(For official use only)

भारत सरकार
रेल मंत्रालय

GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

TECHNICAL SPECIFICATION FOR UPGRADED RADIATOR FAN ASSEMBLY FOR EMD LOCOMOTIVES

SPECIFICATION NO. MP.0.24.00.55 (Rev.- 01)
October, 2009

अनुसंधान अभिकल्प और मानक संगठन
लखनऊ–226 011.

RESEARCH DESIGN & STANDARDS ORGANISATION
MANAK NAGAR, LUCKNOW-226 011

TECHNICAL SPECIFICATION FOR UPGRADED RADIATOR FAN ASSEMBLY FOR EMD LOCOMOTIVES

0.1 INTRODUCTION

In the existing 4000/4500HP EMD Locomotives, water acts as a coolant. The water temperature is controlled by means of radiator banks and AC motor-driven cooling fans. The radiators are located in a hatch at the top of the long hood end of the locomotive. The hatch contains the radiator assemblies, which are grouped in two banks.

Radiator Cooling fan motors used on existing 4000/4500HP EMD Locomotives are of the inverted squirrel cage induction type and are 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 of the stator. Two 52” cooling fans (8 blades) which operate independently are located in the hood under the radiators and blow the cooling air upwards through the radiator cores. They are numbered 1 and 2 with the No. 1 fan being closest to the cab. For fuel efficiency, each cooling fan is driven by a two-speed AC motor, which in turn is powered by the companion alternator. As the engine coolant temperature rises, the fans are energized in sequence as determined by the computer control system.

As additional cooling is required, the fans switch to full speed in progression as coolant temperature rises. As coolant temperature drops, the fans switch off one at a time. The cooling fans are controlled by the computer which act on the contactors. The computer also controls the fan sequencing duty cycle and speed (low or high) to ensure even fan and contactor wear. The two-speed cooling fan system consists of two full speed contactors (FCFA and FCFB) and one slow speed contactor (FCS) per cooling fan motor. The system maintains the coolant temperature within a predetermined range of from 79º C to 85º C.

The EMD locomotives (WDG4 & WDP4) have been upgraded to 4500 GCV from 4000 HP. This increase in horsepower results in increased thermal loading of the engine. The efficiency of the engine cooling system, therefore, needs to be increased to take care of this increased thermal loading. This specification has been framed to cover the requirements of upgraded radiator fan to take care of improved cooling of 4500 CV locomotive.

This specification has been divided into four sections. Items/equipment covered in each section are listed as below:

Section – 1: Axial flow cooling fan.
Section – 2: Radiator fan motor.
Section – 3: Tests.
Section – 4: Miscellaneous requirements.

0.2 SCOPE

This specification covers the technical requirements of design, manufacture, testing and supply of complete Radiator Cooling fan assembly to be used on 4500HP EMD locomotives.

0.3 SCOPE OF SUPPLY

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

0.4 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.

SECTION – 1

AXIAL FLOW COOLING FAN

1.0 MOUNTING REQUIREMENTS

The mounting holes of proposed 54” fan shall remain same as that of existing 52” design. However, the outer dimensions of 54” fan are slightly bigger due to the provision of lifting lugs.

The existing EMD locomotive fan has a span of 52 inches. For upgrading this fan for higher airflow, the span shall be increased to 54 inches while keeping the same / new blade profile or a new blade profile. The mounting arrangement and location on the locomotive shall be kept same as the existing fan.

The RDSO drawing no. SK.DP.-4065 for the proposed 54” radiator fan showing mounting arrangement and location of mounting holes is placed at **Annexure - 5**. 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.

1.1 OPERATING REQUIREMENTS

1.1.1 Fan Air Temperature

The ultimate criterion is to meet the Engine System standard of 99 °C water out of the engine at 47°C ambient at full rated engine load. The design ambient air temperature range is -4°C to 66 °C for cold side fan applications.

1.1.2 Altitude Operation, Barometer and Air Density

1.1.2.1 Fans may be operated on locomotives from sea level to 1200 meters and barometer readings from 20 in-Hg. to 30 in-Hg. The air density may vary between 0.048 Ib/ft3 to 0.095 lb/ft3 .Nominal air density is 0.070 lb/ft3.

1.1.2.2 The fan and drive system is expected to operate at both ambient extremes of section 1.1.2.1 without failure.

1.1.3 Fan Duty Cycle

1.1.3.1 All locomotives are expected to operate at 96% availability of the 8760 hours per year (or 8410 locomotive hours per year.)

1.1.3.2 Locomotive cooling fan speeds are proportional to engine speed and operating/ambient temperature conditions. Cooling fans are two speed fans, with a high (2x engine speed) and low (1x engine speed) setting. Engine speed schedules for 4500HP EMD locomotives are included at **Annexure - 1** of this document.

1.1.3.3 Typical Duty Cycles for Locomotives with the corresponding Engine Speed Schedule (Percentage time in each throttle notch) can be found in **Annexure - 1**. Fan duty cycle is dependent on engine speed and ambient air conditions. Fans are controlled via locomotive software.

1.1.3.4 A maximum of 10 starts per hour can be expected for locomotive cooling fans.

1.1.4 Shock Loads & Vibrations

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

1.1.4.2 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

1.1.4.3 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.

1.1.4.4 Component Vibration

All components must be fully functional during and after an eight-(8) hour shaking test at all identified resonances in all 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.

1.2 FAN DESIGN

1.2.1 Fan Assemblies

1.2.1.1 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 1.4.2.4 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.

1.2.1.2 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 – 4.**

1.2.1.3 Weight Restriction: Weight of the proposed 54" cooling fan should not exceed 1500 Lbs. Any deviation from specified maximum weight shall require approval by RDSO.

1.2.2 Hub and Blade Assembly

1.2.2.1 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.

1.2.2.2 Fan hubs must meet the casting quality requirements outlined in **Annexure - 3.** A complete analysis shall be performed on each hub design. It is the responsibility of the supplier to perform, document and report on the analysis and conform to the requirements stated within **Annexure – 3.** Alternatively the criteria set in ASTME – 155 for level 1 may also be followed.

1.2.2.3 Cooling fan blades must meet followings:

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

(b) Structural Reliability: The fan blade is a critical rotating part and should be oversped to identify safe operating speeds up to at least 15% over maximum operating speed. The over speed time may be mutually decided between supplier and the purchase/RDSO. Maximum normal operating temperatures approach 400°F. No fatigue failures are expected and no failures due to defects as cracks existing in blade prior to fan assembly, will be accepted without investigation and elimination of any causes found to result from design or manufacture.

(b.1) The Blade root area: This area is defined as the blade-to-blade fillet area and the blade area extending 1 in. toward the blade tip from the blade end of the fillet (2 3/8 in. out from the base mounting surface).

The external surface of this area should be free of any cracks caused for whatever reason, e.g. ejection from die while blade is yet hot and weak. Additionally, the surface of this area is to be free of impressions from lubricant residues soldering on mold.

Internally this area is to be as free of porosity and other defects as possible. Casting tooling and procedure are to be designed to make the blade root area the soundest area of the casting. No defect is to be in this area which will reduce the capacity of the blade to withstand operating stresses. Qualification of the blade manufacturing procedure is to be established and maintained by periodic evaluation 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 measured 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.

(b.2) 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.

(b.3) 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

(b.4) Mounting Base Surface

The concave, cylindrical mounting surface under the blade base is to be free of any burrs or raised edges which would prevent the blades from properly seating against the hub.

(c) Blade lot identification

Blades are to be marked by each lot of blades produced by a single mold during one shift. This is to facilitate inspection and isolation by lot if blades are found defective.

1.2.2.4 Structural analysis of the hub and the blades and the hub and blade assembly is the responsibility of the supplier. This shall be performed via FEA analysis or physical testing by the supplier the results of which shall be approved by RDSO.

1.2.2.5 The supplier must submit calculated mean and alternating strain data for the blades, hub and support structure along with fatigue-life calculations which indicate that the life goals stated below in item 1.4.2 can be met.

1.2.2.6. The supplier is responsible for determining the fan blade critical speeds of each new application of his fan to ensure that such speeds do not directly coincide with the engine throttle notch positions/speeds outlined in **Annexure - 1**. Fundamental local natural frequencies should not coincide with excitation frequencies unless significantly damped in that fan life goals are not compromised. Modal analysis is acceptable to to determine the natural frequencies.

1.2.2.7. The fan must be capable of over speed operation at 15% over 8^{th} throttle speed without sustaining structural, mechanical or electrical damage. The over speed time may be mutually decided between supplier and the purchase/RDSO. FEA results or similar products tested at the same or higher RPM is acceptable data to submit.

1.2.2.8. The fan must be within the mechanical yield criteria at these over speed conditions. FEA results are acceptable.

1.2.3 Fan frame

1.2.3.1 The fan frame will bear the load of the drive system (stator) of the fan.

1.2.3.2 Fans are to be mounted to the cooling hatch by means of threaded studs welded to the hatch and equally spaced around the fan- opening cutout. The fan frame must provide the necessary amount of clearance holes with bolt-circle dimensions, bolt-hole diameters and hole and position tolerances.

1.2.3.3 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.

1.2.3.4 Fan frames must have an identification name plate applied in a visible location around the fan frame ring. Nameplate must be stamped with the fan assembly part number and an Identifying serial number/date code unique to that particular fan assembly. The nameplate will be riveted to the fan frame ring.

1.3 PERFORMANCE REQUIREMENTS

1.3.1 Performance Characteristics

1.3.1.1 Minimum required operating point for locomotive cooling fan (at standard air density of 0.070 lb/ft3) is shown below:

<u>Design Operating Point</u>

Minimum Air Flow (full speed): 77,500 CFM (at air density of 0.070 lb/ft3)
Static Pressure: 3.0 in-WG
Fan Speed: 260 – 1905 Synchronous RPM (2% slip permissible)

Input to the radiator fan at 8th notch engine rpm shall be approximately 212 volts maximum, 127 Hz maximum, 3-phase supply. At this point, maximum power consumed by the radiator fan (for full speed operation) shall not exceed 90 HP.

1.3.1.2 Specific cooling fan operating parameters will be established and confirmed by the supplier.

1.3.1.3 Supplier shall provide all fan performance curves showing fan efficiency (%), fan horsepower (HP) and fan static pressure (in-WG) versus fan airflow (CFM).

1.3.2 Test Data

1.3.2.1 Supplier is required to submit fan test data and performance curves generated using approved fan test chamber layouts and practices. The tenderer shall indicate clearly criteria adopted for evaluating the results.

1.3.2.2 Supplier must adhere to the test requirements for the radiator cooling fan assembly.

1.3.2.3 Running Tests are also to include, but are not limited to, running current readings and vibration levels that must be logged and documented.

1.3.3 Contaminant/Chemical Compatibility

1.3.3.1 Throughout its service life, the fan will 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.

1.3.3.2 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.

1.4 QUALITY ASSURANCE

1.4.1 Qualification

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

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

1.4.2 Reliability

1.4.2.1 No wear out failures are expected in first 6 years of service. The maximum failure rate goals are as follows:

Component	2 year cumulative failure rate	6 year cumulative failure rate
Cooling Fan Motor	1 %	3 %
Fan Frame & Blades	0.2 %	0.6 %

1.4.2.2 Reliability Model - Mean Time Between Failure (MBTF)

1.4.2.2.1 The device reliability is to be calculated using the mean time between failures. The calculated reliability shall meet or exceed the reliability goal specified in clause 1.4.2.1 above.

1.4.2.2.2 MTBF is defined as 8,760 hours times the number of units in the field during the year, divided by the total number of failures in the year.

1.4.2.2.3 The system MTBF must be guaranteed for the same number of years as the warranty period.

1.4.2.2.4 For MTBF predictions, the total failure rate is the sum of the failure rates of all active parts.

1.4.2.3 Reliability Critical Parts, Assemblies, And Processes

The manufacturer shall prepare a list of critical parts, materials and processes affecting reliability. These items are identified for attention because:

- The failure of any one of them will cause the product to fail.
- They are crucial to system operational reliability.
- Their failure rates or endurance characteristics are not known with sufficient certainty.

The documented measures to control the effectiveness and quality of these items will be assessed at manufacturer audits and design reviews.

1.4.2.4 Reliability Development Growth Testing (Demonstration of Achieved Reliability)

1.4.2.4.1 Bench testing: For any new design or any major change, Reliability growth testing (RGT) is required. This will be a start stop cycling with predetermined overload. This will be a comparison testing with the current design. The test needs to be properly designed to simulate locomotive conditions and needs RDSO approval. This test shall be optional and shall be conducted only in case the product is found lacking in performance during field trials. Alternately, bench testing on similar products at the same static pressure and RPM can also be submitted in place of testing with consent of the purchaser.

1.4.2.4.2 The manufacturer shall demonstrate that the products delivered meet the specified, numerical reliability requirements of section 1.4.2.1.

1.4.2.4.3 The actual field reliability shall be monitored, beginning with the first unit delivered, and the results plotted monthly and projected forward one year into the future. If the actual failure rate is less than the guaranteed maximum failure rate and remains so for one year after the order quantity has been delivered, this requirement will be satisfied. If, at any time, legitimate projections of the actual field failure data show that the guaranteed maximum failure rate will be exceeded, RDSO will assist the manufacturer in setting up a reliability development / growth test. This will include a closely monitored and well defined test program to correct the problem(s). RDSO reserves the right not to proceed with production based on the field test results.

SECTION – 2

RADIATOR FAN MOTOR

2.1 SCOPE

Radiator motor, an 8/16 pole single winding induction motor is used to drive locomotive cooling fans. The motor parts consist of a rotor that is pressed into a hub and a stator which contains the motor shaft. The fan and motor assembly is located below (cold side) the radiator assemblies and the air movement is in the upward direction. The ambient temperature is 47 ºC. The fan and motor assemblies shall be equipped with the numbers of blades required to meet this specification. The fan assembly shall be totally enclosed, non-ventilated except for the clearance between the rotating hub and frame to prevent the ingress of dirt, water, and other foreign material.

2.2 PERFORMANCE REQUIREMENTS

2.2.1 RATING

2.2.1.1 Horsepower Rating

The motor shall not consume more than 90 HP at full RPM & at rated voltage and frequency. The rating plate on the motor must indicate the designed HP. Horsepower varies with the cube of frequency or motor speed.

2.2.1.2 Poles/ Connection

The motor will have a 8/16 pole winding connected for variable torque.

2.2.1.3 Frequency

2.2.1.3.1 Rated Frequency: The motor shall be capable of operating with up to 127 Hz of 3-phase AC supply.

2.2.1.3.2 Frequency Ranges: The supply frequency may vary from 35 to 127 hertz under normal conditions.

2.2.1.3.3 Frequency Change: Frequency changes are approximately linear in time with rates no higher than 7.5 hertz per second.

2.2.1.4 Voltage Ranges

2.2.1.4.1 Rated Voltage: For rating purposes, the motor will be rated at 212 volts and/or proportional to approximately 1.67 volts/hertz at frequencies other than 127 Hz

2.2.1.4.2 Steady State: The supply is regulated to maintain approximately constant volts per hertz (constant flux).

The nominal supply voltage line to line is approximately 1.67 volts per hertz across the frequency range. The minimum and maximum voltages at a frequency are the nominal ± 10%.

Following are ranges for selected points of interest:

Frequency (Hz)	Nominal volts	Minimum volts	Maximum volts
127	212	191	233
35	63	56.7	69.3

2.2.1.4.3 Transient: During transient conditions, the system voltage may dip to 85% of the minimum steady state value for no greater than (15) seconds. These voltage dips occur when other motor loads are started in the system. During such conditions, the running motor must not drop below the breakdown point of the speed torque curve.

The system may experience over-voltage conditions resulting in voltages 5% greater than the maximum steady state value. Such conditions may occur during initial cold locomotive operation and will not last longer than 20 minutes.

2.2.1.5 Rated Torque

Rated motor torque for radiator fan motor shall be 179 pound feet in the high speed mode. Rated motor torque shall be 45 pound feet in the low speed mode

2.2.1.6 Rated Slip

The percent motor slip shall be approximately 2 % at conditions defined above.

2.2.1.7 Locked Rotor Current

The motor locked rotor current shall not exceed 950 A in the high speed mode at rated voltage and frequency. It shall not exceed 475 A in the low speed mode at rated voltage and frequency.

2.2.1.8 Efficiency

The motor efficiency shall be a minimum of 88 % at rated conditions at high speed so *as* not to penalize overall locomotive efficiency (Mechanical losses not counted in the calculation). It shall be a minimum of 70 % at rated conditions at low speed so as not to penalize overall locomotive efficiency. (Mechanical losses not counted in the calculation.)

2.2.1.9 Special Performance Considerations

Load currents for the motor are not specified, however the nominal full load current in the 16 pole (half speed mode) should not exceed 50% of the nominal full load current in the 8 pole (full speed) mode. This is necessary to assure that the stator current density (and temperature rise) is no higher in the half speed mode than in the full speed mode.

2.2.2 MOTOR TESTING : (Please see Clause 3.2 of this specification)

2.3 PHYSICAL REQUIREMENTS

2.3.1 ELECTRICAL REQUIREMENTS

2.3.1.1 Winding Insulation

2.3.1.1.1 The motor insulation should be capable of operation at a 90°C ambient temperature Class H, with temperature rise in accordance with NEMA MG1.

2.3.1.1.2 The insulation shall be class H or better.

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

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

2.3.1.2 Motor Leads

2.3.1.2.1 The motor leads are to be supported by end turns and exit the stator at the final point of support and be aimed directly for the appropriate conduit opening.

2.3.1.2.2 Motor rotation in both speed modes will be counter-clockwise when facing the flange end and when driven by phase sequence 1-2-3.

2.3.1.2.3 The motor leads shall be labeled *as* follows for proper speed mode and direction of rotation.

SPEED	LINE1	LINE2	LINE3	OPEN	TOGETHER
Low	1	2	3	4,5,6	
High	6	4	5		1,2,3

2.3.1.2.4 The motor leads shall be sized AWG # 1 for the high speed winding current and size AWG #3 for the low speed winding current and have Teflon insulation. The lead length shall be as required per the fan assembly drawing. Lead color is to be specified on the stator drawing. As an option all leads may be one color if marked with tape to represent the normal colors indicated on the print. Any change in the lead size shall be carried out only after consent of the purchaser.

2.3.2 MECHANICAL REQUIREMENTS

2.3.2.1 The stator and rotor shall be mounted in accordance with drawing approved by RDSO. The motor shall be used in a similar assembly that has appropriately sized conduit pipes.

2.3.2.2 The motor shall be totally enclosed and non-ventilated except for the clearance between the rotating hub and frame.

2.3.2.3 The motor shaft and flange shall be vertical and must support a hub, rotor, and blade weight of no greater than 480 pounds.

2.3.2.4 The motor shall be equipped with two anti-friction bearings of shielded or sealed type capable of continuous duty in the application. The thrust bearing shall be lubricated with 400 degree F class grease. The pilot bearing shall be lubricated with 300 degrees F class grease.

2.3.3 MOTOR WEIGHT

The weight of the rotor and stator shall be specified on component drawings.

2.4. DUTY CYCLE AND ENVIRONMENTAL REQUIREMENTS

2.4.1 Duty cycle

2.4.1.1 The motor shall be subject to operation at the following duty cycles. This cycle is representative of "lower" engine speed locomotives.

The duty percentages are for engine operation at the given speed. This duty cycle is known *as* medium duty. Higher or lower duty could affect the time spent in each notch by as much as a factors of 1/2 to 2 times the percentages given.

DUTY CYCLE

Locomotive Throttle Position	Engine RPM	Frequency in Hz	Locomotive duty cycle %
8	954	127	17
7	863	115	4
6	764	102	4
5	675	90	4
4	572	76	4
3	486	65	4
2	354	47	4
1	260	35	4
IDLE	260	35	46
Dynamic Brake			9

2.4.1.2 Frequency changes may occur while the motor is running and will occur in no less than 2 seconds per step increase in frequency.

The motor speed mode will be changed in response to engine cooling requirements. Control algorithms will be designed to limit motor cycling to 7.5 cycles or high speed starts per hour.

2.4.2 ENVIRONMENTAL REQUIREMENTS

2.4.2.1 The ambient temperature will range from -20 to 90°C.

2.4.2.2 The motor is subject to normal locomotive vibration per the attached "3G" vibration curve at **Annexure - 2**.

2.4.2.3 The fan assembly will be subject to water and other airborne contaminants including road bed dirt and diesel soot.

2.4.2.4 The motor will be subject to 100% humidity and/or water condensation on the winding due to rapid temperature changes.

2.5 DOCUMENTATION

2.5.1 Material

Specification of the material utilized in the winding assembly must be provided in case desired by the purchaser.

2.5.2 Process specification

Process specification for the dip and bake or impregnation and bake process must be provided in the QAP.

2.5.3 Drawings

Two sets of motor Outline drawings and OGA drawings shall be provided.

2.5.4 Changes

All changes to the materials, processing, or design of the motor must be communicated to RDSO in an expedient fashion so that effect on the user railway units can be considered.

2.6 RELIABILITY/DURABILITY/LIFE STANDARDS

2.6.1 All motors are to be warranted against design and manufacturing defects under the service conditions and requirements described above for a period of 24 months from the date of putting into service or 30 months from the date of supply, whichever is earlier. Details of warranty are described in clause 4.2 of this specification.

2.6.2 The failure rate of the motor shall not exceed 1% at two years of service. Both electrical and mechanical failures will be considered in lump sum. At six years of service, the failure rate shall not exceed 3% with no maintenance prior to six years. Supplier participation is required to resolve problems in the event that failure rates exceed or are projected to exceed those above.

2.6.3 At six years of service, the motor will receive maintenance including electrical checks, new bearings, and new cavity grease if incorporated in the design. No maintenance prior to this interval is performed (including additive regreasing, cleaning, etc.).

2.6.4 The life of the motor with two maintenance overhauls *as* defined above will be 16 years. The stator insulation system should be designed such that substantial deterioration does not begin in the life period.

2.6.5 The motor will be subject to diagnostic testing utilizing a Hi pot of 2400 V AC for 1 second insulation resistance tester.

2.6.6 The motor supplier shall provide service support for the motor for the life of the motor design life *as* defined above.

SECTION – 3

TESTS ON COMPLETE ASSEMBLY

3.1 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 maintained.

3.1.1 Preliminary Inspections

a) 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.

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 comprise 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, Satan washers should not extend beyond the top edge of the hub as shown on the hub/blade assembly drawings.

c) Check clearance between the longest blade and fan shroud. The clearance is to be no less than the tolerance specified on the drawing at any point around the shroud.

d) Winding resistance checks are to be made by the stator supplier. It may be useful to measure winding resistance to ensure that the leads are routed through the correct conduit. Lead set 4-5-6 (low speed leads) will always have a lower resistance than lead set 1-2-3 (high speed leads).

e) 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 flex conduit. Check that the plug is properly assembled.

f) 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.

3.1.2 Fan Assembly Information

Radiator Fan Assembly shall be a 54-inch, two- (2) speed, Q-type fan operating at 127Hz. The fan operates at 1-x Engine Speed in low-speed mode and at 2-x Engine speed in high-speed mode.

Stator winding shall be Consequent Pole type with working voltage 212 VAC (at 8^{th} notch engine speed).

3.1.3 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.

3.1.4 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 at 60 hertz to the winding after it has been appropriately connected.

Do not energize the winding for more than 15 second during this test. Measure and record low speed test readings first, then high speed. Take readings accurately and quickly to avoid excessive temperature rise in the motor.

The chart below specifies the test voltage limits, maximum variation in locked rotor voltage readings, maximum difference between phase currents for each motor, and the magnitude range of the locked rotor current.

LOCKED ROTOR TEST

Mot or Part	Speed Mode	Test Voltage	Maximum Variation - Locked Rotor Voltage	Locked Rotor Amps Min - Max	Maximum Variation - Locked Rotor Current
Stator	Low Speed	75 to 90 V	4V	160 - 185 amps	5 amps

3.1.5 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 at 60 hertz to the winding after it has been appropriately connected.

The chart below specifies the test voltage limits, maximum variation in running toad test readings, synchronous motor speed for 60 hertz, maximum differences between the phase currents for each motor and the magnitude range of the running load current. The measured currents must fall within the range specified and must be balanced. - not to exceed the maximum difference expressed in the chart.

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. Values for fan running currents are to meet the values in the table below:

RUNNING FAN LOAD TEST

Motor Part	Speed Mode	Test Voltage	Maximum Variation in Running Voltage	Load Run Amperage Min - Max	Maximum Variation in Running Current	Synchronous Speed at 60 Hz
Stator	Low Speed	80 to 95 V	2 V	56 - 70 arrps	4 amps	450 RPM

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 in high-speed (8-Pole) mode at a synchronous speed of 900 RPM at 60-Hz. While operating at 900RPM, 60 Hz, the Horizontal and Vertical vibration velocities, i.e., first order vibration velocities monitored, shall 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.

3.1.6 High Potential Test

Within 5 minutes of the running test, make a high potential test on the stator winding for 10 seconds at 1400 volts-AC test voltage level. Subsequently high potential test because of re-testing or rework should be conducted at 1000 volts-AC reduced test voltage level.

3.1.7 Connection Charts: The connection chart is shown below:

SPEED	LINE1	LINE2	LINE3	OPEN	TOGETHER
Half	1	2	3	4,5,6	
Full	6	4	5		1,2,3

3.1.8 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.

3.2 MOTOR TESTING

3.2.1 ROUTINE TESTS

3.2.1.1 Manufactured rotors shall receive a high potential test as per section 3.1.6. Manufactured fan and motor assemblies shall generally receive a test as per NEMA MG1-12.51 / 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 in the above clauses, shall be part of the routine test:

- Preliminary Inspections (clause 3.1.1)
- Locked Rotor Test (clause 3.1.4)
- Running Tests including Vibration Test (clause 3.1.5)
- High Potential Test (clause 3.1.6)

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

3.2.1.2 For high potential test purposes the rated terminal volts is 212 V AC.

3.2.2 TYPE TESTS

A type test shall be performed per IEEE 112A / IEC 60349 Pt-II, IS:4722-2001 and IS:4029-1967, if modifications are proposed which might alter performance or at the request of the RDSO. Descriptions of these tests are as follows:

3.2.2.1 Load tests

Load tests measure amps, horsepower, kilowatts, speed, power factor, efficiency, and torque up to 150% of rated load for the ratings defined in clause 2.2.1.1 of this specification. These tests should be performed in both speed modes at nominal, minimum, and maximum continuous voltage.

3.2.2.2 Locked rotor tests

Locked rotor tests measure amps, kilowatts, power factor and torque. These tests should be performed in both speed modes up to maximum voltage at rated frequency.

3.2.2.3 Speed-torque test

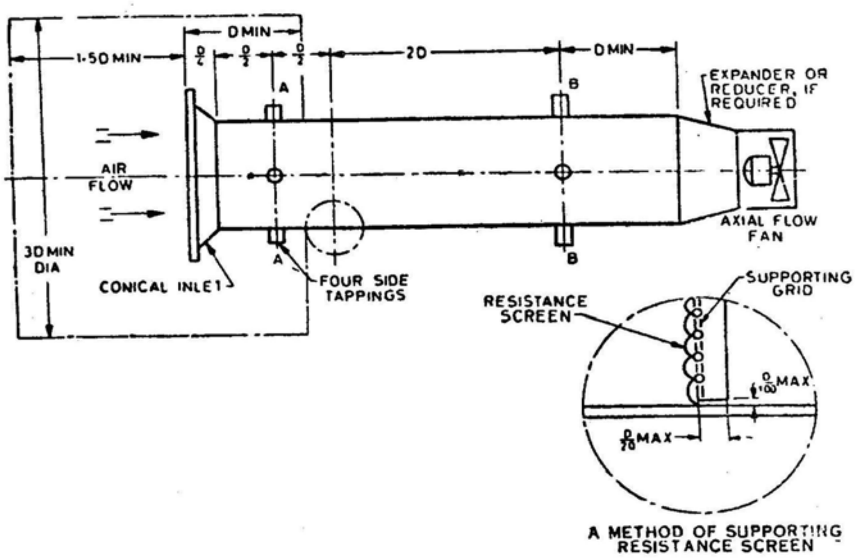
Speed-torque tests measure torque, amps, and power factor vs. speed. These tests should be in both speed modes at nominal, minimum continuous, and minimum transient voltage at rated frequency.

3.2.2.4 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 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	77500 cfm	41	75

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



ARRANGEMENT FOR AIR DELIVERY TEST

SECTION – 4

MISCELLANEOUS

4.1 QUALITY ASSURANCE PROGRAMME, INSPECTION & TEST CERTIFICATE

4.1.1 Quality assurance: The manufacturer shall submit its internal quality assurance programme (QAP) to the RDSO for approval. The manufacturer shall, on demand by the RDSO or any other inspecting agency nominated by the RDSO, make the records of checks carried out during internal quality assurance exercise available for scrutiny. The QAP proposed by the manufacturer for the DBR assembly offered shall be submitted with the offer.

Inspection tests shall be similar to the routine test programme. Final acceptance of the radiator fan assembly shall be made at the purchaser's premises.

4.1.2 The manufacturer shall afford the inspector all reasonable facilities and necessary assistance to check that the radiator fan assembly is being supplied in accordance with this specification. The first prototype of the radiator fan should be tested at the firms premises by RDSO / DLW representatives. The exemption in witnessing any test at stage of prototype / routine inspection shall be taken jointly between RDSO/DLW and the tenderer.

Three copies of test certificates shall be supplied giving the following details:

a) Railway, Unit, Order Number
b) Supplier's name
c) Batch number
d) Results of all acceptance tests.

4.2 WARRANTY

The complete radiator fan assembly shall be warranted for satisfactory and trouble-free operation for a period of 24 months from the date of putting into service or 30 months from the date of supply, whichever is earlier.

4.2.1 All aspects of workmanship and design shall be covered by this warranty. The supplier shall immediately provide arrangement for rectification of failures reported under warranty.

4.2.2 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.

4.3 MAINTENANCE MANUAL

The manufacturer shall supply free copies of approved operating and maintenance instructions. 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.

4.4 FAILURES DURING WARRANTY PERIOD UNDER MAINTENANCE CONTRACT

4.4.1 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.

4.4.2 In case of repeated failures, necessary changes in the design of radiator fan assembly put in service or in production line are to be made by the manufacturer. Investigation tests, if considered necessary, are to be arranged/conducted by the manufacturer.

4.5 TESTS, FIELD TRIAL AND PRODUCT APPROVAL

4.5.1 The tests on the complete radiator fan assembly shall be as per Section-3 of this specification.

4.5.2 Type test will 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.

4.5.3 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.

4.5.4 The prototype unit will be tested by RDSO 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.

4.5.5 In case a radiator fan assembly is found suitable in type tests, field trial on the locomotive shall be carried out on a limited 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.

4.5.6 In case of successful completion of field trial, the radiator fan assembly shall be approved for a restricted period to be decided by the purchaser. Final approval shall be given only after extensive use on the locomotives.

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

4.5.8 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.

4.6 MARKING AND PACKING

4.6.1 All major components of the radiator fan assembly such as fan, motor etc., shall bear for identification a serial no. and manufacturer's name. Radiator fan assembly shall be provided with a suitable rating plate giving usual information including the following:

a) Manufacturer's name
b) Type and serial no. of motor
c) Type and serial no. of fan
d) Date of manufacture
e) Nominal and short time ratings

4.6.2 The rating plate shall be clearly visible when radiator fan assembly is installed in position. Identification numbers shall also be suitably stamped on non- interchangeable matched components to facilitate radiator fan assembly to prevent mixing up.

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

4.7 OTHER DETAILS

4.7.1 The manufacturing drawings shall exhibit clearly the material specification, welding symbols, manufacturing tolerances and other details that are necessary for manufacture of the components.

4.7.2 The set of drawings shall be sent for RDSO approval at the time of the prototype tests of radiator fan assembly.

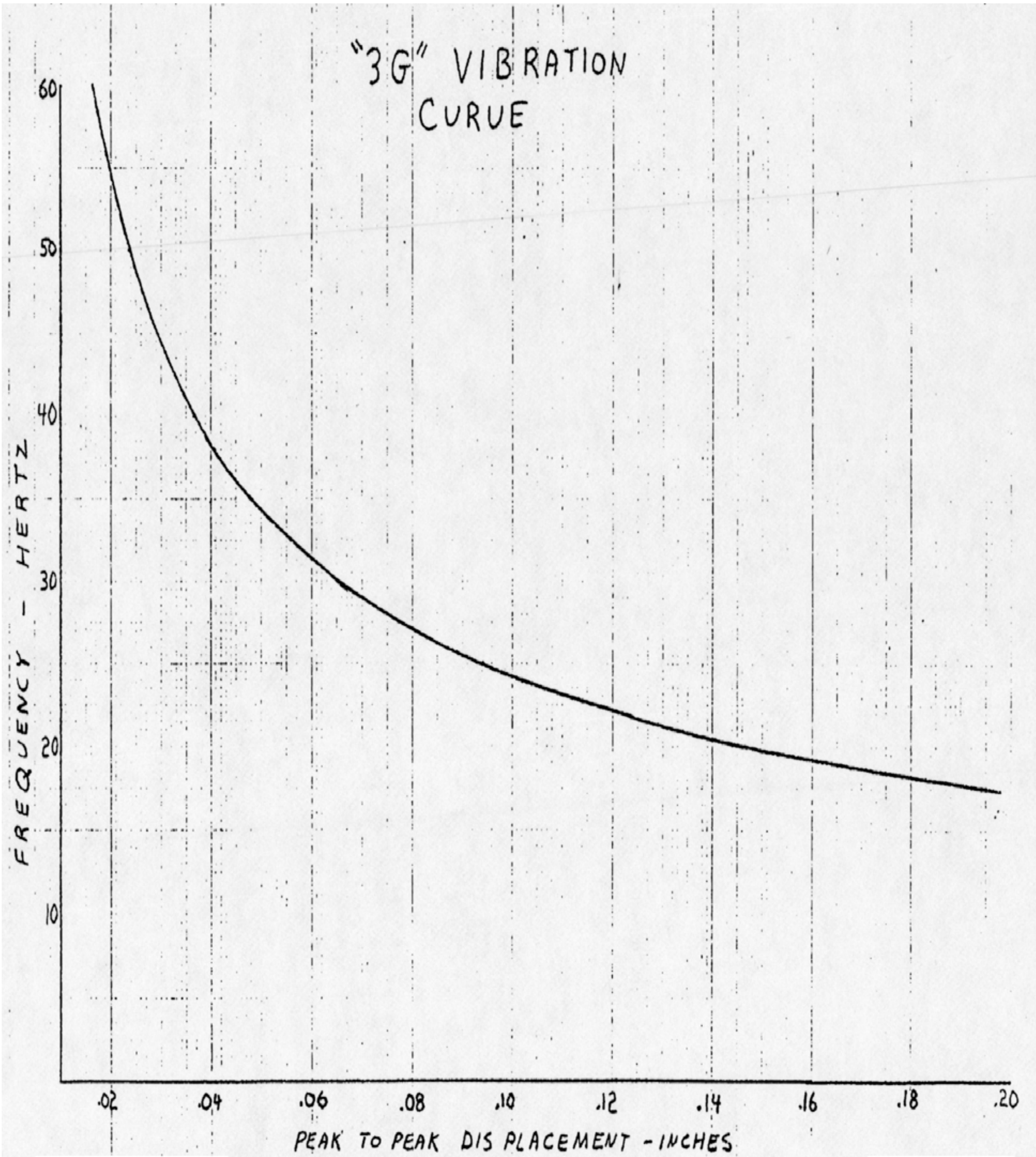
Annexure - 1

SAMPLE ENGINE SPEED SCHEDULES

8.1. Engine speed schedules are shown here to give a representation of the fan speeds and duty cycle. The fan speed are proportional to engine speeds as noted In the highlighted text below. These schedules and speeds are subject to change and modifications at any time.

Throttle	Engine Speed RPM	Fan Speed RPM (High/Low) (with 2% slip permissible)	Locomotive Duty Cycle (% in throttle)
8	954	1870 / 935	17
7	863	1691 / 846	4
6	764	1497/ 749	4
5	675	1323 / 662	4
4	572	1121 / 561	4
3	486	953 / 476	4
2	354	694 / 347	4
1	260	510 / 255	4
IDLE	260	510 / 255	46
DB			9

Annexure - 2


"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

Annexure – 3

AXIAL FLOW FAN HUBS - CASTING QUALITY REQUIREMENTS

Following instructions define quality requirements for axial flow cooling fan hubs. The quality requirements apply equally at two stages: 1) at dimensional and metallurgical qualification of sample castings and 2) following qualification, during subsequent pilot and full production runs. At the first stage, all specified casting quality aspects will be evaluated; at the second stage, selective evaluations (within the scope of the quality requirements) may be performed at-the discretion of RDSO.

"Critical areas" of fan hub castings are defined in Figure-1 for dual wall castings. The dual wall design is utilized in Radiator fan applications where the inner wall provides a surface for shrink fit of the rotor iron (core). In this application the inner wall experiences a significant tensile hoop stress. The integrity of the outer wall is of utmost importance since this wall must sustain the high centrifugal loads imposed on the hub by the blades of the rotating assembly.

Casting quality requirements consist of the following:

1. Conformance to blueprint dimensional requirements.

2. Conformance to radiographic soundness standards as follows:

   a. In areas 1 through 3 in Figure-1, castings must conform to Quality Level A per Aluminum Association Standard AA-CS-M5-71.
   b. In all other areas, castings must conform to Quality Level C per Aluminum Association Standard AA-CS-M5-71.

3. Conformance to specified material chemistry requirements.

4. Conformance to specified mechanical property requirements; tensile specimens to be removed, in general, from any position on the blade wall; specimens may, however, be removed from any of areas 1 through 3 of Figure-1 or from any other non-riser area of the casting.

5. Conformance to visual porosity standards as defined below:

   Visual porosity, as discussed here, applies to porosity uncovered by machining, and therefore differs in a technical sense from a radiographic discontinuity as detected on radiographic film. It is intended that visual porosity requirements should be consistent with the radiographic requirements given above. Unlike radiographic inspection of castings, visual inspection of machined surfaces is performed on 100% of hubs machined at firm's premises.

   In general, isolated porosity in machined areas must be no larger than 1/8" diameter and 1/16" in depth. Multiple pores in this category must be separated sufficiently to clearly have no interactive effect (generally at least 2" apart).

Clustered porosity is considered a more severe condition than an isolated pore since some interactive stress concentration effect occurs and since a more severe subsurface condition is likely. In the case of porosity clusters where porosity is nearly round at the surface, porosity diameter should not exceed 1/16" diameter and pores must be separated by 1/8".

Continuous and nearly continuous non-circular porosity is an even more severe condition which causes high stress concentration and often reflects a worsening subsurface condition. The dimensions of this type of porosity should not exceed 1/8" surface length and 1/16" in depth. Surface areas in this category should be separated sufficiently to clearly have no interactive effect (generally at least 2" apart).

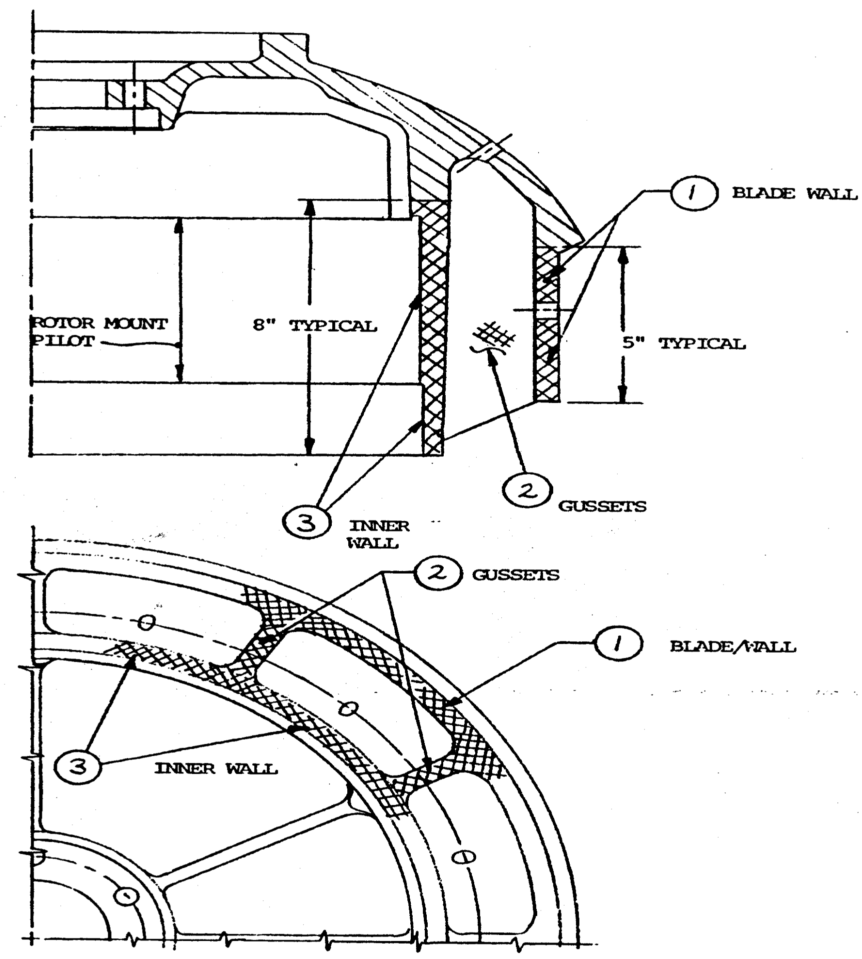
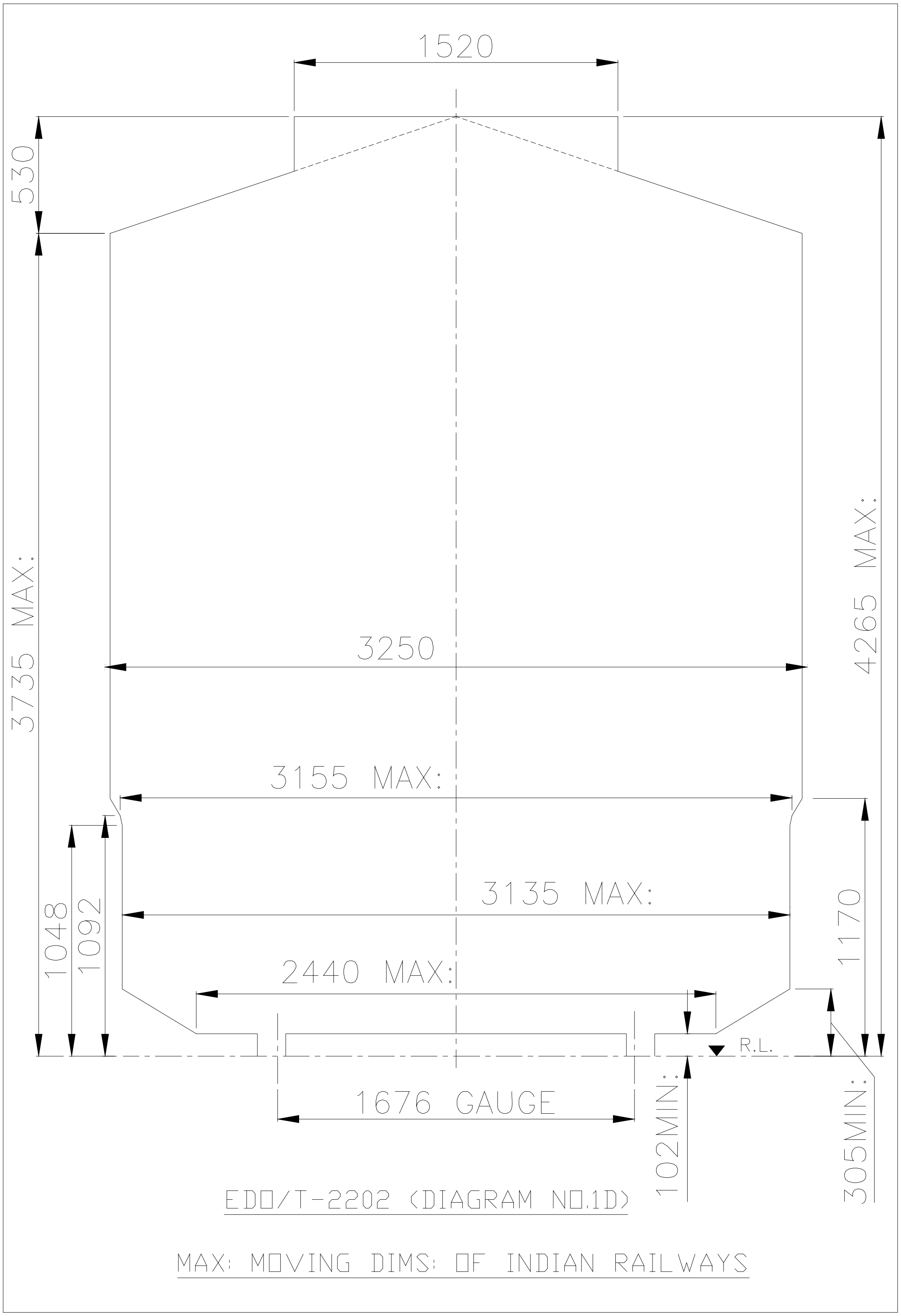
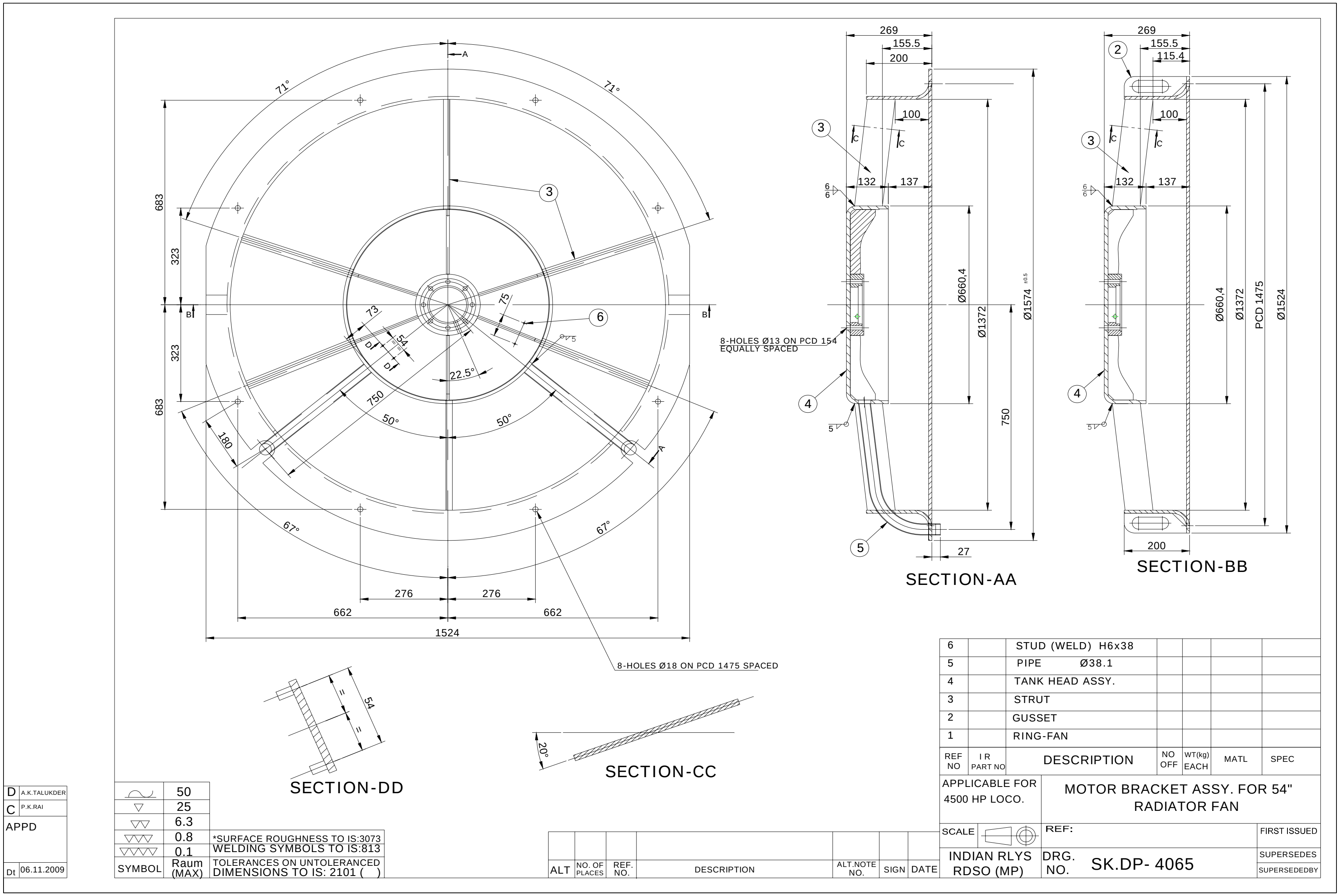


Figure - 1

Annexure – 4


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

Annexure - 5


SECTION-AA
SECTION-BB
SECTION-CC
SECTION-DD
8-HOLES Ø13 ON PCD 154 EQUALLY SPACED
8-HOLES Ø18 ON PCD 1475 SPACED
6 STUD (WELD) H6x38
5 PIPE Ø38.1
4 TANK HEAD ASSY.
3 STRUT
2 GUSSET
1 RING-FAN
REF NO
I R PART NO
DESCRIPTION
NO OFF
WT(kg) EACH
MATL
SPEC
APPLICABLE FOR 4500 HP LOCO.
MOTOR BRACKET ASSY. FOR 54" RADIATOR FAN
SCALE
REF:
FIRST ISSUED
SUPERSEDES
SUPERSEDEDBY
INDIAN RLYS RDSO (MP)
DRG. NO.
SK.DP- 4065
ALT
NO. OF PLACES
REF. NO.
DESCRIPTION
ALT.NOTE NO.
SIGN
DATE
*SURFACE ROUGHNESS TO IS:3073
WELDING SYMBOLS TO IS:813
TOLERANCES ON UNTOLERANCED DIMENSIONS TO IS: 2101 ( )
SYMBOL
Raum (MAX)
50
25
6.3
0.8
0.1
D A.K.TALUKDER
C P.K.RAI
APPD
Dt 06.11.2009