GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

TECHNICAL SPECIFICATION

FOR

GAS TURBINE KIT AND ACCESSORIES FOR HIGH HORSEPOWER NATURAL GAS TURBINE LOCOMOTIVE (HPNGTL) FOR INDIAN RAILWAYS (IR)

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FINAL DRAFT

Engine Development Directorate
Research Designs & Standards Organisation
Manak Nagar, Lucknow, U.P., INDIA – 226 011

1. INTRODUCTION

Indian Railways want to manufacture a gas turbine based locomotive for heavy-haul and goods train operation. For this purpose, IR (RDSO) wants to procure the gas turbine kit and accessories which can be fitted on the gas turbine based locomotive.

2. SCOPE OF SUPPLY

The following shall be the tenderer's scope of supply:

1. Gas Turbine engine
2. Power block control system
3. Alternator and its drive
4. Cryogenic vessel
5. LNG conditioning unit
6. Air inlet and conditioning unit
7. Exhaust system
8. Noise reduction system
9. Lubrication system
10. Lubrication cooling system
11. Adaptation items to fit the above kit on the locomotive
12. Essential spares and consumables for two years warranty period.

The gas turbine shall be tested at the manufacturer's test bed before supply to Indian Railways. For this purpose the tenderer shall supply the gas turbine and other associated equipments to Indian Railways pre-tested and with all valid test certificates. IR personnel shall witness the testing of all the major equipments. IR personnel shall be associated and trained during commissioning of the prototype equipments.

3. PHASE- WISE DELIVERABLES

Phase 1

Gas Turbine kit as given in clause 2 above shall be fitted on two WDG4 locomotive underframes. To ensure the proper fitment and functioning of the equipments supplied by the tenderer, the tenderer should inter-alia submit

i. Outline drawings and 3-D models of associated hardware for HPNGTL power module, cryogenic vessel, LNG conditioning system and all the equipments under tenderer's scope of supply denoting their boundary dimensions, mounting (connection) dimensions, mass, centre of gravity, footprints, overall envelop dimensions and requirements for their mounting on locomotive.

FINAL DRAFT

ii. Complete sets of design documents for prototype of HPNGTL power block, cryogenic vessel, LNG conditioning system and all the equipments under tenderer scope of supply; list of products to be purchased; drafts of Operation Manuals (OM) including OM for associated hardware. The tenderer shall collaborate with RDSO during the process of this detailed design, and its approval. Safety measures considered in design of the Gas Turbine kit shall be intimated to IR.

iii. Based on the drawings, specifications etc. provided by the tenderer, IR will carry out underframe modification, long-hood structure modification, vehicle dynamics simulation and interfacing of the systems provided by the tenderer to the IR equipments in consultation with the tenderer. All test schemes will be worked out by RDSO in consultation with the tenderer.

iv. Tentative approvals of the designs furnished by the tenderer shall be done by RDSO. The tenderer shall provide all assistance to RDSO during the tentative approval process of their equipments. The tenderer shall undertake manufacture of the equipments under their scope of supply only after tentative approvals by RDSO.

Phase 2

i. Type testing of the equipments under the renderer's scope of supply at tenderer's works shall be conducted by the tenderer and witnessed by IR's representatives. Test scheme for the type tests for these equipments shall be furnished by the tenderer and approved by RDSO.

ii. Underframe will be provided by IR. Bogie fully equipped with traction motors, cables etc. will be supplied by IR. Matching of characteristics of traction motor and locomotive traction control system with Gas Turbine alternator and its fitment on G4 bogie will be devised by RDSO in consultation with the successful tenderer.

iii. Locomotive control system and the Traction control system with AC:AC drive will be provided by IR. Current and voltage from the Gas Turbine alternator will be conditioned by the Locomotive Control System so that the same is suitable for feeding into the Traction motors of the locomotive.

iv. The successful tenderer shall provide full details of the POWER BLOCK CONTROL SYSTEM WITH DIAGNOSTICS so that the same can be interfaced by RDSO. The interfacing will be devised by RDSO in consultation with the control team of the successful tenderer.

v. Computer controlled braking system, driver safety system, cab air-conditioning system and the driver communication system will be provided by IR.

vi. Fitment of the gas turbine kit and accessories on underframe and fitment of all required parts on the locomotive will be done by IR in consultation with the tenderer. For this purpose,

FINAL DRAFT

requirements of any special infrastructure to be provided by IR must be clearly spelt out by the tenderer in their offer.

Phase 3

i. Load box testing of the locomotive fitted with gas turbine kit and accessories shall be done by Indian Railways jointly with the tenderer representatives. During load box testing, performance of various equipments supplied by the tenderer after fitment on the locomotive shall be verified. For this purpose, the tenderer should make available relevant measuring equipments for measuring the performance parameters of the equipments supplied by them. Test schedule for the load box testing shall be framed by RDSO in consultation with the successful tenderer.

ii. After the load box testing of the gas turbine kit fitted locomotive is successful, the locomotive shall be sent for field trials for a period of six months. Test schedule will be developed by IR in consultation with the tenderer. Tenderer shall be associated during the field trials and provide support and solutions during the field trials of the HPNGTL. Tenderer's support will include expertise, materials, manpower etc.

iii. Operation and maintenance support for running of locomotive shall be provided by the tenderer for initial two (02) years of the warranty period.

iv. Operational, technical and maintenance support shall be provided by the tenderer for the gas turbine kit and accessories supplied by them during the normative life of the locomotive fitted with the gas turbine kit. Tenderer should indicate their willingness to support serial production of HPNGTL as and when the Ministry of Railways, Government of India decides to take up serial production.

4. SYSTEMS REQUIRED

4.1. The offered system and corresponding subsystems shall be designed to comply with the latest relevant International standards satisfying all design/simulation criteria/safety and operational requirements. These shall be listed by the tenderer in their offer.

4.2. HPNGTL for Indian Railways shall generally be equipped with following subsystems like: Gas Turbine Engine (GTE), LNG carrier vaporizer (LNG conditioning system), power block control system (for GT, traction motors generator and LNG carrier vaporizer (LNG conditioning system)), air intake system, exhaust duct and its noise suppression system, GTE air cooling system and GTE and generator bearings lubrication system, AC generator, GTE and generator oil cooling system, intake air purification system are to be developed for gas turbine locomotives for IR. The features of these sub system should preferably be in line with, as indicated in brief, in following paragraphs.

4.2.1. Gas Turbine Engine (GTE)

1. Capable of delivering 8.3 MW of power output under ISO conditions.

FINAL DRAFT

2. Indicative GTE efficiency of 30% at full load under ISO conditions. Indicative Maximum fuel flow at idling under ISO conditions less than 20% of fuel flow at full power.
3. Gas turbine should have electric start system facility.
4. Monitoring and diagnostic system (sensors) of GTE should be integral with power block control system.
5. Gas turbine structure should have provision of inspection holes for facilitating visual inspection of gas air duct and to facilitate easy accessibility of routine maintenance parts.
6. GTE should be having inlet air purification device, inlet device, low pressure axial compressor and high pressure compressor, combustion chamber, a high pressure turbine, low pressure turbine, a turbine support and a power turbine, heat exchanger, exhaust device and blow off circuit.

4.2.2. LNG Carrier

Size of the LNG tank with required accessories should be designed to suit the long hood of WDG4 locomotive under frame. It should be within Maximum Moving Dimensions (MMD) listed at annexure 1. Locomotive should be capable to give a lead of 800 Km with full tank.

4.2.2 LNG conditioning system

The system should be able to convert LNG to natural gas (NG) and provide complete gas vaporization with preliminary LNG conditioning i.e. provision of NG required composition (purity), temperature and pressure at all operating points as well as at GTE starting.

4.2.3 Air intake system

Inlet Air purification system should be designed as independent part of the power unit. This system should be designed to purify air as per engine need. Engine continuous operations to be ensured in case of marginal filter clogging. Air inlet helix lemniscates and the helix itself to be designed of very light material for reduction in weight.

4.2.4 Exhaust duct and Exhaust duct noise suppression system

Exhaust and exhaust duct noise suppression system should be designed for providing exhaust gases smooth deceleration and suppressing exhaust noise so that the level of a locomotive external noise does not exceed the required values. Design should take into account that its profile should not adversely affect the effectiveness of power unit. Exhaust system design should also include a heat exchanger for gasification of LNG. The locomotive shall be designed that noise level should comply US standard 40 CFR part 201. The exhaust gas temperature measured at 1 m distance from exhaust grid not to exceed 300 ^{0}C in all operating conditions.

4.2.5 Power unit diagnostic and control system

Power unit control system is should be microprocessor based and should provide control of GTE, traction motors generator and LNG conditioning system. Design should provide regulation of GTE assigned operating conditions and limiting of the critical parameters according to rotor speeds and

FINAL DRAFT

turbine gas temperature. The system should provide diagnostics and protection of the equipment to be controlled. The system should receive commands from locomotive control system and transmit to it information about GTE condition in real time through communication line. Tenderer shall provide the interfacing details of the power block control system along with the communication protocol to RDSO. Interfacing will be done by RDSO in joint collaboration with tenderer.

4.2.6 GTE Air cooling system and Oil system of gas turbine and generator bearings

A blow off circuit should be suitably designed for preventing excessive air heating in GTE high temperature stator parts. Suitable engine oil cooling system to be designed for cooling and lubrication of bearings, gearings and contact seals in assemblies of rotor supports and accessory gear boxes at all engine power settings. Suitable capacity Oil tank should be located on under frame. Oil should be cooled by using cooling capacity of cryogenic fuel gas. Oil cooling system for cooling and lubrication of generator journal bearings should also be designed with appropriate pumping mechanism. Suitable capacity oil tank should be suitably located on under frame for this purpose.

4.2.7 Alternator

Generator should be capable of delivering 8.15 MW (on generator terminals) under ISO conditions. Voltage and current values of Alternator are to be matched with operating modes of traction converters (transducers). Alternator should be mechanically coupled with GTE and foot mounted. The proposed alternator shall be capable of matching with gas turbine output at different notch positions to deliver the output as per requirement. Alternator should be so designed to have high reliability and be safe in operation.

5. TECHNICAL REQUIREMENTS

i. Power output of gas turbine should be 8.3 MW or higher.

ii. Maximum operating speed of the locomotive shall be 110 kmph and the trial speed shall be 120 kmph with new wheel of 1092mm.

iii. Overall dimensions of the locomotive shall be within the maximum moving dimensions for BG rolling stock in India.(Enclosed in the specification at Annexure-1)

iv. The gas turbine kit and accessories supplied by the tenderer should be such that the maximum axle load of the locomotive should preferably not exceed 20.32 t after taking into account the equipments to be provided by IR.

v. The existing track condition and site condition of Indian Railways is attached at Annexure-2.

FINAL DRAFT

6. GENERAL REQUIREMENT

i. Specific fuel consumption engine notch-wise and characteristics curves of gas turbine engine shall be provided by the tenderer to RDSO for evaluation of engine performance. It is also necessary to indicate output shaft speed (in revolutions per minute) at which useful service output is developed.

ii. Experimental emission data at all notches and different load and rpm obtained at their test bed shall be provided by the tenderer to RDSO. Gas turbine offered by the tenderer should at least comply with US EPA tier 1 emission standards.

iii. Various Maintenance schedules of all equipments supplied by the tenderer shall be furnished. Normative life of various equipments shall also be specified. Details of special tools and jigs/ fixtures required if any, for the maintenance of the Gas turbine locomotive shall also be submitted.

iv. Transmission coupling between 'turbine engine' and 'alternator' should be rigid and capable to transmit the rotational torque with minimum transmission loss. Allowable limits of radial, axial and angular displacements of shafts of transmission coupling shall be furnished to RDSO for approval.

v. Tenderer shall disclose the safety norms incorporated / considered for design of LNG carrier and GTE. Major safety features of the LNG bullet and GTE shall be clearly brought out in the tender. The tenderer shall follow the relevant and globally accepted safety norm in designing and manufacturing of offered equipments.

vi. Break-up of the power absorbed by auxiliary machines shall be furnished in the tender. Design should be such that maximum utilization of traction power from Traction Alternator could be used for traction application.

vii. 'Lubrication oil system' for Gas turbine engine and for other major equipments shall be indicated in the tender. The system should include the information like capacity of lubrication circuit, dissipation of heat power by lubricating oil and lubricating oil temperature at rated output, oil pressure, power consumption etc.

7. FUEL FOR GAS TURBINE ENGINE

The fuel to be supplied for fuelling of HPNGTL locomotives shall be LNG. Chemical composition of the supplied fuel shall generally lie in range as indicated in table-1. Turbine combustor and associated piping and equipments etc. shall be so designed that these do not degrade by LNG and exhaust gases as applicable.

FINAL DRAFT

Table 1: Composition of LNG to be used as fuel for HPNGTL

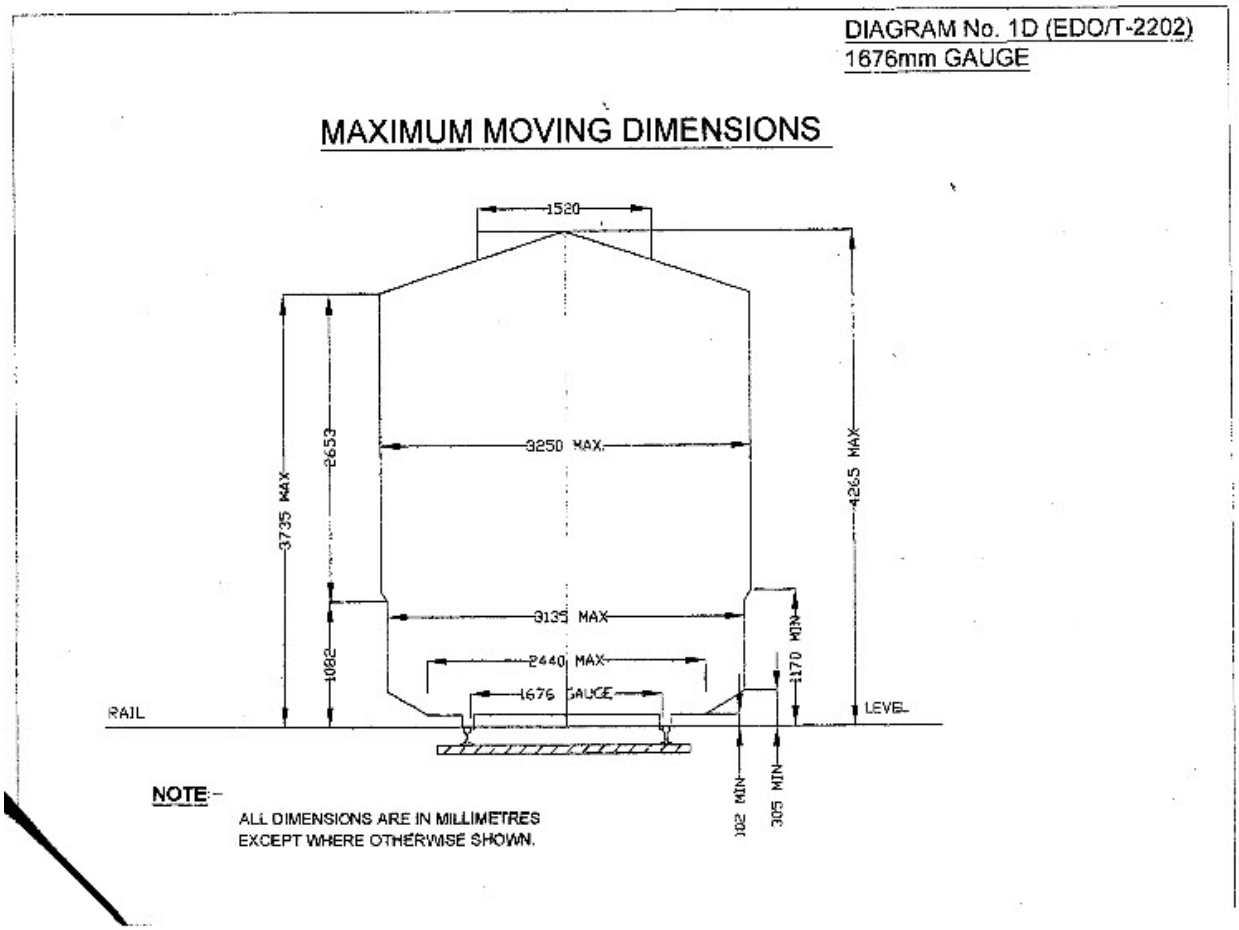
Sl.No.	COMPONENTS	LNG Composition Range (mole %)
1.	Methane	83 to 99
2.	Ethane	0.3 to 12.0
3.	Propane	0.2 to 3.6
4.	Iso Butane	0.1 to 1
5.	n-Butane	0 to 0.1
6.	N_2	0.03 to 1.40

8. List of Annexures

Annexure-1 MMD
Annexure-2 Existing track condition and site condition related to Indian Railways
Annexure-3 Technical data of traction motors

FINAL DRAFT

Annexure-1



Note: Dimension 3135 is under consideration to 3050.

FINAL

Annexure-2

1.0 REFERENCE FOR SITE CONDITION:

i) Ambient Temp. 50 ° C
iii) Inlet air temp. for traction motors 55 ° C max.
iv) Altitude 600 Meters

Rainfall: Very heavy in certain areas (100% saturation during Monsoon in certain areas). Atmosphere during hot weather: Extremely dusty and desert terrain in certain areas. The HPNGTL offered shall be designed to work in coastal areas in humid/salt laden atmosphere.

2.0 EXISTING TRACK CONDITION RELATED TO Indian Railways:

Vibrations and shocks**:** The offered TM is capable to withstand the vibrations and shocks in service are as below:

i) Max. Vertical acceleration - 2 g
ii) Max. Longitudinal acceleration - 3.5 g
iii) Max. Transverse acceleration - 1.5 g
('g' being acceleration due to gravity)

Track Parameters:

	Gauge Broad Gauge (BG)	1676 mm (nominal)
	Track structure	The track is to a standard of 60 kg, 90 UTS rails on Pre-stressed concrete sleepers of M+& (1660) density and minimum depth of ballast cushion below sleeper is 300 mm below the sleepers. Or 52 kg, 90 UTS rails on Pre-stressed concrete sleepers of M+& (1540) density and minimum depth of ballast cushion below sleeper is 250 mm depth below the sleepers.
	Sharpest curve	175 m radius. Vogel's layout or its internationally accepted equivalent for negotiability, throw over at head stock & coupler movement with details of clearances. (But for sharpest curve also available on Punalur-Seengottai Station of Madurai division is 145.83 m radius of Indian railways.)
	Turn out to be negotiated	A locomotive is checked for passage in both directions over standard BG 1 in 8.5 turnout. Vogel's layout or its internationally accepted equivalent for negotiability, throw over at head stock & coupler movement with details of clearances.
	Maximum Super elevation	185 mm (For permanent Structure) 165 mm (For Operation as per provision of IRPWM 2004)
	Maximum cant deficiency	100 mm

FINAL DRAFT

	Clearance above the rail level	The locomotive shall be so designed that no component shall infringe minimum clearance of 102 mm above rail level with the locomotive fully Loaded and wheels in fully worn condition.		
	Permissible track tolerances		BG Main Line	BG High Speed Route(C&M 1 Vol 1)
		Unevenness (3.6 m base)	< 10 mm (B Category) Or < 15 mm (C Category)	< 6 mm (A Category) Or < 10 mm (B Category)
		Twist (3.6 m base)	< 2.08 mm/meter (7.5 mm chart) (B Category) Or < 2.78 mm/meter (10.0 mm chart) (C Category) Or < 2.78 mm/meter (Above 10.0 mm chart) (D Category)	< 2.08 mm/meter (7.5 mm chart) (B Category) Or < 2.78 mm/meter (10.0 mm chart) (C Category)
		Gauge variation	<± 6 mm (B Category) Or < Above± 6 mm(C category)	<± 3 mm (A Category) Or <± 6 mm (B Category)
		Alignment (7.2m base)	>3mm≤5mm (B Category) Or >5mm (C Category)	>3mm≤5mm (B Category) Or >5mm (C Category)
		Gauge on curve On curves of > 350m radius On curves of < 350m radius	-5mm to +3mm Up to +10mm	

FINAL DRAFT

Annexure-3/1

Technical Data / Rating of the Traction motor used in WDG5 Locomotive governed by RDSO Specification No.MP.0.2400.72 (Rev-00), Sep-2010:

Sl.No	Parameter	Value
1.	Nominal stall torque (Nm)	10811
2.	Nominal continuous torque (Nm)	7960
3.	Maximum RMS VL-L (V)	1910
4.	Maximum (Continuous) RMS current (A)	267
5.	Input Electrical Power (kW)	645
6.	Maximum permissible over speed (rpm)	3320
7.	Circuit	Y
8.	Insulation dass (^{0}C)	200

Annexure-3/2

Technical Data / Rating of the Traction motor used in WAG9 Locomotive governed by CLW document No 4TMS.096.069 dated june-2008. :

Sl. No	Parameter	Rated Point	Maximum
1.	Stator Frequency (Hz)	65	132
2.	Motor Voltage (Phase to Phase) (V)	2180	2180
3.	Stator Current (A)	270	393
4.	Power Factor	0.88	---
5.	Torque (Nm)	6330	9200
6.	Power (kW)	850	850
7.	Motor Speed at shaft (rpm, minimum)	1284	2584

FINAL DRAFT