LP compressor
- GT HP compressor
- GT LP turbine
- Generator X (2), Y (2)

The GT channels are utilizing Entek 120 series monitors and provided with serial communication and hardwired communication (trips) to the PCS safety system.

B3.6.6.9 *Speed Monitoring System*

Speed monitoring is accomplished by accurate digital speed channels, which are part of the processor basic system. Speed points are used for sequencing and protection on the following shafts:

- Gas turbine LP, IP and HP shafts (NL, NI & NH)
- Starter Speed shaft (NS)

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Overspeed detection is via 2oo3 voting.

B3.6.6.10 *Hardwired Safety System (HSS)*

The hardwired safety system is outside the processors for additional safety. Each critical failsafe shutdown device is wired to a master trip circuit and repeater contacts are wired to the processors input circuitry for annunciation and displays on the HMI. The HMI displays the alarm and trip points sequentially with time and date.

The HMI display includes a first event flashing feature for operator convenience. Alarm acknowledge and rest pushbutton are provided.

A listing of Alarms and Shutdowns is provided on the following pages. This listing is preliminary and subject to change due to final design.

B3.6.6.11 *Alarm And Shutdown Listing*

B3.6.6.11.1 *Gas Turbine*

	Alarm	Shutdown
GT LP, IP & HP compressor pressure high.	(X)	( )
GT LP, IP & HP compressor temperature high.	(X)	( )
GT thrust piston cavity pressure	(X)	( )
GT manifold pressure	(X)	( )
GT starter overspeed	( )	(X)
GT underspeed	( )	(X)
Governor failure	( )	(X)
GT exhaust temperature high	(X)	(X)
GT inlet filter diff. press. high	(X)	(X)
GT instrument air low pressure	(X)	( )
GT enclosure temperature high	(X)	(X)
GT Vibration	(X)	(X)
Governor loss of signal	(X)	( )
GT exhaust diff. temperature high	(X)	( )
Open thermocouple element	(X)	( )
GT enclosure differential pressure high	(X)	( )
GT oil debris	(X)	( )
GT overspeed	( )	(X)
GT bearing RTD temperature high	(X)	(X)
GT Lube oil low pressure	(X)	(X)
GT Lube oil supply temp. high	(X)	(X)
GT Lube oil system fault	(X)	(X)
GT hydraulic oil filter differential pressure high	(X)	(X)
GT starter cooler oil temperature high.	(X)	( )
GT starter hyd. oil reservoir level low	(X)	( )
GT starter hydraulic oil filter differential pressure high	(X)	( )
GT L.O. reservoir level low/high	(X)	( )
GT L.O. filter diff. pressure high.	(X)	( )
GT standby L.O. pump running	(X)	( )

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B3.6.6.11.2 *Generator*

	Alarm	Shutdown
Generator trip	( )	(X)
Generator voltage alarm	(X)	( )
Generator exciter diode failure	(X)	( )
Generator high bearing temp	(X)	(X)
Generator vibration high	(X)	(X)
Generator winding high temp	(X)	(X)
Reverse power trip	(X)	( )
Generator electrical fault	(X)	(X)
Dead bus	(X)	( )
Standby lube oil pump operating	(X)	( )
Exciter cooling air discharge high temp	(X)	( )
Spares (8)	(X)	( )

B3.6.6.11.3 *Miscellaneous*

	Alarm	Shutdown
Remote trip to idle	( )	(X)
Fuel gas pressure high	( )	(X)
Fuel gas pressure low	(X)	( )
Remote shutdown with blowdown	( )	(X)
24VDC voltage low	(X)	(X)
Instrument air low pressure	(X)	( )
UCP shutdown bypass timed out	(X)	(X)
Incomplete sequence	( )	(X)
Processor fault	( )	(X)
Cooling fan vibration	( )	(X)
Unit emergency S/D operated	( )	(X)
UCP S/D bypass 5 minute warning	(X)	( )
Remote stop	(X)	( )
Vibration monitor fault	(X)	( )
Fire & gas monitor cir. trouble	(X)	( )
Hazardous Atmosphere	(X)	(X)
Fire	( )	(X)
Spares (6)	( )	(X)

NOTE: Actual points may vary due to final design.

B3.6.7 ***Control System For AC Generator***

B3.6.7.1 *DISPLAYS*

The AC Generator controls HMI and displays described below are in a 2 bay cabinet located in the customer's control room.

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B3.6.7.1.1 *SEQUENCE PROGRESS*

- Unit synchronized
- Closed generator breaker

B3.6.7.1.2 *STATUS (Located in Generator Section)*

- AC Generator breaker closed
- AC Generator breaker open
- AC Generator breaker tripped

B3.6.7.1.3 *AC GENERATOR CONTROL*

Incorporated in the generator metering panel:

- Manual voltage regulator
- Automatic voltage regulator

B3.6.7.2 *AC GENERATOR INSTRUMENTATION*

1%, 4-1/2" diameter: Switchboard Meters, Switchboard Class Switches

- Front of panel mounted:
  - One (1) Ammeter (GAM), with selector switch, generator output
  - One (1) Voltmeter (GVM) with selector switch, generator
  - One (1) Voltmeter (BVM) with selector switch, bus
  - One (1) Wattmeter (GWM)
  - One (1) Varmeter (GVARM)
  - One (1) Exciter Field Ammeter (GEFAM)
  - One (1) Exciter Field Voltmeter (GEFVM)
  - One (1) Generator Frequency Meter (GFM), generator
  - One (1) Generator Frequency Meter (BFM), bus
  - One (1) Synchroscope

Control and Selection

- Front of panel mounted:
  - Two (2) Circuit Breaker Position Lights
  - One (1) Circuit Breaker Control Switch (43/52G)
  - One (1) Voltage/Var Control Switch (43AVC)
  - One (1) Manual Voltage Control Switch (43MVC)
  - Two (2) Voltmeter Switch (43GV)
  - One (1) Generator Speed Control Switch
  - One (1) Manual/Auto Synchr. Selector Switch
  - One (1) Synchroscope Control Switch

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- One (1) Synchronizing Light

B3.6.7.3 *ADDITIONAL INSTRUMENTATION*

The following are provided:

- Synchronizer with check relays
- Automatic voltage regulator

A multifunction AC Generator protective relay is provided:

- AC Generator stator thermal detector, No. 49G
- Negative sequence relay, No. 46
- Loss of excitation relay, No. 40
- Reverse power relay, No. 32
- Overcurrent relay, No. 51V with voltack restraint
- AC Generator differential relays, No. 87G
- AC Generator ground fault relay
- AC Generator over voltage relay, No. 59
- AC Generator ground fault relay, No. 64G, 59G
- AC Generator field ground fault relay, No. 64F
- Lock out relay, No. 86G
- Synch CK relay, No. 25
- Time delay relay 62
- Field undervoltage relay 27F
- Dead Bus 27
- Volts/Hertz 24
- Over/under freq 81

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B3.6.8 Gas Start Sequence

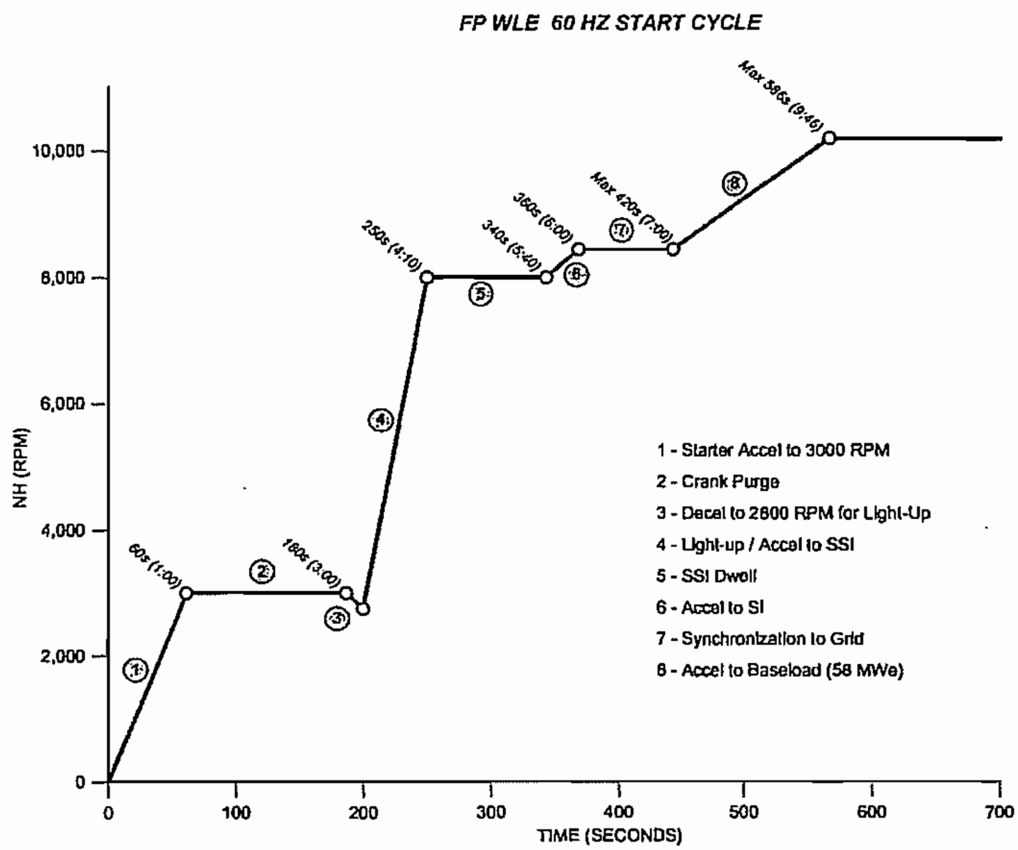

Figure B3.6-2: Typical Start Sequence

B3.6.8.1 Start Time

The start-up sequence time, for a simple cycle Industrial Trent 60 application, is 9 minutes 46 seconds from pressing the start button to reach full baseload. This includes an allowance for 2 minutes system purge time.

For exhaust heat recovery applications additional purge time will be required to purge the extra exhaust system volume.

B3.6.8.2 Start Sequence

Prior to start initiation, all alarms and trips must be cleared and the Trent 60 package must be in a ready-to-start status.

The high-pressure shaft is accelerated to 3000 rpm NH by starting the hydraulic start system, and providing high-pressure oil to the positive displacement hydraulic motor mounted on the engine gearbox. The engine speed increases at a rate controlled by the starter pressure and the dynamic load of the HP rotor and typically takes 60 seconds, the control system initiates the purge timer to ensure three air changes of the exhaust system.

Prior to ignition the HP spool speed is reduced to 2800 rpm to assist start up control and prevent the engine lighting in a stall. Ignition is initiated and gas is admitted to the gas injectors. Successful ignition is detected by two sets of 17 thermocouples at the low-pressure turbine entry. The unit will shutdown if a successful ignition is not confirmed within a predetermined time.

Acceleration to engine idle speed proceeds once ignition is established, the overrunning type clutch remains fully engaged to assist engine acceleration until starter cut speed at 4,500 NH rpm.

Fuel flow increases at a controlled rate as a function of time to prevent over fuelling and over temperature. The control system monitors the acceleration schedule, critical pressures, and temperature limits.

The engine will continue to accelerate to SSI (Sub Synch Idle), at which speed it will remain for a minimum 90 second hot purge dwell period (maximum is site specific), before accelerating to SI (Synch Idle). At that point, the auto synch unit takes control for synchronization to the grid. Following synchronization, the unit will accelerate to base load or a pre-specified power at 0.35mw/sec rate. For the Trent 60 WLE during the acceleration to power, water injection will start at 5 MW to prevent gas migrating back into the water manifold.

B3.6.8.3 *Start Permissives*

The following start permissives have to be satisfied and the ready to start indication obtained to allow engine start:

- EMS ready to start, i.e. fuel metering valves, are closed, high speed shut off valve closed, speed references at minimum position;
- Gas fuel pressure >22 bar(a) (>319 psi (a));
- Common gas turbine oil temperature >15°C (>59°F);
- Common gas turbine oil level not in alarm;
- NH speed <500 rpm;
- Generator lube oil temperature >10°C (>50°F);
- Generator lube oil level not in alarm;
- GenSet not tripped;
- Vibration monitor not in alarm;
- Fire / gas detection system not in alarm;
- All MCC switches are in auto position.

Upon selection of GenSet start, the following will occur:

- The following auxiliary systems will start:
- Gas turbine enclosure cooling / ventilation fans;
- Generator / turbine coupling pressurization / cooling fan;
- Main hydraulic control oil pump;
- Generator standby lubrication oil pump.
- Initiate starting package sequence and control:
- Start hydraulic start motor;

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- Ramp hydraulic start pump servo valve to increase pump flow and accelerate engine to purge speed (NH = 3500 rpm);
- When NH reaches 3200 rpm a purge timer is initiated. (Typically purge timer is two minutes and 15 minutes for simple cycle and combined cycle respectively - actual timings dependant on exhaust system configuration).
- Initiate engine pre-start checks.
- After purge is complete gas turbine start sequence is initiated:
  - Energize ignition and open high speed shut off valve;
  - Open torch fuel metering valve and check for light off;
  - When light off is successful, ramp fuel valves to accelerate gas turbine to idle speed;
  - Ramp hydraulic start pump servo valve to assist gas turbine;
  - When NH reaches the engine self sustained speed, starter motor and ignition are cut off;
  - When NH reaches idle speed, fuel metering valves will be controlled by NH loop;
  - Check LP shaft breakaway is made at 1000 rpm and, if satisfied, NH reference is raised to accelerate gas turbine;
  - Gas turbine will continue accelerating until it reaches 2500 rpm approximately, fuel metering will then be controlled by NL loop;
  - When NL loop is in control, NL reference is raised to continue accelerating the gas turbine;
  - Once NL exceeds 2600 rpm, generator field breaker is closed to energize the generator;
  - When NL reaches 2950 rpm approximately, the automatic raising of NL reference will cease and synchronization sequence will start;
  - Auto synch unit is energized.
- Auto synch unit will pulse NL reference and generator voltage to match generator voltage and speed to that of the grid / when signal is given to close the generator breaker.
- When breaker closes, NL reference will be raised to a minimum setting of 5 MW;
- Loading is raised manually or automatically by raising NL reference to the desired power setting;
- Standby generator oil pump will stop when main lube oil pump shaft driven pressure is satisfied (NL » 2000 rpm).

Note: NL = LP spool speed

NH = HP spool speed

B3.6.9 GenSet Protection

B3.6.9.1 Normal Shutdown Sequence

Upon operator initiated stop command, the following stop sequence is initiated automatically:

- The unit will unload at a controlled rate to provide a safe and smooth shutdown of the unit;
- When the unit reaches 0.5 – 3.0 MW, the AC Generator breaker is tripped;

- The gas turbine will continue unloading at the controlled rate until it reaches the minimum self-sustaining idle speed. The bleed valves, as well as the low pressure bleed doors, are scheduled open.
- The gas turbine will remain at idle speed for five minutes to cool down. After the cool down period has timed out, fuel gas is isolated by closing the high-speed shut-off valve, the fuel metering valves are closed, and the vent valves are open.
- After five minutes from fuel gas isolation, the control oil pump is stopped. After 30 minutes from fuel gas isolation, the gas turbine enclosure and AC Generator cooling fans are stopped. When 30 minutes has elapsed from the time that NL speed is detected as zero, the AC Generator lube oil pump is stopped.

B3.6.9.2 *Emergency Shutdown*

In the case of an emergency shutdown, the fuel gas is immediately isolated by closing the high-speed shut-off valve and the fuel metering valves. The gas fuel system is vented, the cool down period is bypassed and the stop sequence for auxiliary systems follows as described above.

B3.6.9.3 *Trip Conditions*

The following faults (among others) initiate an immediate trip of the gas turbine (lockout trip):

- Combustor flame failure;
- Gas turbine combustion gas temperature high;
- Shaft shear protection;
- Starter overspeed;
- Gas turbine lubrication oil pressure failure;
- Low pressure compressor, bleed valves failure;
- AC Generator lubrication oil pressure failure;
- Enclosures fire detection;
- LP shaft overspeed;
- IP shaft overspeed;
- Gas turbine enclosure gas detection;
- AC Generator differential protection;
- AC Generator ground fault;
- Loss of gas turbine enclosure ventilation;
- Operator initiated emergency shutdown;
- Hydraulic starter temperature high;
- IP / LP turbine overheat.

Controlled trip: Engine will decelerate through a controlled cool down and shutdown sequence.

The following faults (among others) will initiate a controlled trip:

- LP / IP / HP dual speed sensor failure;
- Fuel metering valve position feedback failure;
- LP / IP inlet guide stator vanes position feedback failure;

- LP / IP / HP thrust bearing position feedback failure;
- Vibration high;
- Gas turbine lube oil temperature high;
- AC Generator bearing temperature high;
- AC Generator stator temperature high;
- Gas turbine gearbox cooling air temperature high;
- Hydraulic control oil pressure low;
- Inlet filter ΔP high;
- AC Generator cooling failure;
- Gas turbine lube oil level low;
- Generator lube oil level low;
- Hydraulic control oil level low;
- Combustion noise.

The following are incomplete sequence trips:

- Fail to reach 500 rpm NH;
- Fail to reach ignition speed;
- Fail to light up;
- Fail to reach idle;
- Fail to break away LP shaft;
- Fail to reach synchronous speed.

The following AC Generator protection only trips the AC Generator breaker and excitation field breaker:

- Loss of field;
- Reverse power;
- Voltage controlled over current;
- Negative sequence;
- Voltage / Frequency protection.

B3.6.10 Air Water/Glycol Heat Exchanger

SCOPE OF SUPPLY INCLUDING:	
Vendor:	Ecodyne, Air Exchanger or Equal
Cooling:	Air to Water/Glycol Mix (40%/60%)
Quantity	Two (2) 3 x 50% Air Fan Coolers - one cooler servicing each two units (Where 50% fan duty is for one unit)
Fouling Factor	0.001 ft2hr f / btu
Fans	3 x 50% Fans
Max Amb. Temperature	91 degF
Tube	Welded Carbon Steel

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Tube Material	SA214 Carbon Steel
Fin Type	L-Tension or L-Footed
Fin Material	Aluminum
Nozzle Material	SA105 Carbon Steel
Header Material	SA-516 GR. 70
Support Structure Mat'l	Galvanized steel
Cooler Motor Driver	V-Belt Type 1800 RPM 460VAC/3Ph/60Hz TEFC Electric Motor Murphy Vibration Switch Driver: 25 HP
Support Structure	Header Access Fin Guard or fall-off Guard
Code	ASME
Estimated Size	~13'2" x 47' x 12'-6" W x L x H (approx)
Estimated Weight	~46,000 lbs (approx)
Fin Fan Cooler Mount:	Foot Mounted – free standing
Noise Level of the Cooler:	85 dB(A) at 3 ft distance and 5.5 ft above the cooler
Cooler Auxiliaries:	Water Pump Skid Including: 2 x 100% Pumps 15 Hp Electric Motor Driver per Pump Expansion Tank Interconnecting piping and wiring to Junction Box

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B3.7 TRENT 60 - DRAWINGS

The following drawings are included to assist comprehension of the main and auxiliary systems involved in the scope of a typical power generation plant. It should be noted that the drawings are not project-specific and do not necessarily represent the scope of supply.

Description	Trent 60 WLE
General Arrangement	
General Arrangement	GED00008872
Auxiliary Equipment General Arrangement	GED00010890, Sheet 1 – 4 & GED00008874, Sheet 3
SCR General Arrangement	5338 Sheet 1 & 5397 Sheet 2
SCR P&ID	5339
CEMS Enclosure General Arrangement	5395
CEMS Analyzer	5340
Fin-Fan Cooler P & ID	14144-1DPD
Fin-Fan Cooler G/A	14144-001 Sheet 1
Foundations	
Foundation and Loading Plan	GED00008873
SCR Foundation Plan	5396
Fin-Fan Cooler Foundation	14144-001 Sheet 2
CEMS Enclosure Foundation Plan	5401
Combustion Air System	
Combustion Air Diagram	GED00011158
Purge Air	
P30 Purge Air Diagram	GED00011327
GenSet Enclosure Ventilation Air Systems	
GT/AC Generator Ventilation Air Diagram	GED00011159
Fuel System	
Gas Fuel Diagram	GED00011328
Liquid Fuel Diagram	GED00011820
Water System	
Water Injection Diagram	GED00011333
Water Flush Diagram	GED00011334
GT Hydraulic Start, Lube and Control Systems	
Engine Lube/Hydraulic Start Oil Diagram	GED00011330

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Description	Trent 60 WLE
Hydraulic Control Diagram	GED00008617
Gas Turbine Ignition and Instrumentation	
Engine Ignition and Instrumentation Diagram	GED00011156
IGV/BOV Control Diagram	GED00011697
Fire and Gas Detection and Suppression	
Fire and Gas GT/AC Generator Enclosure Diagram	GED00011160
Gas Generator Wash and inhibit Facilities	
Water Wash Diagram	GED00011332
Instrument Air	
Instrument Air Diagram	GED00011326
AC Generator – General Arrangements, Oil Lubrication and Cooling Systems	
AC Generator Lube Oil Diagram	GED00011331
AC Generator Instrumentation Diagram	GED00011155
Single Line Diagrams	
HV Single Line Diagram	GED00009093
Generator Curves, Data and PSS Model (from Section B3.3.6)	
Shipping and Onsite Installation	
Shipping and Onsite Installation	GED00008875

B3.8 OPERATION AND MAINTENANCE MANUALS

B3.8.1 Introduction

The Trent 60 Genset O&M manuals deliver that information necessary to 'support' the Operation and Maintenance of the equipment supplied and consist of Rolls-Royce authored material supported by equipment supplier (Vendor) manuals.

The O&M manuals in themselves do not constitute day to day operational procedures. The O&M manuals are intended to deliver a sufficient level of information to enable the Site Owner/Operator to develop Operating and Maintenance Procedures for use within their own safe working practices.

B3.8.1.1 Brief Description of 'Standard' Manuals

The following is a brief description of the standard O&M Manual:

B3.8.1.1.1 Description and Operating Guidelines

Full system description and Operating procedures covering the Rolls-Royce scope of supply including the items covered below.

Operating Guidelines will consist of integrated pre-start, start, normal running and shut down including Controlled Shut Down (CSD) and Emergency Shut Down (ESD) procedures.

B3.8.1.1.2 Maintenance

Preventive maintenance tasks are identified in a periodic Maintenance Schedule with references to specific instructions.

Corrective Maintenance instructions are not available within the standard manual package.

B3.8.1.1.3 Equipment manuals

All equipment manuals are assembled and indexed for ease of use.

B3.8.1.2 Plant Definition

The O&M Manual describes:

- Gas Turbine
- AC Generator
- Package Control System
- Gas Turbine Hydraulic Start Oil System
- Gas Turbine Hydraulic Control Oil System
- Gas Turbine Lubrication Oil System
- Gas Turbine Instrumentation
- Gas Turbine Acoustic Enclosure, Ventilation & Combustion Air Systems
- Gas Turbine Fuel and Emission Control System
- Gas Turbine Fire Protection/Detection System
- Gas Turbine Compressor Water wash and GT Module Drain System

- Generator Lubrication Oil System

B3.8.1.3 *Media*

B3.8.1.3.1 *Electronic O&M Manuals*

CD format with Adobe Acrobat files are provided in the Contract Price.

B3.8.1.3.2 *Paper O&M Manuals*

Paper O&M Manuals can be provided in addition to the CD format if requested, at an additional cost.

Binders

All O&M manuals are bound in Rolls-Royce or sub vendor standard binders.

Binders are of the 'D' ring type and accommodate 3 or 4 hole drilled paper plus tabs.

Spine Cards

Spine cards are produced in colour and identify the Customer, the Site, the binder content and the publication number.

Paper Stock

All O&M manuals with the exception of Vendor manuals are printed on 8½" x 11" (Letter), 11" x 17" (Tabloid), A4 or A3 paper. Vendor manuals are provided on the Vendor's own standard paper stock.

B3.8.1.4 *Copyright*

The content of the O&M manuals remains the property of Rolls-Royce, who retain the right to reproduce any part of the O&M manuals in any form as required.

Rolls-Royce grant the Customer free right to copy the supplied O&M manuals for any purpose connected with installing, operating, maintaining, repairing and training on the equipment supplied.

B3.8.1.5 *Updates*

Genset O&M manuals will be regularly updated by issue of bulletins.

B3.8.1.6 *Language*

Operating Manuals in English.

Maintenance Manuals in English