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GOVERNMENT OF INIDA
MINISTRY OF RAILWAYS

TECHNICAL SPECIFICATION

FOR

TRACTION GEAR AND PINIONS (GEAR RATIO 5.4)

FOR USE ON

WAG9 CLASS OF LOCOMOTIVES

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ISSUED BY

RESEARCH DESIGNS AND STANDARDS ORGANISATION
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TECHNICAL SPECIFICATION FOR TRACTION GEAR AND PINIONS (GEAR RATIO 5.4) FOR USE ON WAG9 CLASS OF LOCOMOTIVES.

1.0 FOREWORD

WAG9 class of 3 Phase Electric Freight locomotives were supplied by M/s ABB (subsequently acquired by M/s Bombardier Transportation) with gear ratio of 5.133 (77:15). In order to achieve higher tractive effort on loco wheels at starting, it has been decided to provide gear-pinions with increased gear ratio of 5.4 (approx.)

2.0 SCOPE

2.1 Through this specification, it is intended to specify performance requirements for the gear –pinion sets with high gear ratio (5.4). The manufacturer shall design and develop the gear-pinion set capable of delivering required torque. The manufacturer shall be free to choose the number of teeth in pinion and gear so as to get the optimum performance within the overall dimensional restrictions. No modification is envisaged in the traction motor shaft, locomotive axle, gear case or any other equipment. In exceptional cases, however, slight changes in gear case dimensions may be considered if found feasible in overall mounting arrangement.

2.2 Following shall be the scope of work:

- Design and development of gear and pinion as per performance requirements given vide clause 6 of this specification.
- Submission of complete design to RDSO and getting design approval.
- Manufacturing of prototype gear-pinion sets.
- Prototype tests along with RDSO and CLW.
- Association with CLW for fitment of prototype sets.
- Bulk production of the balance ordered quantity after clearance of prototype.
- Association with RDSO, CLW and Railways for performance monitoring.
- Replacement and investigations in case of warranty failures

2.3 After approval of the design of successful tenderer, by RDSO, all the drawings and design documents submitted to RDSO by the firm shall become the property of RDSO

3. STANDARDS TO BE FOLLOWED

DIN 17210 Case hardened steels (Technical delivery condition).

DIN-867 Concepts and parameters associated with cylindrical gears and

DIN-3960 Cylindrical gear pairs with involute teeth.

DIN-3962 Tolerance for cylindrical gear teeth

DIN-3963 Tolerance for cylindrical gear teeth (tolerance for working deviations)

DIN-3967 System of gear fits: Backlash/tooth thickness allowances/Tooth thickness tolerances (Principles)

IEC-61373 Vibration and shocks in rolling stocks.

IEC-77 Requirements of equipment for use in Rail Vehicles.

4 QUALIFICATION CRITERIA

The tenderer must have in-house design, development, manufacturing, testing facilities and capability with adequate experience for such gear/pinion for traction rolling stock application of specified power capability. This must be substantiated in tender by way of attaching necessary documents. Tenderers not having adequate competence in this field will not be considered.

5 CLIMATIC AND ENVIRONMENT CONDITIONS

5.1 Maximum atmospheric temperature :

Under sun $70^{o}C$
Under shed $50^{o}C$

5.2 Humidity : 100% saturation during rainy season.

5.3 Reference site conditions :

Ambient temp.	$0^{o}C$ min., $50^{o}C$ Max.
Humidity	60%
Altitude	160m above mean sea level.

5.4 Rain fall : Very heavy in certain area.

5.5 Atmosphere during hot weather : Extremely dusty and desert terrain in certain areas.

5.6 Coastal Area : Humid and salt laden atmosphere. Gear & Pinion will be designed to work in coastal area.

5.7 Vibration: The gears and pinions and their mounting arrangement shall be designed to withstand vibrations and shocks encountered in service as specified in IEC 61373 and IEC-77 publication unless otherwise prescribed.

6 PERFORMANCE REQUIREMENTS

The gear-pinion set shall be designed to meet the following requirements of performance:

6.1 Gear Ratio: The gear pinion set shall have gear ratio of 5.4± 0.02

6.2 Maximum Torque at start : 10500 N-m on each Traction Motor.

6.3 Centre distance between gear and pinion: 464 mm.

6.4 Duty Cycle : Locomotive working in adverse terrain has to negotiate longer period at lower speeds. The typical duty cycle encountered in operation would be as given below:

Speed in Km/h	% of total running time of Locomotive	Tractive effort (KN)
0-10	5	>500
10-30	10	450
30-60	20	350
60-80	50	230
80-100	15	180

Duration of slow speed operation at 15 KMPH or less with fully applied TE – Not less than 30 min.

6.5 Gear Oil to be used : Presently Klubersynth GH-6 220 oil is being used. An indigenous alternative of this oil having equivalent properties and viscosity values of 430 cst and 45 cst at 40°C and 100°C respectively may also be used in future. Characteristics of Klubersynth GH-6 220 are given in **Annexure- 1**.

6.6 Accuracy Class: The gears and pinion shall conform to accuracy class 6 of DIN-3962.

6.7 The pinion shall be of plug-in type design. The plug profile should match corresponding traction motor shaft dimension. Drawing No. – 3EHM 112015

6.8 "There should be no appreciable wear on pinion-gear after3 lakh kMs of service in average working conditions of the Locomotives".

7.0 DRIVE SYSTEM DETAILS

The relevant details of the existing drive system of WAG9 class of locomotives are furnished below for reference:

7.1 Type of wheel arrangement : Co-Co Document No. 3EHP620083 pertaining to Locomotive data.

7.2 Total mass of Locomotive: 123 ± 1% Tonne.

7.3 No. of Axles :6

7.4 Wheel diameter : New 1092 mm
Half worn : 1054 mm
Fully worn : 1016 mm.

7.5 Axle Load: 20.5 ± 2% Tonne.

7.6 Max Service Speed: 100 KMPH

7.7 Traction Motor Type: 6FRA 6068- Three phase asynchronous. See document – 3EHP620083 pertaining to traction motor data.

7.8 Traction Motor mounting : Axle hung nose suspended.

7.9 Traction Motor shaft output : 850 kW

7.10 Traction Motor max speed : 2584 rpm.

7.10 Traction motor nominal speed : 1280 rpm

7.11 Total power of Locomotive : 6000 HP

7.12 Drive assembly drawing of WAG9 Locomotive with 77/15 gear ratio : Drg. No. 1BO11-00267 Rev-6.

7.13 Tractive Effort V/s Speed : Document No. HBTB4907727

7.14 Gear Case of existing WAG9 Loco: ABB drawing no. 1B 011-00226.

7.15 The copies of the documents and drawings mentioned in this section can be obtained from CLW/Chittaranjan.

8 MATERIAL

8.1 Gears and pinions shall be manufactured from forging quality steel in accordance with DIN 17210.

8.2 Chemical composition and physical properties : The gears and pinions shall be manufactured from the material conforming to specification No. DIN 17210, Grade 17Cr Ni MO6. Use of alternate material if proposed ,should be clearly specified in the tender offer for scrutiny and shall have prior approval of RDSO. The tenderer shall have to submit physical and chemical properties of proposed material along with comparison with specified material and governing specification.

9 MANUFACTURING PROCESS

9.1 The bores of the gear and pinion shall be ground finished before finish grinding the teeth.

9.2 The surface texture of the bores of gear and pinion shall not be coarser than the values specified in the relevant ABB drawings pertaining to original gear/pinion supplied in WAG9 Locomotives.

9.3 All machined gears and pinions should be suitably heat-treated to achieve the physical properties for the core as specified in the relevant material specification.

9.4 Depth of heat treated gears and pinions : For checking the case depth, one `spy-piece' shall be provided per container when box carburising and at least one but preferably two (towards top and bottom of furnace) when case carburising. The spy piece shall be of section, which adequately simulates that of the teeth, which it represents and shall be placed near to but not on the gear teeth. The `spy piece' shall be of the same material from which the gears are made.

9.5 After carburising, the spy piece shall be hardened and tempered along with the gears it represents, and then broken. Hardness survey of the case shall be carried out after grinding and polishing as per IS:6416.

9.6 Tenderer proposing to use any alternative method should clearly specify so in tender offer giving details for scrutiny and prior approval of RDSO.

9.7 Micro Examination : At least one `spy piece' per carburising batch shall be microscopically examined for establishing absence of cementite net work or free cementite etc. in the carburised case. Retained austenite content of 15% - 30% may be permitted in the carburised case. Any alternative method may be adopted only with the prior approval of the purchaser.

10 TEST SCHEDULE

10.0 This section specifies certain tests which have to be necessarily included in the test schedule for type testing of the products.

10.1 The following tests shall be conducted at the works of the gear manufacturer or in approved test house at manufacturer's cost on the test sample selected for this purpose. At least one sample per cast shall be subjected to the following tests.

10.1.1 Ultimate tensile strength

10.1.2 Yield stress

10.1.3 Elongation percentage.

10.1.4 Impact strength

10.1.5 The test procedure and result shall conform to the relevant material specification. The results so obtained shall be produced to RDSO for approval.

10.2 Test Samples :

10.2.1 A sample from a bloom of relevant cast selected at random shall be first forged down to ¼ of the original section and then a test bar of diameter as per relevant specification shall be turned from the forging. Any alternative method may be used only with prior approval of RDSO.

10.2.2 This test bar shall then be heat treated along with the gear /pinion of the same case as indicated in Clause 9.0 and then the test piece machined. It shall carry the following markings of identifications:

- Steel used
- The cast number.

10.3 Chemical composition :

One test sample, per cast, shall be chosen for this test. The cuttings from the samples used for testing the physical properties, can also be used for determining chemical analysis as per IS:228. Any other standard used for this purpose shall be furnished to RDSO for approval of the test method.

10.4 Test on rough forged gear/ blanks :

All forged blanks, before any machining is performed on them, shall be tested ultrasonically for ensuring freedom from casting and forging defects.

10.5 Test on finished gears/ pinions :

The hardened teeth of all gears, after appropriate heat treatment, shall be tested for surface hardness. The hardness shall be measured at four equidistant points in the proximity of the root circle of the teeth. The average value of four readings shall conform to the values specified in design. The variation between the maximum and minimum values shall not exceed 20 points HV or a value agreed between the supplier and the purchaser.

10.6 Crack Detection :

All the gears and pinions shall be subjected to crack detection by suitable method such as magnetic method, dye-penetrant method or fluorescent test after heat-treatment. If considered necessary, ultrasonic testing can also be employed to check any internal cracks in the finished gears.

11 **TEST PLAN**

11.1 The manufacturer shall furnish a test plan for type tests, including all above tests and any other routine tests considered necessary by them, for the approval of RDSO along with their tender offer. The inspecting officer shall inspect the gear and pinion at various stages of manufacture for conformity with specification as well as in the finished condition before authorising delivery. However, this authorisation does not relieve the supplier of his liability with respect to the imperfections which may appear subsequently.

11.2 The type test protocol shall entail verification of various parameters defined in normative standards, this specification and those used in the design. The draft test protocol shall be submitted by the manufacturer, which will be mutually discussed and approved by RDSO.

11.3 The geometry of the plug-in pinion shaft is of vital importance. The manufacturer shall make/provide suitable gauge to check accuracy of pinion shaft profile to the required standard during testing of the finished product at Acceptance test stage. For the information of the manufacturer, this geometry is presently being checked with a gauge No. 092-9850026 of M/s Kaeible – Gmeinders, Anton-Gmeinderstrable 3, D-6950 Mosbach, Germany. The supplier shall consider use of similar gauge for the tests and measurements.

11.4 The manufacturer has to prepare proper jig to measure the backlash of matched gear and pinion at Acceptance test stage. Presently, jigs of type ABB's Drg. No. IB011-00269 for Pinion and ABB's Drg. No. IB011-00270 for Gear are being used.

11.5 The ultrasonic test specification proposed for gear/pinion is provided at **Annexure-2**.

11.6 The intention of these tests mentioned in the test plan is to ensure conformance of various parameters of raw materials, stage processes as defined in the listed normative standards and values used for the design. Besides above, RDSO and/or CLW may inspect any intermediate stage processes, duly informing such intention reasonably in advance.

12. **Life Cycle Costing Details** :

The entire design of the gear and pinion shall be based on achieving maximum life from the equipment while delivering the required performance. In order to get an assessment of life cycle costs, the tenderer shall supply following details on Life Cycle Costing of gear and pinion sets.

(a) Initial cost (inclusive of all taxes).
(b) Operating cost :
- Cost of lubrication per 1000 Km
(c) Expected life in Km. of pinion and gear upto reaching quality R-12 condition.
(d) Disposal cost less residual/scrap value.

13 **DOCUMENTS TO BE FURNISHED**

13.1 The tenderer shall submit Clause-by-clause compliance of this technical specification alongwith the offer document. Statements like "noted" will not be treated as compliance. The tenderer has to explicitly write "complied" or "not complied" with narration where applicable.

13.2 The following documents shall be submitted along with the tender document :

13.2.1 Life Cycle Costing details as per clause 12.

13.2.2 Design calculation for arriving at the gear ratio.

13.2.3 Raw material specification

13.2.4 Process Specifications.

13.2.5 Safety margins at worst case

13.2.6 Quality Assurance Plan for manufacturing gear and pinions.

13.3 The successful tenderer shall submit the following documents to RDSO for design clearance:

13.3.1 Dimensional drawings.

13.3.2 Detailed design calculations for arriving at the dimensions proposed.

13.3.3 FEM Analysis result.

13.3.4 Proposed inspection/overhaul/replacement schedule

13.3.5 Reliability giving expected life and expected wear rate during normal operation as per duty cycle , Clause No. 6.4.

13.4 Documents/Tests to be submitted after design approval but during production:

13.4.1 Metallurgical test certificate of raw materials as defined in the relevant clauses of this specification. RDSO representative shall witness such tests.

13.4.2 Stage inspection certificates as defined in this specification at relevant clause. RDSO/CLW representative shall witness the same.

14 PROTECTION AND PACKING

14.1 The gears/pinions shall be suitably protected against oxidation and corrosion by three coats of ready mixed paint, brushing Bitumins black to IS:158 (Specification for ready mixed paint, brushing, Bitumenous, black, lead free, acid, alkali, water and heat resisting for general purpose) or with any other approved anti-rust compound capable of being removed easily by white spirit or kerosene oil allowing sufficient drying time between each coat. After the last coat has dried, the gear/pinion shall be covered with waterproof paper. The gear/pinions shall then be suitably placed to prevent any damage during transport and handling. Any alternative method may be used by the manufacturer only with prior approval of RDSO.

Encl: Annexure- 1 & 2

Annexure-I

Properties of synthetic gear oil Klubersynth GH6 220

S.No.	Properties	Klubersynth GH6 220
1.	Appearance	Clear & Bright
2.	ASTM color	1.5
3.	Kinemetic viscosity @ 40°C.cst	221.50
4.	Kinematic viscosity @ 100°C.cst	38.58
5.	Viscosity Index	227
6.	TAN mg KOH/gm	0.74
7.	Pour point, °C	-33
8.	Flash Point, °C	288
9.	Sp Gravity	1.05
10.	Cu Corrosion, 121 °C/3hr	IA
11.	Rust test D665(A)	Pass
12.	Gear Oil Oxidation Test: ASTM D2893 - % KV change @ 100 °C - Precipitation number D-91	 4.6 Nil
13.	- Weld Load Kg - Wear Scar Dia, mm @ 40kg, 1800rpm, 54 °C 1hr.	200 0.60

ANNEXURE-2

TENTATIVE STANDARD FOR ULTRASONIC TESTING AND ACCEPTANCE OF TRACTION GEARS AND PINIONS

1.0 Gears/ Pinion forging shall be tested ultrasonically for soundness from one of the two sides (flat) faces. In case of gears, the scanning could be restricted to the film position, the scanning shall be done with a 2/2.5 MHz, 25 mm dia probe. The ultrasonic test unit used shall be either Krauntkramer `USIP 10' or another instrument of similar or improved characteristics.

2.0 The range shall be so adjusted that the back echo from the opposite face for a particular size of gear/ pinion under test shall occur at the extreme end of screen and its amplitude shall be approx. 75% of the full screen height. With this setting, the scanning shall be done by moving the probe circumferentially. In case the radial thickness of the rim of the gear and that of the pinion is considerable, the scanning may be done following multiple concentric paths separated by one probe position.

3.0 Criteria for Acceptance/ Rejection :

3.1 Any flaw indication, the amplitude of which is greater than 25% of that of back echo obtained from an adjacent location, shall be rejected.

3.2 Flaw indication, the amplitude of which are less than 25% of back echo, obtained from adjacent location may be accepted provided the back echo at that location is not less than 80% of the original and the total no. of such flaw indications obtained on that gear/ pinion is less than 5 and each flaw is separated from the other by more than 125 mm distance. Where there is a continuous flaw indication, the spread of the flaw shall not cover more than one probe position in any direction. Where such indications are obtained, scanning shall be done in all radial directions at that location to verify the spread of flaw.

3.3 Where there is a flaw indication in the first quarter of the usable length of the trace, the same shall be confirmed by a scan from the opposite face.

3.4 Where the back echo is reduced to less than 80% of the original, the gear/ pinion shall be rejected.
