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TECHNICAL SPECIFICATION OF RADIATOR COOLING FAN ASSEMBLY FOR WDG5 (5500HP) LOCOMOTIVE

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TECHNICAL SPECIFICATION OF RADIATOR COOLING FAN ASSEMBLY FOR WDG5 (5500HP) LOCOMOTIVE

0.1 SCOPE

This specification covers the technical requirements of design, manufacturing, testing and supply of complete 54" dia. radiator cooling fan and AC motor assembly to be used on 5500HP EMD locomotives.

This specification has been divided into two sections. Details of Items/equipment are covered in section – 1 and list of tests to be conducted is in Section – 2.

This specification shall be read along with the RDSO's Schedule of Technical Requirement (STR) no. MP.STR.EM.02.02.10 (September, 2010) to determine the qualification criterion (Infrastructure, manufacturing/testing facilities etc.) of the manufacturers who offer their Radiator Cooling Fan & Motor for WDG5 Locomotives.

0.2 TERMS AND DEFINITIONS

Fan: Assembly of motor, frame and the hub and blade assembly.

Hub: Cast aluminum support structure for the fan blades. It houses rotor in radiator cooling fans (inside-out AC motor design).

Blade: Bolt on airfoil blade. Blades bolted to the fan hub.

Hub/Blade Assembly: Machined and balanced assembly of the hub, blades.

Fan Frame: Supporting structure for the motor. May contain inlet shrouds, outlet diffusers, guards, guide vanes and electrical conduits. Frame bolts to the locomotive structure.

Motor: AC 3-phase motor to drive the hub and blade assembly. The motor parts (rotor core) may be integral with the hub.

Similar Product: Similar product implies a fan and motor assembly of similar design & rating and used on locomotive application.

Purchaser: Means Indian Railways / RDSO.

0.3 SYSTEM DESCRIPTION:

In the Locomotive, water shall act as coolant. The water temperature shall be controlled by means of radiator banks and AC motor-driven cooling fans. The radiators shall be located in a hatch at the top of the long hood end of the locomotive. Two inverter driven AC motors with 54" cooling fans shall be located below (cold side) the radiator assemblies in loco's long hood carbody structure and the air movement shall be in the upward direction.

The convertor which shall act as a drive for radiator fan motor shall be a combination of Rectifier and Inverter. Input to convertor shall be from companion alternator.

Temperature probes shall be mounted at the engine water pump inlets to provide engine coolant temperature information to the loco control computer. The computer shall control

engine coolant temperature by controlling the speed of each of the two radiator cooling fan motors. For this, the power output of inverter shall be controlled by controlling the firing signals to Inverter's semiconductor devices.

The system shall maintain the coolant temperature within a predetermined range from 79º C to 85º C. As the water temperature rises and exceeds the operating range lower limit, the fans shall be energized by the control computer. As cooling requirement increases with rise in coolant temperature, the fans shall speed up smoothly to full speed. As coolant temperature drops, the speed of fans shall also reduce accordingly and finally get switched off one at a time as coolant temperature goes below the lower limit of the operating temperature range.

The motors shall be inverted squirrel cage induction type and shall be an integral part of the cooling fan assembly. The term "inverted" indicates that they differ from the conventional squirrel cage motor in that the rotor is located outside the stator. Two 54" cooling fans shall be located in the long hood under the radiators and blow the cooling air upwards through the radiator cores. The fan and motor assemblies shall be equipped with suitable numbers of blades as per requirement to meet this specification.

0.4 SCOPE OF SUPPLY

Scope of supply covers complete Radiator Cooling Fan and Motor Assembly including motor and fan blades.

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SECTION – 1

1.0 MOUNTING REQUIREMENTS

1.1 The fan orientation and direction of air flow shall be in the vertical direction through the radiators.

1.2 The drawing of 54" radiator fan showing outer dimension, mounting arrangement and location of mounting holes is placed at **Annexure - III**.

The drawing has been provided to define the approximate envelope dimensions as well as to define the dimensions that specify the mounting of the assembly on the locomotive hood. This is essentially to ensure that all makes of fans are interchangeable as a complete assembly. The dimensions that are internal to the assembly and do not have any interface with the loco or do not have bearing on the MMD can differ. The successful tenderer must submit an outline drawing with critical dimensions for approval of RDSO/purchaser.

2.0 OPERATING REQUIREMENTS- ENVIRONMENTAL CONDITIONS:

2.1 Fan Air Temperature

The ultimate criterion is to meet the Engine System standard of 99 °C water out of the engine at 50°C ambient at full rated engine load. The design ambient air temperature range is -40°C to 66°C for cold side fan applications. The fan assembly shall be capable of withstanding excursions to 66°C for duration's up to 1-hour in length.

2.2 Altitude Operation, Barometer, Air Density and Humidity

2.2.1 Fans may be operated on locomotives from sea level to 11000 ft and barometer readings from 20 in-Hg. to 30 in-Hg. The air density may vary between 0.048 lb/ft3 to 0.095 lb/ft3. Nominal air density is 0.070 lb/ft3. The humidity range shall be 0 to 100%.

2.3 Contaminant/Chemical Compatibility

2.3.1 Throughout its service life, the fan may be exposed to direct sunlight, rain, snow, ice, salt, diesel exhaust, oil, coal dust, brake shoe dust, sand and other contaminants. Fan life goals shall not be compromised due to exposure to these elements.

2.3.2 Fans may also be subjected to contact with a variety of fluids and chemicals during its service life on the locomotive. Fan assemblies and components must be able to withstand contact with common locomotive fluids without degradation to the mechanical, structural or electrical integrity as specified herein.

2.3.3 The motor shall be subject to normal locomotive vibration as per the attached "3G" vibration curve at **Annexure-IV**.

3.0 FAN ASSEMBLIES- PHYSICAL REQUIREMENTS & PRODUCT PERFORMANCE

3.1 Fan assemblies are to be qualified via an approved Reliability Growth Testing plan laid out by the fan supplier and approved by RDSO. See section 7.9 of this specification for more details. RGT testing on similar products at the same static pressure and RPM can also be submitted in place of testing.

3.2 Space Allocation: Fans shall be so designed that both the fans fit within the following dimension:

Length: 180”
Width: 70”
Depth: 26”

3.3 Clearance Restrictions: The maximum fan height allowed on hood-mounted fans must not exceed Indian Railway’s MMD restrictions. The fan height is measured from the mounting surface to the topmost point on the fan and guard assembly. MMD drawing is attached at **Annexure – V**

3.4 Weight Restriction: Weight of the proposed 54” cooling fan shall not exceed 1600 Lbs. Any deviation from specified maximum weight shall require approval by RDSO. Weight can be negotiable when all other factors are considered like – cost, performance, delivery, etc. The weight of the rotor and stator shall be specified on component drawings

3.5 Shock Loads & Vibrations

The following structural loads must be sustained by fans without causing any other non-structural damage that would impair the fans operation.

3.5.1 Shock Loads Fan : Assembly shall be designed to withstand +500 and -500 triangular or half sine wave shaped, mechanical shock pulse of 3G (for 25 msec or less in duration) in both directions in each plane (total no. of shocks shall be 3000 in all three planes) while installed in mounting scheme dictated by the application.

3.5.2 Yield Stress for Component Design

Yield Stress loads:	Radial	3 g
	Vertical	1g

Acceptance Criteria: All stresses must be below the minimum guaranteed yield stress of the material.

3.5.3 Fatigue Stress for Component Design

Fatigue Stress loads:	Radial	+/- 0.6g
	Vertical	1g (+/- 0.4g)

Acceptance Criteria: No predicted fatigue crack initiation observed at 10 million cycles.

3.5.4 Component Vibration

All components must be fully functional during and after an eight (8) hour shaking test at each identified resonances in any directions. The following acceptance criteria apply for component vibration at these conditions:

+/- 2g running between 0 and 37.5 Hz
+/- 1g running between 37.5 and 127 Hz

It should be noted that blade pass frequencies and their effects on the fan assembly should always be considered when designing and testing new fan models to avoid exciting a structural resonance in the

fan assembly. If FEA results are higher than yield, when subjected to the above requirements then a functional test is required. If the FEA results are lower than yield, when subjected to the above requirements, then no functional test is required.

3.6 Hub and Blade Assembly

3.6.1 The blades, hub and supporting structure must be designed to withstand indefinite operation throughout the entire fan speed range and life of the fan. Design factors to be considered during the design and analysis of cooling fan components and assemblies should include, but are not limited to aerodynamic forces, air flow loads and centrifugal loads as well as the structural loads of the fan and fan structure.

3.6.2 Cooling fan blades must meet the following:

(a) Fans shall be made of cast aluminium to EMD specification no. EDPS-175 or superior.

(b) Aerodynamic: This requirement shall be fulfilled by the adherence to drawing dimensioning.

(c) Structural Reliability: The fan blade is a critical rotating part and should be over sped to identify safe operating speeds up to at least 20% over maximum operating speed without sustaining structural, mechanical or electrical damage. The over speed time may be mutually decided between supplier and the purchaser/RDSO. From reliability point of view, the fan be subjected to 10 cycles to over speed RPM stated above and dwell there for 1-minute each time. No fatigue failures are expected and no cracks in blade prior to fan assembly, will be accepted. The fan must be within the mechanical yield criteria at these over speed conditions.

Strain Gauge validation: Validation testing of the design and FEA analysis of the blades, hub, frame and structure via strain gauge testing is to be performed and results shall be submitted to RDSO. FEA results or similar products tested at the same or higher RPM is acceptable data to submit.

(d) Blade Internal Quality: This shall be such that the cast surface is intact with no porosity or other internal defects visible. Porosity exposed by machining of the spot faced mounting holes is to be limited to a maximum of 1/16 inch dia. and 1/16 inch deep for individual pits and any two consecutive pits shall not be closer than 2 inches.

(e) Blade Surface Quality: No grinding, sanding or other material removing methods shall be used to blend or remove surface defects. For salvage purposes only surface treatment methods specially agreed upon by RDSO will be permitted.

The overall cast blade surface shall be smooth and free of defects such as:

- Roughness from checks or cracks in mold
- Incomplete fill
- Cold Shuts
- Scab patches
- Sinkage
- Shrink cracks, hot cracks, cracks of any nature

(f) Blade Pass Frequency: Blade Pass Frequency and their effects on the fan assembly shall be considered during design and test to avoid exciting structural resonance in the

fan assembly. The supplier is responsible for determining the fan blade critical speeds to ensure that such speeds do not directly coincide with the engine throttle notch positions/speeds outlined in **Annexure - I**. Fundamental local natural frequencies should not coincide with excitation frequencies. Modal analysis is acceptable to determine the natural frequencies.

(g) Qualification of the blade manufacturing procedure is to be established and maintained by periodic evaluation (at the interval of every 3 years) of individual fan blade structure.

It will consist of:

- X-ray examination to level one (1) as per ASTME 155.
- Bending test with blade base secured and design force applied normal to a plane including the blade axis and blade root cord.
- Sectioning and examination of the blade root area.
- Dye penetrate check over entire blade with emphasis on examination of blade root area for cracks, cold shuts or other defects.

3.7 Fan frame

3.7.1 The fan frame will bear the load of the drive system of the fan.

3.7.2 Fan assemblies will be lifted on and off locomotive structures with the use of an overhead crane along with lifting chains or Sings, hooks and/or lifting fixtures. The fan should be structurally designed with this in mind. Provisions will be made on for lifting points.

3.7.3 Fan frames must have an identification name plate applied in a visible location around the fan frame ring. Nameplate shall be stamped with the Make, fan assembly Part number, identifying Serial Number, Month & Year of Manufacturing, of that particular fan assembly. The nameplate will be riveted to the fan frame ring. The rating plate on the motor must indicate the serial number, designed HP, voltage range and frequency range of operation, Rated RPM, insulation class, resistance.

3.7.4 Mechanical & Electrical Interface: Fan mechanical as well as electrical interfaces to be supplied via layout drawings by the supplier.

4.0 PRODUCT PERFORMANCE REQUIREMENTS

4.1 Electrical Requirements- Winding Insulation

4.1.1 The insulation shall be class H or better.

4.1.2 The insulation system shall have sufficient physical strength to prevent the detrimental winding movement as a result of duty cycle.

4.1.3 Hazardous materials such as asbestos shall not be used in the insulation system.

4.2 Motor Leads

4.2.1 Motor rotation will be counter-clockwise when facing the flange end and when driven by phase sequence 1-2-3.

4.2.3 The motor leads shall be proper labeled for proper direction of rotation.

4.3 Fan Duty Cycle

4.3.1 All locomotives are expected to operate at 96% availability out of the 8760 hours per year (i.e. 8410 locomotive hours per year.)

4.3.2 Locomotive cooling fan speeds are proportional to engine speed and operating/ambient temperature conditions. Engine speed schedules for 5500HP EMD locomotives are included at **Annexure – I** of this document.

4.3.3 The motor speed may be changed in response to engine cooling requirements. Typical Duty Cycles for Locomotives with the corresponding Engine Speed Schedule (Percentage time in each throttle notch) can be found in **Annexure – I.** Fan duty cycle is dependent on engine speed and ambient air conditions. Fans shall be controlled via locomotive software.

4.4 Product Performance Characteristics

4.4.1 Minimum required operating point for locomotive cooling fan (at standard air density of 0.070 lb/ft3 and at full power –Throttle-8) is shown below:

Design Operating Point (Nominal values)
(A) FAN

- Air Flow to be delivered to the cooling system by both the fans working together (at full speed): 150,000 CFM (at air density of 0.070 lb/ft3)
- Static Pressure: 3.0 in-Wg
- Fan Static Efficiency: 50%

(B) AC MOTOR (Reference – EMD ETI#932)

- Maximum power consumed by the radiator fan (for full speed operation) shall not exceed 80 BHP.
- Minimum Motor Efficiency: 90%
- Minimum Power Factor at full load: 75%
- Rated Frequency at Normal Operating Conditions: 133.3Hz
- Maximum Supply Frequency at over load condition: 146.7Hz
- Frequency Ranges under Normal Operating Conditions: Frequency changes are approximately linear in time with rates no higher than 7.5Hz/second.
- System voltage under Normal Operating Conditions shall be generator supplied sine wave and shall be 445 Volts and/or proportional to 3.33 Volts/Hz @ frequencies other than 133.3Hz.
- The steady state nominal supply voltage across the frequency range shall be 3.33Volts/Hz. Maximum/Minimum steady state voltage at a frequency shall be +/- 10% of nominal. The voltage Vs frequency curve is attached at **Annexure-II.**

4.4.2 Transient Voltage (cold start): The system may encounter over-voltage conditions resulting in voltages 5% greater than the maximum steady state value for maximum 20 minutes duration.

4.4.3 Transient System Voltage: During transient conditions, the system voltage may dip to 85% of minimum steady state value for no greater than 15 seconds.

4.4.4 The HIGH SPEED Locked Rotor Current at rated voltage and frequency shall not exceed 725 A. The Locked Rotor Torque at rated voltage and frequency shall not be less than 100% of rated torque. The Pull-Up Torque at rated voltage and frequency shall not be less

than 100% of rated torque. The Breakdown Torque at rated voltage and frequency shall not be less than 250% of rated torque.

4.4.5 The motor shall be able to dissipate the additional power losses caused by harmonic currents and voltages due to the non-sinusoidal waveform distribution.

4.4.6 The motor winding insulation shall accommodate inverter switching transients of 4000V/µsec.

4.4.7 The motor shall be capable of operating in field weakening where the volt/hertz can be less than nominal at lower throttle notches without exceeding motor breakdown torque. This is to allow the motor to run at higher speeds (frequency) than the available voltage would normally allow. Al lower throttle notches (idle to 3rd notch), volt/hertz will not be less than 75% of nominal. From 4th to 8th notch, volt/hertz will vary linearly with engine speed from 75% to 100% of nominal.

4.4.8 Specific cooling fan operating parameters will be established and confirmed by the supplier. The critical speeds of the fan assembly shall be identified by supplier during design and analysis from fan operating speed schedule.

4.4.9 Noise: Locomotive noise levels are not to exceed a decibel level of 87dBA at a distance of 100ft. from the locomotive centre line. Supplier has to ensure locomotive sound levels are not adversely affected by the operation of the component fan(s).

4.4.10 Dynamic Balancing: The rotating assembly shall be balanced in 2-planes up to speeds in accordance with maximum design operating speeds (RPM). Dynamic Balancing shall be performed to a maximum imbalance of 5 in-oz Max Total (2.5 in-oz per plane)

4.4.11 Supplier shall provide following fan performance curves showing:

(i) fan efficiency (%)versus fan airflow (CFM).
(ii) fan air power (Watt) versus fan airflow (CFM).
(iii) fan static pressure (in-WG) versus fan airflow (CFM).
(iv) fan input power versus motor RPM
(v) fan input current versus motor RPM.

4.4.12 Rated Slip: The percent motor slip shall be approximately 2 % at conditions defined in Annexure-I.

5.0 POWER SUPPLY

The motor power will be supplied by a 3ø inverter whose switching wave forms will range from 6-step block pattern for up to 15 minutes to a sine wave PWM. During sine wave PWM, third harmonic injection technique may be used to increase the inverter output fundamental voltage as required.

6.0 QUALITY ASSURANCE

6.1 Qualification: The responsibility for design qualification testing of the radiator fan assembly shall be with the manufacturer of the design.

6.2 Supplier selection, qualification, product approval and supplier expectations shall be in accordance with RDSO vendor guidelines.

6.3 The supplier shall comply with production part approval process PPAP for production parts including all supporting documentation. The supplier shall provide written agreement to adhere the PPAP requirements over the life of the products. Supplier shall submit technical details, QAP, Design Data of the product. Process specification for the dip and bake or impregnation and bake process must be provided in the QAP. Specification of the material utilized in the winding assembly must be provided in case desired by the purchaser. Two sets of motor Outline drawings and OGA drawings shall be provided

6.4 Supplier shall demonstrate that qualifying fixtures, test equipments, gages etc. are calibrated and certified to international standards.

6.5 The supplier shall have a quality registration: minimum shall be ISO 9001.

7.0 RELIABILITY:

7.1 The design shall be such that no wear out failures of fan assembly are there in the first 8 years of service.

7.2 Field Test Validation :In case the tenderer has designed this radiator fan assembly for the first time; at least 2 nos. radiator fans shall be put on locomotive and observed for a period of 4 to 6 months before clearance is given for supply of balance fans.

This field trial can be dispensed-with for tenderer that has already manufactured and supplied radiator cooling fans to this design (as per the present specification).

7.3 Overhaul: The equipment shall be required to be overhauled at or after 8 years.

7.4 Fan Motor Bearing/Grease: The motor and bearing grease and lubrication shall be sealed and survive unmaintained through the first overhaul @8 years. No maintenance prior to this interval shall be required to be performed.

7.5 The life of motor with one maintenance overhaul as defined above shall at least be 16 years. The stator insulation system should be designed such that substantial deterioration does not begin in the life period.

7.6 Reliability Critical Parts, Assemblies, And Processes

The manufacturer shall prepare a list of critical parts, materials and processes affecting reliability. The documented measures to control the effectiveness and quality of these items will be assessed at manufacturer audits and design reviews**.**

7.7 Reliability Development Growth Testing (Demonstration of Achieved Reliability)

Bench testing: For any new design or any major change, Reliability growth testing (RGT) is required. This will be a start-stop cycle with predetermined overload. This will be a comparison testing with the current design. Test shall be carried for up to 40000 cycles per fan (based on severity level) at maximum design operating speed (RPM). The test needs to be properly designed to simulate locomotive conditions and needs RDSO approval. This test shall be mandatory for the first time suppliers.

8.0 Warranty:

8.1 The complete radiator fan assembly shall be warranted for satisfactory and trouble-free operation for a period of 36-months from date of commissioning on locomotive.

8.2 All aspects of workmanship and design shall be covered by this warranty. The supplier shall immediately provide arrangement for rectification including replacement, if required, of failures reported under warranty.

8.3 Warranty period of the radiator fan assembly may be extended as per mutual agreement between RDSO and supplier if it has undergone major design modifications during the warranty period.

8.4 The motor supplier shall provide service support for the motor after warranty period also.

9.0 MAINTENANCE MANUAL

The manufacturer shall supply free copy of one approved operating and maintenance instructions with each 5 loco sets of fan assembly or as demanded by the shed. These instructions will be upgraded accordingly with any design changes, which may be required during the life of the equipment. The manufacturer, as required, shall supply a parts list, schematic, and exploded view drawings of the equipment, as applicable.

10.0 FAILURES DURING WARRANTY PERIOD UNDER MAINTENANCE CONTRACT

10.1 In case of any failures, the details of failure and action taken to arrest re-occurrence of similar failure in future with failure analysis report etc. is to be submitted to RDSO.

10.2 In case of repeated failures (more than 5 similar failures in a single year), necessary changes in the design of radiator fan assembly put in service or in production line shall be made by the manufacturer. Investigation tests, if considered necessary, shall be arranged/ conducted by the manufacturer.

11.0 TESTS, FIELD TRIAL AND PRODUCT APPROVAL

11.1 The tests on the complete radiator fan assembly shall be as per Section-2 of this specification.

11.2 Type test shall be performed on one prototype unit of given design to verify that product meets the specified design requirements. However, routine tests shall be carried out on each equipment.

11.3 The supplier shall submit detailed type and routine test programs to RDSO for its approval. RDSO may also decide to carry out some special tests on the radiator fan assembly, which are not covered by the test programme.

11.4 The prototype unit will be tested by RDSO and DLW representative(s) at the manufacturer's premises or at mutually decided venue where all the facilities should be made available for carrying out the prototype test and the total cost of the tests shall be borne by the manufacturer.

11.5 In case a radiator fan assembly is found suitable in type tests, field trial on the locomotive shall be carried out on 6 number of prototypes for six months. All the modifications

required due to defects noticed or design improvements found necessary as a result of the test / trial shall be carried out by the tenderer in the least possible time. Total cost of such modifications/design changes shall be borne by the manufacturer.

11.6 In case of successful completion of field trial, the radiator fan assembly shall be approved for 6 months. Final approval shall be given only after 20 numbers have worked satisfactorily for 6 months without any failure attributable to design of the fan/motor. The failure shall be investigated jointly by RDSO and the supplier. Whether a failure is related to design shall be decided by RDSO.

11.7 If mutually agreed between manufacturer and RDSO, witnessing of routine test may be waived off for sets manufactured after the prototype. The routine test of equipment, for which witnessing has been waived off shall be accepted after successful scrutiny of test results submitted to RDSO.

11.8 The purchaser reserves the right to repeat the type test of the radiator fan assembly should it be felt necessary by the purchaser to do so. The properties and composition of materials used in different components of the radiator fan assembly shall not be changed without fresh type clearance of the radiator fan assembly by RDSO.

12.0 MARKING AND PACKING

12.1 All major components of the radiator fan assembly such as fan, motor etc., shall bear for identification- a serial no., manufacturer's name, etc. as mentioned in para. 3.7.3.

12.2 Identification numbers shall also be suitably stamped on non- interchangeable matched components to facilitate radiator fan assembly to prevent mixing up.

12.3 The complete radiator fan assembly shall be suitably packed in wooden water proof boxes to prevent damage during transit and handling

SECTION – 2

TESTS ON COMPLETE ASSEMBLY

13.0 Routine Test Instructions: This section describes the test criteria and limits associated with the complete 54-inch diameter A.C. cooling fan. These tests must be performed on all fan assemblies and records be maintained.

Manufactured fan and motor assemblies shall generally receive a test as per EMD ETI#932, NEMA MG1, IEC 60349 Pt-II, IS:4722-2001 and IS:4029-1967. Alternately suppliers testing procedure may also be used after approval by RDSO. Following tests, as described below, shall be part of the routine test:

- Preliminary Inspections (clause 13.1)
- Locked Rotor Test (clause 13.3)
- Running Tests including Vibration Test (clause 13.4)
- High Potential Test (clause 13.5)

Records of these tests shall be maintained for a minimum of five years.

13.1 Preliminary Inspections

a) **Visual Inspection**: Check the machine for rating plate, lifting lugs, paint quality and aesthetic look as per clause 3.7 of this specification.

b) Physically check that all bolts are properly torqued to the values stated on the drawings (blade to hub, spacer to hub, frame to stator, hub to shaft flange and balance bolts) and that all hardware is of the proper grade. Be sure that any and all unused balancing holes are plugged. There are to be no unused balance holes in the hub that could allow the ingress of dirt, water or other ' foreign materials that may compromise the performance and/or life of the fan assembly. Balance holes should be drilled such that they do not contact the structural ribs of the fan hub. Balance washers should not extend beyond the top edge of the hub as shown on the hub/blade assembly drawings.

c) **Dimensional check**: All the critical dimensions shall be checked as per the OGA drawing supplied by the tenderer. Clearance between the longest blade and fan shroud shall be checked. The clearance is to be no less than the tolerance specified on the drawing at any point around the shroud.

d) If the assembly is equipped with flexible conduits and plugs, verify that the flexible conduit is tight to the frame conduit and that the plug is tight to the flexible conduit. Check that the plug is properly assembled.

e) Dynamically balance hub and blade assemblies to within 2.5 oz-in per balance plane (5 oz-in total per hub and blade assembly). This is an important parameter and balance values need to be recorded and traceable back to a particular fan assembly serial number

f) Winding resistance checks are to be made by the stator supplier.

g) Conduct an **insulation resistance test** (ground test) prior to energizing assembly. Apply 1000 Volts-DC for 10 seconds with megger. An acceptable assembly should read a minimum of 1 Mega ohm.

13.2 Fan Test Power Supply

RDSO and the supplier will agree upon the power supply for fan testing and qualification. A synthesized three-phase AC-power source (Inverter), capable of delivering voltage and current waveforms closely resembling the fan operation in locomotive service, is acceptable.

Performance tests may also be conducted with a power supply providing balanced phase voltages closely approaching a sinusoidal waveform. The frequency will be closely regulated according to the actual service value.

Test limits and ranges listed below for both locked rotor tests and running tests will vary depending on the power supply used. Changes to these values will require the review and approval of RDSO.

13.3 Locked Rotor Test:

The purposes of this test are to confirm proper rotor construction and alignment between the stator and rotor. The hub and blade assembly must be locked to the frame to prevent rotation. The locking device must be able to restrain a torque of 600 foot – pounds. The test is performed by applying the specified voltage (of 200V) at 60 Hz frequency to the winding after it has been appropriately connected

Do not energize the winding for more than 15 second during this test. Take readings accurately and quickly to avoid excessive temperature rise in the motor.

During this test, the test voltage, maximum variation in locked rotor voltage readings, maximum difference between phase currents for each motor and the magnitude of the locked rotor current shall be recorded as below:

LOCKED ROTOR TEST

Motor Part	Test Voltage (L- L)			Maximum Variation - Locked Rotor Voltage	Locked Rotor Amps (Phase)			Maximum Variation - Locked Rotor Current
	A-B	B-C	C-A		A	B	C	
Stator								

During type testing, the lock rotor test shall be performed at rated voltage and rated frequency and the readings should conform to that given in section 4.4.4. Measure of kilowatts, power factor and torque shall also be done during the type test.

13.4 Running Tests:

The purposes of these tests are to confirm proper stator construction, direction of rotation, proper mechanical assembly, and balance of the hub and blade assembly. The test is performed by applying the specified voltage (of 200V) at 60 hertz to the winding after it has been appropriately connected.

During the test, the test voltage, maximum variation in running load test voltage readings, synchronous motor speed for 60 hertz, the magnitude of the running load current and maximum differences between the phase currents for each motor shall be recorded as under.

RUNNING FAN LOAD TEST

Motor Part	Test Voltage (L – L) at 60Hz (Min-Max limit : 185-220 V)			Maximum Variation in Running Voltage	Load Run Amps per phase			Maximum Variation in Running Current	Synchronous Speed at 60 Hz
	A-B	B-C	C-A		A	B	C		
Stator									

As the motor accelerates, the direction of rotation should be verified. All fans should rotate clockwise when looking down at the fan when the fan is oriented as on the locomotive. This direction should yield upward airflow through the fan. Normal direction of rotation should occur when the motor is connected per the connection chart and the phase sequence of the power source is 1-2-3.

VIBRATION:

The fan assembly is to be checked for high vibration levels in order to identify any potential running fan problems. Any deviation to vibration or running test values requires the review and approval of RDSO.

The fan should be set to run at specified voltage (of 200V) at 60 hertz as in the above test. While operating at synchronous speed at 60 Hz, the Horizontal and Vertical vibration velocities, i.e., first order vibration velocities monitored, shall be recorded. It should not exceed 0.12 in/sec. in either planes (Horizontal/vertical/axial).

It is the responsibility of the supplier to log all test data for each fan assembly. Fan serial numbers and all running test data, including running currents and voltages, two-plane dynamic balance readings and vibration velocities, should be fully documented.

13.5 High Potential Test

Within 5 minutes of the running test, make a high potential test on the stator winding for 10 seconds at 2000 volts-AC test voltage level. Because of re-testing or rework, subsequent high potential test should be conducted at reduced test voltage level of 1400 volts-AC. For high potential test purposes, the rated motor terminal volts may be taken as 445 VAC.

13.6 Upon completion of the testing, be sure that the fan plugs and cable leads are protected from damage by tucking them in a place so as to prevent damage during handling.

14.0 TYPE TESTS

A type test shall be performed as per EMD ETI#932, NEMA MG1, IEEE 112A, IEC 60349 Pt-II, IS: 4722-2001 and IS: 4029-1967, by RDSO and DLW representatives at the firm premises. Further, if modifications are proposed at the later date, that might affect the performance, the type test shall be repeated. The type test shall include all the test covered under section-13. Descriptions of additional tests to be conducted under type test are as follows:

14.1 Load Tests & Temperature Rise Test

Load tests measure amps, horsepower, kilowatts, speed, power factor, efficiency, and torque up to 150% of rated load for the ratings defined in clause 4.4.1 of this specification. These tests should be performed at nominal, minimum, and maximum continuous voltage.

14.2 Noise Level Test:

Maximum sound level recorder at a distance of 2 m from the fan frame shall not exceed 110dB. The test should be conducted at rated voltage and frequency of motor.

14.3 Speed-Torque Test

Speed-torque tests measure torque, amps, and power factor vs. speed. These tests should be in speed modes at nominal, minimum continuous, and minimum transient voltage at rated frequency.

14.4 Over-speed Test: The test shall be conducted at 1.2 times the maximum speed of the motor.

14.5 Weighment : Weight of the complete fan assembly shall not be more than 1600 lbs maximum.

14.6 Airflow Test: In addition to the tests mentioned in the above paragraphs, a comprehensive airflow test shall be conducted on the prototype fan. This will require that a wind tunnel based test set-up to be manufactured as per IS-3588 (latest revision). The airflow test shall be conducted as per IS-3588 at the manufacturer's premises.

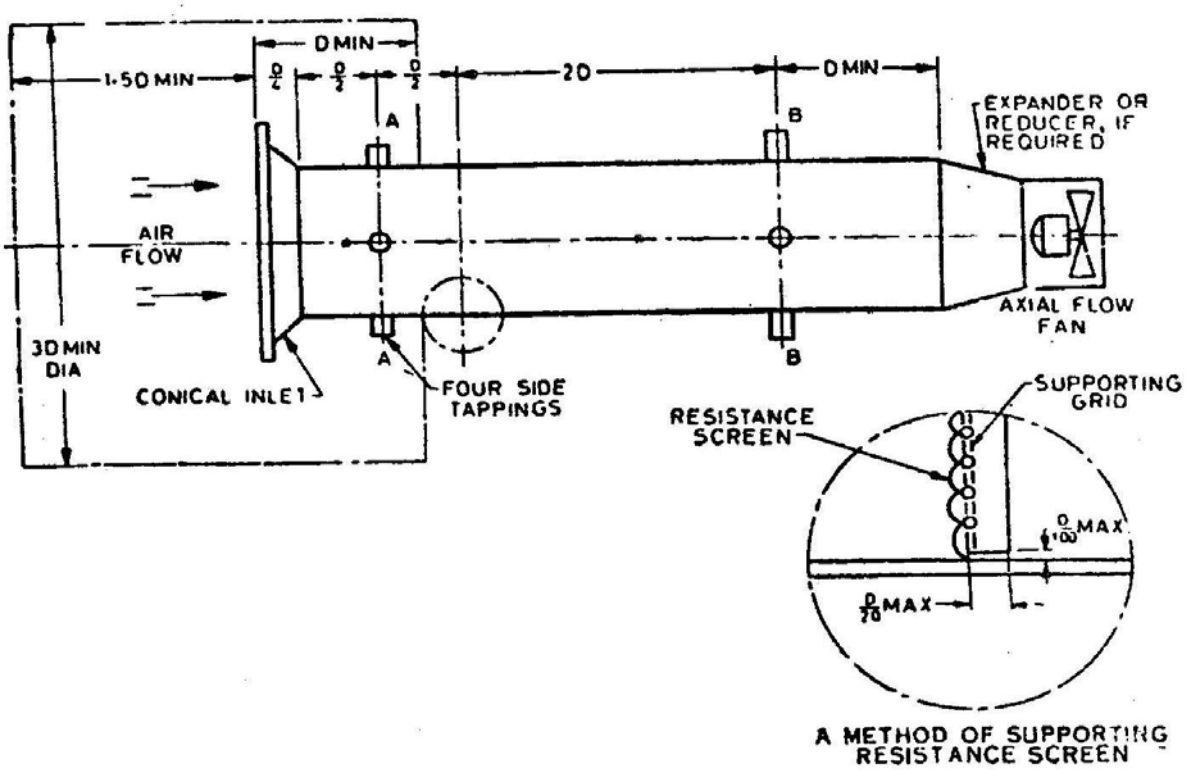
The data shall be recorded is shown in the table below:

Data Recorded							Calculated data						
Cond. of Duct	Rated Voltage at rated Hz	Current	Speed RPM	Static Pr. P_{AA}	Dyn. Pr. P_{BB}	Measured Air Velocity	Wt. Of air Wt	Discharge Q (CFM)	Air vel.	Total pr.	Air power	Input power	Eff.
1	2	3	4	5	6	7	8	9	10	11	12	13	14

Curves as per clause 4.4.11 shall be verified. The expected airflow obtained in this test shall not be less than that indicated in the table given below (with variation not exceeding - 2%):

% CLOSED	**AIR FLOW**	**Static pressure at AA (mm WG)**	**Static pressure at BB (mm WG)**
100% OPEN	75000 CFM	41	76.2

Sections AA and BB, as described in IS-3588 are shown in the sketch below:



ARRANGEMENT FOR AIR DELIVERY TEST

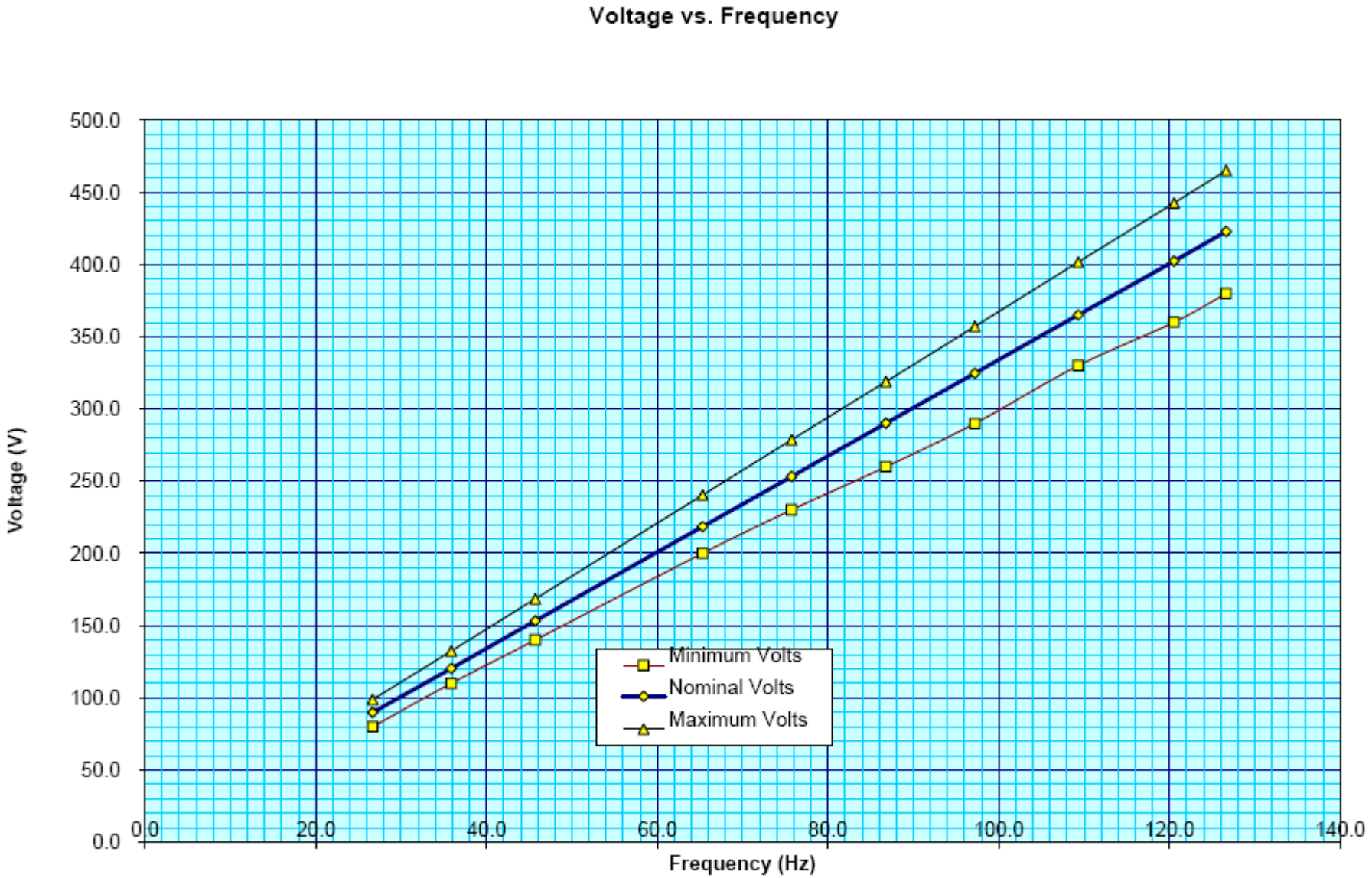
Annexure - I

SAMPLE ENGINE SPEED SCHEDULES

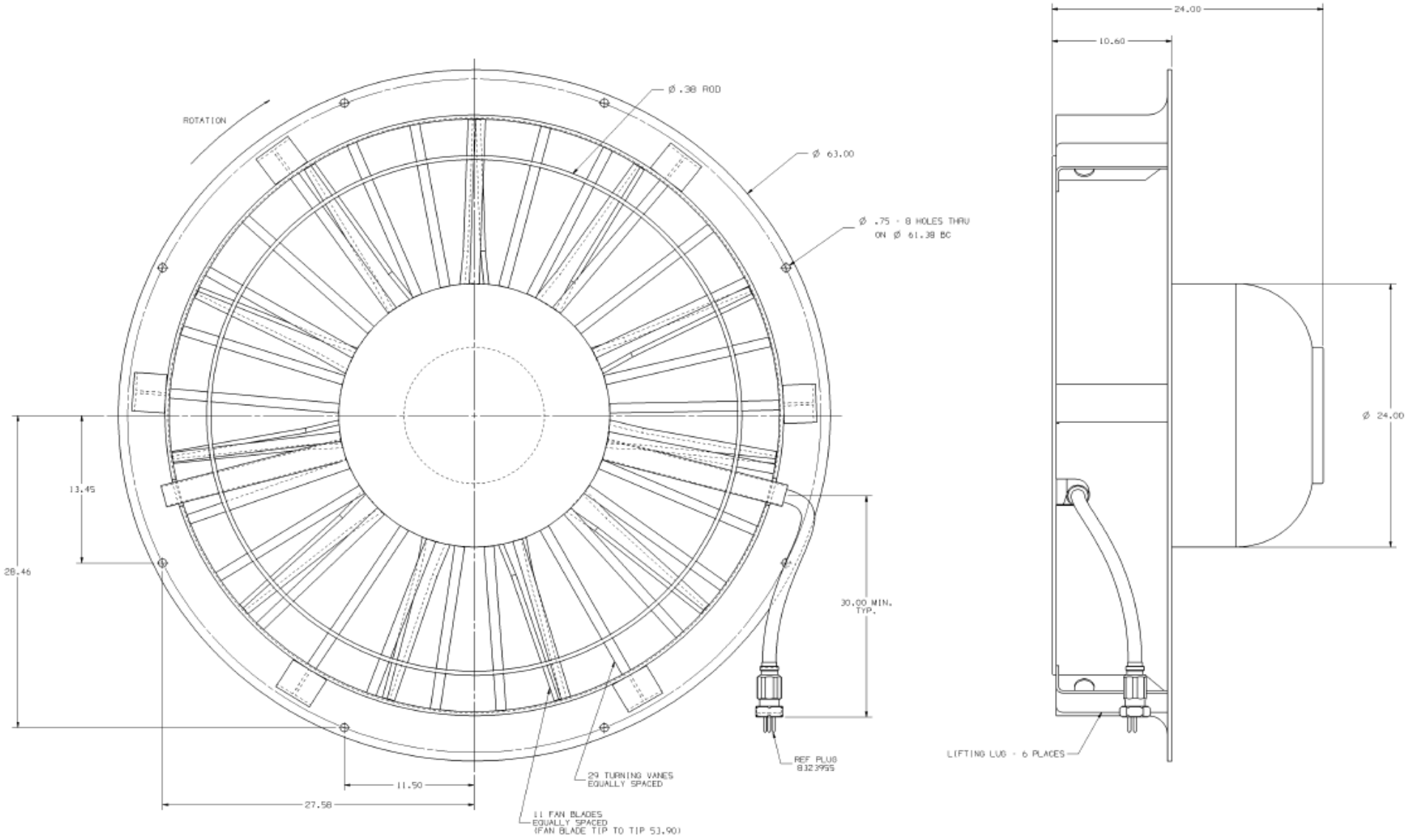
The sample engine speed schedules are shown here to give a representation of corresponding supply voltage, supply frequency and duty cycle. These schedules are subject to change and modifications at any time.

Throttle	Engine Speed (RPM)	Frequency (Hz)	Nominal Voltage	Minimum Voltage	Maximum Voltage	Locomotive Duty Cycle (% in throttle)
8b	950	126.7	423	380	465	17
8a	904	120.5	402	360	443	17
7	820	109.3	365	330	402	4
6	729	97.2	325	290	357	4
5	651	86.8	290	260	319	4
4	568	75.7	253	230	279	4
3	490	65.3	219	200	240	4
2	343	45.7	153	140	169	4
1	269	35.9	120	110	133	4
IDLE	200	26.7	90	80	99	46
DB	343	45.7	153	140	169	9

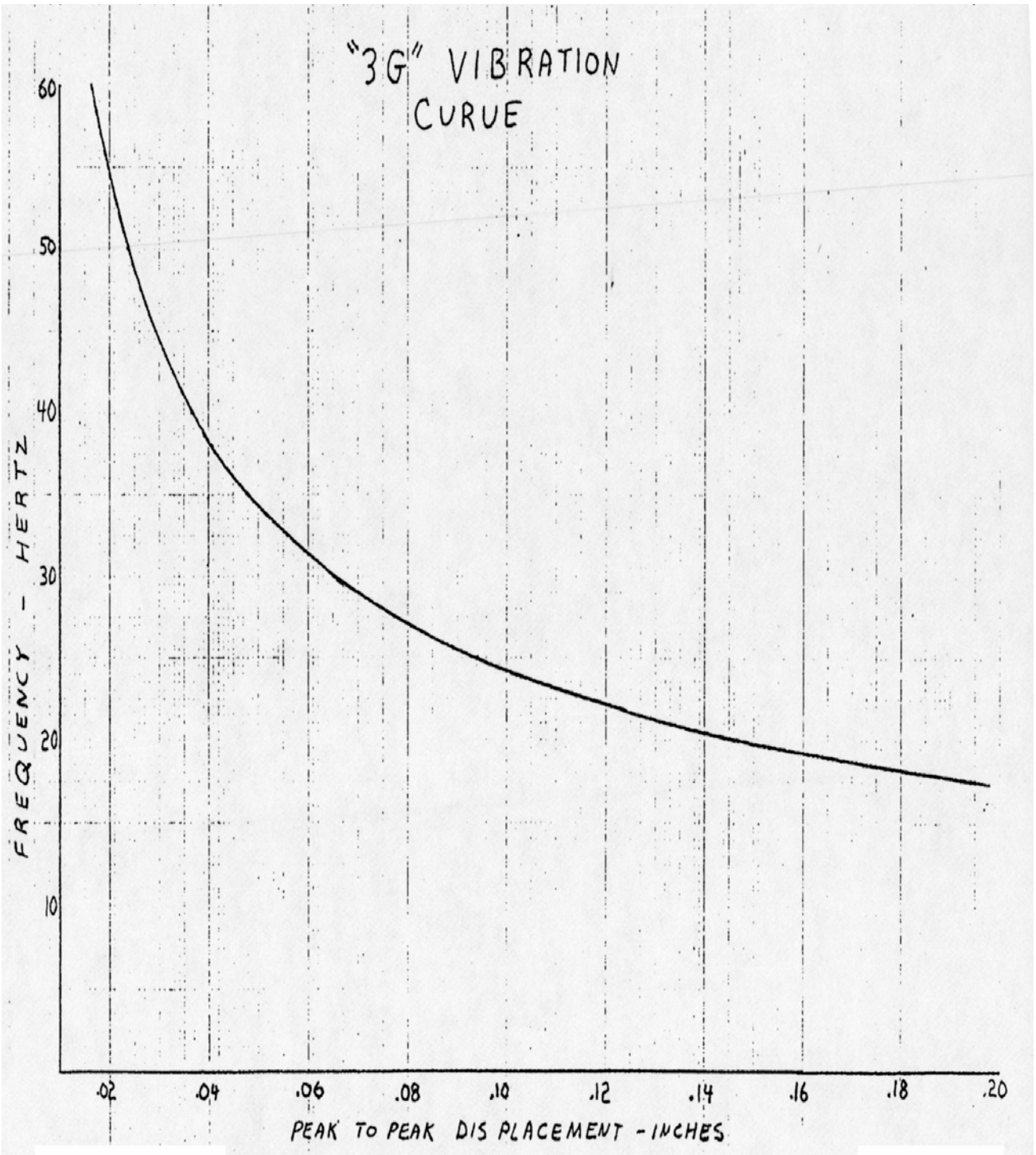
Annexure-II

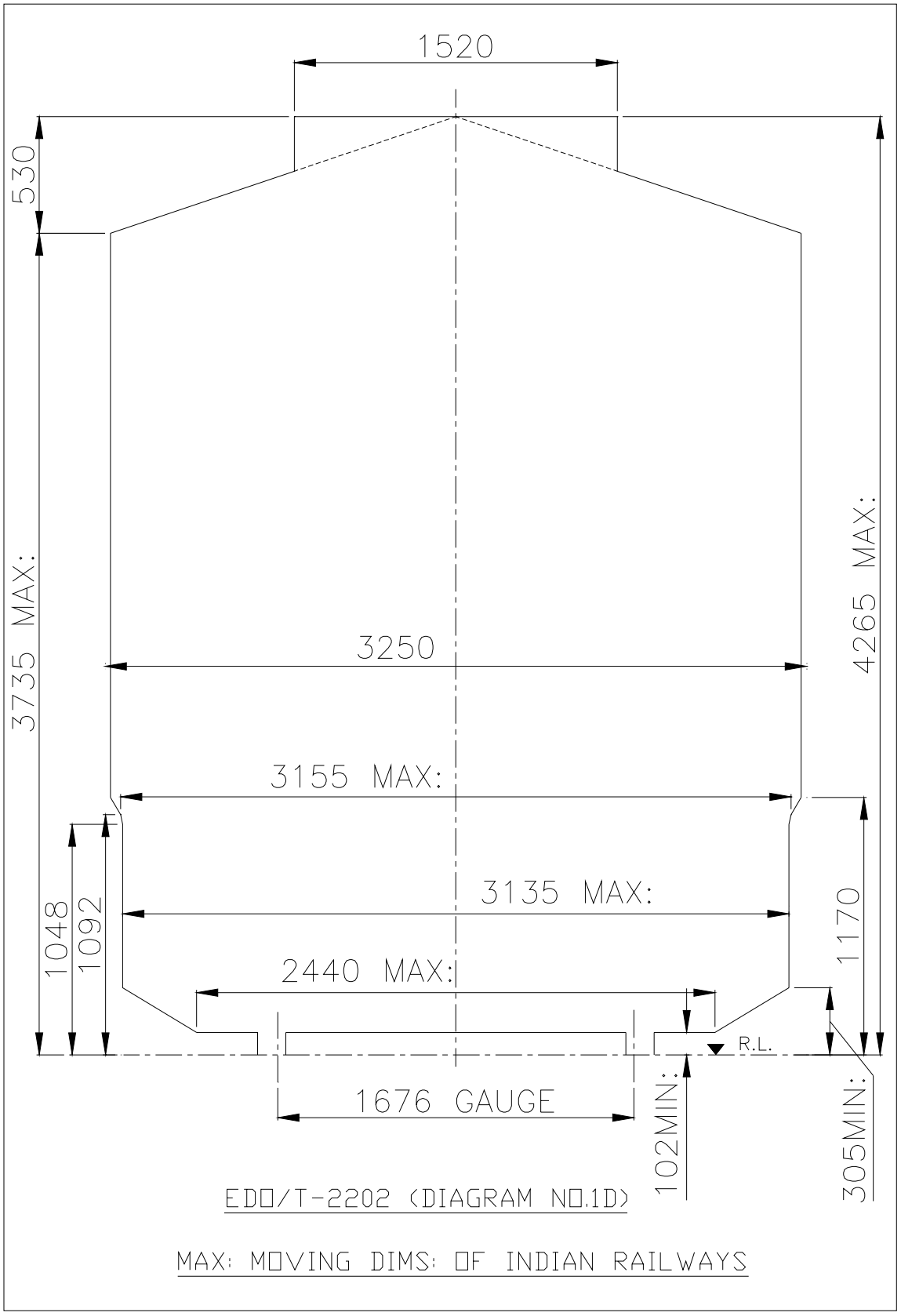

Voltage vs. Frequency
Voltage (V)
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
Frequency (Hz)
Minimum Volts
Nominal Volts
Maximum Volts

Annexure-III



Annexure - IV


"3G" VIBRATION CURVE
FREQUENCY - HERTZ
60
50
40
30
20
10
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
PEAK TO PEAK DISPLACEMENT - INCHES


1520
530
3735 MAX:
4265 MAX:
3250
3155 MAX:
3135 MAX:
2440 MAX:
1048
1092
1170
R.L.
1676 GAUGE
102MIN:
305MIN:
EDC/T-2202 (DIAGRAM NO.1D)
MAX: MOVING DIMS: OF INDIAN RAILWAYS