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GOVERNMENT OF INDIA

MINISTRY OF RAILWAYS

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SPECIFICATION FOR 3 PHASE AC SMALL MOTORS WITH BUILT IN INDIVIDUAL INVERTER FOR DIESEL ELECTRIC LOCOMOTIVES

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1.0 FOREWORD

1.1 At present, DC Fuel pump motor, DC Crank case motor and DC cyclonic filter dust exhauster blower motor (referred as small motors) are being used as coupled to the fuel & governor pump, crank case blower and cyclonic filter blower on WDM2, WDG3A,WDP3A,WDM3A & WDM3D diesel-electric locomotive. The power for these motors is obtained from 72±1 V control voltage fed by aux. generator or from 64V battery. The DC motor requires excessive maintenance because of commutation and the reliability is also very poor.

1.2 This specification is intended to serve as a guide line for the development of individual inverter driven AC Fuel Pump Motor, AC Crank Case Motor and AC Cyclonic filter dust exhauster blower motor for use on diesel electric locomotives on Indian Railways.

1.3 RDSO may permit any deviation considered an improvement over existing specification with a view to avoid any failures and reduced maintenance and to improve the reliability of motors.

2.0 SCOPE

2.1 This specification covers the requirements of design, manufacture, testing and supply of 3ϕ AC Fuel pump motor, AC Crank case motor and AC cyclonic filter dust exhauster blower motor with built in individual inverter.

2.2 Each locomotive is equipped with one fuel pump motor, one crank case motor and two cyclonic filter dust exhauster blower motor. Purchaser can purchase these motors with inverter separately or as a full loco set.

2.3 The blower fans shall also be supplied along with the Crank case motor and Cyclonic filter dust exhauster blower motor.

3.0 TERMINOLOGY

For the purpose of this specification, the following definitions shall apply:-

3.1 Input Voltage: The DC voltage which is applied across the input terminals of the inverter.

3.2 Output Voltage: The AC voltage available across the out put terminals of the inverter.

3.3 Rated Voltage Range: It is the range of input voltage over which the inverter will operate satisfactorily.

3.4 Rated Voltage: It is the voltage to which all the inverter characteristics are designed.

3.5 Inverter: It is an assembly comprising of semi conductor and associated electronic and electrical components used for DC to AC inversion for the purpose of driving AC motor which include circuit for stabilized power output, surge suppression and other

protective circuits adopted by the manufacturers for ensuring satisfactory performance and reliability of the inverter unit.

3.6 AC Fuel Pump Motor: It is the 3 phase AC motor to be used as a driver for fuel booster pump and governor pump.

3.7 AC Crank Case Motor: It is the 3 phase AC motor to be used as a driver for the crank case blower fan.

3.8 AC Cyclonic filter dust exhauster blower motor: It is the 3 phase AC motor to be used as a driver for cyclonic filter blower fan.

4.0 SERVICE CONDITIONS

4.1 The equipment shall operate satisfactorily under the following climatic conditions:

i) Variation of ambient temperature from 0ºC to 55ºC with 100% relative humidity.
ii) Heavy rainfall with thunder storms.
iii) Dusty and corrosive atmosphere with dust content in air up to 1.6 mg/m cube.
iv) Altitude –1200 m above MSL.
v) The equipment shall be designed to work in coastal area in humid salt laden corrosive atmosphere having max. PH Value of 8.5, sulphate 7 mg/litre and maximum concentration of chlorine 6 mg/litre.

4.2 The equipment shall withstand satisfactorily the vibrations and shocks normally encountered in service as indicated below:

a) Max. vertical acceleration = 3.0 g.
b) Max. lateral acceleration = 3.0 g.
c) Max. longitudinal acceleration = 3.0 g.

5.0 CONSTRUCTIONAL FEATURES:

5.1 GENERAL

5.1.1 The tenderer shall submit the drawing showing overall dimensions as well as mounting dimensions.

5.1.2 The mechanical construction of the motors with built in inverter shall be such that they can be retrofitted on the existing brackets on present locations in locos. These motors should be matched mechanically as far as practicable with the existing DC motors.

5.1.3 Motor with inverter shall not infringe with any components when mounted at its existing location on the diesel locomotives and can be directly connected with the existing wiring without any change required.

5.2 INVERTER

5.2.1 The inverter shall be built in with respective motors. They shall be of rugged construction.

5.2.2 The equipment shall be hose proof and tested in accordance with IS 4691. The degree

of protection shall be IP 65

5.2.3 For dissipation of heat from the power components, a suitable design of heat sink fins shall be provided. The heat sink should be so located as to reject heat outside directly. The heat sink shall be designed for natural ventilation.

5.2.4 Fasteners used in inverter shall be cadmium plated and passivated according to IS:1572. The fasteners shall conform to IS:1364.

5.2.5 The metallic frame of the inverter shall be fabricated from cold rolled annealed steel sheet of 1.6 mm thickness conforming to IS: 513.

5.2.6 The wiring used in the inverter shall conform to highest standards of current engineering practices. All cables and wires used for wiring shall be of copper multi-strand having PTFE insulation of adequate size and neatly secured in position. Elastomeric insulated cables will be used for sizes for which PTFE cables are not available. All the terminations shall be made through crimped eyelets and diagram to be furnished by the supplier. Printed circuit cards specifically designed to suit the circuitry used having plug in arrangement shall be used. Microprocessor based circuits shall be preferred.

5.2.7 The components and assembly of the unit shall conform to RDSO's reliability specification ELRS/SPEC/SI/0015 (latest). The use of electrolytic capacitor shall be avoided to the extent possible in design of the inverter.

5.2.8 The detailed specification of all the power switching devices used along with their test certificates shall be given to RDSO. These devices should be of internationally reputed device manufacturer. Only IGBT /MOSFET type of device shall be used.

5.2.9 Terminals of adequate size shall be provided for input and out put side with distinct identification marks.

5.2.10 The colour of the housing of the inverter shall be finished as in the colour code No. 693 air craft gray of IS:5 "Colour for ready mixed paint". The fins for heat sinks of inverter may be black anodised.

5.2.11 Motor switching ON shall be done through DC circuit breaker. Inverter shall be designed to ramp the current and voltage at the time of switching ON to take care of the excess drawl of current and consequent drop of voltage.

5.3 AC MOTORS

5.3.1 All the motors are industrial type squirrel cage induction motors and due care for starting and operating current at minimum/maximum voltage and current limit shall be taken under normal, abnormal, and fault conditions.

5.3.2 The degree of protection for motor enclosure as per IS: 4691/IEC 34-5 shall be IP 54.

5.3.3 Stator construction - The stator winding shall be suitably strengthened mechanically and vacuum pressure impregnated with insulating resin to resist the effect of vibration, lubrication, oil fumes, diesel fumes, dust and moisture.

5.3.4 Rotor construction- Dynamically balanced pressure die cast aluminium alloy shall be used.

5.3.5 Shaft- The material of shaft shall be EN 24 suitably heat treated to achieve improved hardness to avoid wear & tear in service.

5.3.6 Bearing- Sealed bearing with high temperature grease should be adopted to assure minimum maintenance and long life. These bearings should be imported SKF/FAG of European origin or NSK/Japan. The bearing design shall have the following features:-

5.3.6.1 In addition to provisions of required interface/tolerances on bearing housing, the floating side of the bearing should be suitably preloaded.

5.3.6.2 The minimum L10 life of bearing shall be 100,000 hours.

5.3.7 Winding wires- Dual coated enameled winding wires as per IS-13730 part 13/1993 shall be used. Dual coat means base coat with polyesterimide enamel MT 533.39A / TR 543.38 and top coat with Allotherm 602L-35S or 602L-31S of Doctor Beck & Co.

5.3.8 The test on winding wires shall be conducted as per IS 13778 Part 1 to 6 and IS: 13730-13. Separate documentation for these tests shall be maintained by the manufacturers, indicating the winding wire supply particulars. Kapton covered enameled winding wire conforming to IS: 11395 may also be used.

5.3.9 Impregnation- Vacuum pressure impregnation (VPI) process shall preferable be adopted with Schenectay Beck India's solventless unsaturated polystermide impregnating resin Dobeckan FT 2005/500 EK.

5.3.10 The winding shall be subjected to pressure impregnation as per recommended procedure of varnish manufacturer.

5.3.11 Slot/Interphase insulation- Calendared Nomex 410-Kapton-Calendered Nomex 410 i.e. NKN or Nomex 418 sheet shall be used for slot liner and wedge separator. Uncalendared Nomex (Nomex 411)-Kapton-Nomex 411 sheet shall be used for inter layer and inter phase insulation. The tenderer shall state in his offer the brand names of insulating materials proposed to be used. The material used and insulation system as a whole shall correspond to 'H' class insulation.

5.3.12 The various components of the motor shall be manufactured with such a tolerance so as to enable complete interchangeability of components from one motor to another of same design.

5.3.13 The motor shall be treated suitably for rust and coated with antirust primer and finished with two coats of battleship gray paints.

6.0 APPLICABLE STANDARDS / SPECIFICATIONS

IEC-571-1, IEC 34-5, IEC349-2, IS-4691, IS-1572, IS-513, IS-5, IS-1364, IS-4029, IS-13730 pt13, IS-13778 pt 1 to 6, RDSO's reliability specification no. ELRS/SPEC/SI/0015 (latest).

7.0 EQUIPMENT TECHNICAL REQUIREMENTS OF FUEL PUMP MOTOR WITH BUILT-IN INVERTER

7.1 INVERTER: The inverter shall meet the following requirements:-

7.1.1 Input Voltage (Rated): 72 V DC

7.1.2 Input Voltage Range: 50 V to 90 V DC with 15% ripple. Effect of inverter switching on input DC should not cause ripple current more than 5% at full load. 70% torque should be delivered at 17V DC input voltage. During cranking of loco voltage may dip to 17 V for a short duration. Inverter should not trip during this duration. The input to the AC inverter may be taken directly from the 72 Volt DC battery supply or 72 Volt battery supply can be suitably increased by a DC chopper and then fed in to the inverter.

7.1.3 Output of Inverter: 3ϕ AC

7.1.4 Output waveform: PWM sine wave.

7.1.5 Output frequency: 60 Hz ± 2 Hz in input voltage range 65V to 90 V DC under steady state. V/f control shall be provided for constant torque operation below 65V DC input.

7.1.6 Output power: 1.5HP (Continuous)

7.1.7 Load Power Factor: Expected power factor $\geq$ 0.8 at rated load

7.1.8 Protection:
a) Input under voltage protection (auto reset).
b) Input over voltage (auto reset).
c) Output over load (power on reset).
d) Short circuit (power on reset).
e) Reverse polarity (auto reset).

7.1.9 Cooling: Natural or self-cooled.

7.1.10 Short time rating: Manufacturer shall submit its short time rating for 10 sec duration. This should not be less than 150%.

7.1.11 Input over voltage protection: set at 100 V DC input

7.1.12 Output over load protection: set at 1.5 times the rated current

7.1.13 Reverse polarity: Suitable protection to avoid any damage/adverse effect to the inverter motor set against positive and negative terminals connected in reverse polarity shall be provided.

7.1.14 Control mode: PWM with V/f control

7.1.15 Internal power supply: Wide range SMPS

7.1.16 Power circuit configuration: 3 phase full bridge with ultra fast IGBT/Mosfet.

7.1.17 Control circuit: Micro processor / controller based waveform generator

7.1.18 Harmonic distortion level at full load: Less than 5% upto 20^{th} harmonic (upto 1000 hz) on current.

7.1.19 Efficiency: Shall not be less than 90% at rated input and rated load.

7.1.20 Negative Common electrical system exists on diesel electric locomotive.

7.1.21 Fitment – Inverter shall be fitted directly on the motor.

7.2 AC FUEL PUMP MOTOR:

7.2.1	Quantity:	One no, 3-ϕ AC motor
7.2.2	Rating:	1.5 HP. Continuous
7.2.3	Frequency:	60 Hz ± 2 Hz.
7.2.4	Synchronous speed:	1800 RPM at 72 V DC input voltage.
7.2.5	Slip:	Slip at rated output should be between 3 - 4%.
7.2.6	Actual speed (RPM):	1728 RPM (at 4% slip)
7.2.7	Cooling arrangement:	Self-cooled
7.2.8	Insulation:	Class H
7.2.9	Starting:	On load
7.2.10	Ambient temp.:	55ºC
7.2.11	Type of Winding:	3 phase Delta/Star
7.2.12	No. of poles:	4 poles
7.2.13	Load Power Factor:	$\geq$ 0.8

7.2.14 Mechanical Construction: The mechanical construction of AC motor shall be such that it can be readily fitted on the existing brackets and shall be able to adopt existing fuel pump and governor oil pump on either end of the motor. The motor with inverter should not have any infringement in its existing location on the locomotive. The existing DC motor outline is as per DLW drg no.AM/003.

7.2.15 Short time rating: Manufacturer shall submit its short time rating for 10 sec

duration. This should not be less than 150%.

7.2.16 Efficiency: The overall efficiency of the AC Motor and inverter set should not be less than 80% at full load. The tenderer should indicate the overall efficiency of the motor and inverter set.

7.2.17 Direction of rotation: When connected with the correct polarity, the direction of rotation of the motor shall be same as that of existing DC motor

7.2.18 Vibration level: The vibration level on any part of the motor shall not exceed 15 microns peak to peak.

8.0 EQUIPMENT TECHNICAL REQUIREMENTS OF CRANK CASE MOTOR WITH BUILT IN INVERTER

8.1 INVERTER- The inverter specification shall be same as that of inverter for fuel pump motor except the following:

8.1.1 Input to inverter: Input voltage range 65V to 90 V DC under steady state. V/f control to be provided for constant torque operation below 65V DC input

8.1.2 Output frequency: No exact value fixed. To be indicated in Manufacturer data sheet.

8.1.3 Output power: 0.5 HP (continuous)

8.1.4 Fitment: Inverter shall be directly fitted on the AC crankcase exhauster motor.

8.2 AC CRANK CASE EXHAUSTER MOTOR- The motor specification shall be same as that of motor for fuel pump except the following:

8.2.1 Rating: 0.5HP (continuous)

8.2.2 Output of Inverter: 3ϕ AC

8.2.3 Frequency: No exact value fixed. To be indicated in Manufacturer data sheet.

8.2.4 Synchronous speed: Not more than 3500 RPM at rated voltage 72V DC.

8.2.5 Actual speed (RPM): To be indicated in Manufacturer data sheet (at 4% slip).

8.2.6 Number of poles: 2

8.2.7 Mechanical Construction: The mechanical construction of AC motor shall be such that it can be readily fitted on the existing brackets and shall be able to adopt crank case exhauster blower fan on one end of the motor. The motor with inverter should not have any infringement in its existing location on the locomotive. The existing DC motor is as per DLW drg no-EL/PT/0151.

8.2.8 Blower fan: This should be similar to the blower provided on the

existing DC crankcase motor as per details given in DLW drg no-EL/PT/0151:

i) Blower Capacity: Blower output should not be less than 175 CF/Min. (18.2 m/sec air velocity)

ii) Static Head Vacuum should not be less than 100 mm water gauge.

9.0 EQUIPMENT TECHNICAL REQUIREMENTS OF CYCLONIC FILTER DUST EXHAUSTER BLOWER MOTOR WITH BUILT-IN INVERTER

9.1 INVERTER: The inverter specification shall be same as that of inverter for fuel pump motor except the following:-

9.1.1 Input to inverter: Input voltage range 65V to 90V DC under steady state. V/f control to be provided for constant torque operation below 65V DC input

9.1.2 Output frequency: No exact value fixed. To be indicated in Manufacturer data sheet.

9.1.3 Output of Inverter: 3ϕ AC

9.1.4 Output power: 0.87 HP (continuous)

9.1.5 Fitment: Inverter shall be directly fitted on the AC cyclonic dust exhauster blower motor.

9.2 AC CYCLONIC FILTER DUST EXHAUSTER BLOWER MOTOR- The motor specification shall be same as that of motor for fuel pump except the following:

9.2.1 Quantity: Two numbers

9.2.2 Rating: 0.87 HP (Continuous)

9.2.3 Frequency: No exact value fixed. To be indicated in Manufacturer data sheet.

9.2.4 Synchronous speed: Not more than 3500 RPM at rated voltage 72V DC.

9.2.5 Actual speed: To be indicated in Manufacturer data sheet (at 4% slip).

9.2.6 Number of poles: 2

9.2.7 Mechanical Construction: The mechanical construction of AC motor shall be such that it can be readily fitted on the existing brackets and shall be able to adopt cyclonic dust exhauster blower fan at one end of the motor. The motor with inverter should not have any infringement in its existing location on the locomotive.
The existing DC motor is as per DLW drg no-EL/PT/0277 for Right hand side motor and drg no EL/PT/0276 for Left hand side motor

9.2.8 Blower fan: This should be similar to the blower provided on the existing DC cyclonic filter dust exhauster blower motor as per details given in DLW drg no-EL/PT/0276 and 0277.

9.2.9 Blower Output: Should not less than 650 m^3/ hour (10.96m/sec air velocity)

10.0 TYPE, ROUTINE AND ACCEPTANCE TEST

10.1 Tests are classified as type, routine and acceptance test. These tests shall be carried out at manufacturer's premises and all the instrumentation facilities shall be arranged by manufacturer.

10.2 The type test shall be carried out on one prototype unit. The routine tests shall be carried out on all units. Acceptance test shall be carried out by the inspecting agency for accepting the offered lot. The type test for all the requirements as laid down in this specification shall be done by RDSO and is mandatory for product approval or approval of manufacturer. To ensure consistency in quality, Type test shall be repeated by RDSO after every 5 year interval.

11.0 FIELD TRIAL AND PRODUCT APPROVAL

11.1 In case Inverter driven AC motor is found suitable in type test conducted by RDSO, field trial on diesel locomotives shall be carried out on 2 sets of prototype for a period of two months. Any modification/improvement required in the unit, felt necessary by the RDSO following the fitment and field trials experience on the locomotive shall be carried out by the manufacturer free of cost.

11.2 In case the field trial on locomotive is successfully completed without any problem, the approval of prototype and further trial approval for a limited quantity shall be given for a restricted period to be decided by RDSO. Final approval for series application of the equipment shall be given by RDSO only after extensive use on diesel electric locomotive.

12.0 QUALITY ASSURANCE PROGRAMME & TEST CERTIFICATE

12.1 The manufacturers shall submit their internal quality assurance program to the RDSO/purchaser. The manufacturer shall, on demand by the RDSO/purchaser or any other inspecting agency nominated by the RDSO/purchaser, make the record of checks carried out during internal quality assurance programme available for scrutiny.

12.2 Inspection shall be carried out as per the test program given in this specification. The manufacturer shall afford the inspector necessary assistance required to carry out the test as given in this specification. Manufacturer shall submit two copies of internal test results of the type test carried out as per this specification before offering the prototype unit for type test.

12.3 Manufacturer / Tenderer shall also submit the data as asked in the Annexure

13.0 WARRANTY

The unit shall be warranted for satisfactory and trouble free operation for a period of 2 years from the date of receipt or 18 months from the date of commissioning whichever is earlier.

14.0 MAINTENANCE MANUAL

The manufacturer shall supply free copies of maintenance manual to RDSO/purchasing authority and consignee.

15.0 PACKING AND MARKING

The unit shall be suitably packed in shock/waterproof boxes as to permit convenient handling and to protect against loss or damage during transit and storage. The equipment shall be provided with suitable rating plate for identification giving the following:

i) Manufacturer's name
ii) Type and Serial Number
iii) Date of Manufacture
iv) Rating

16.0 TECHNICAL PARTICULARS AND DRAWINGS

16.1 A complete set of detailed drawings of the equipment (Inverter and AC motors) shall be submitted to RDSO for prior approval. All the technical data, design data, circuit diagrams and other technical parameters concerning each item of inverter and AC small motor shall also be submitted by the manufacturers. The manufacturer shall submit the bill of material to RDSO for prior approval. Once approved this bill of material should not be changed by manufacturer unless approved again by RDSO.

16.2 The tenderer may suggest superior design features if any which can be considered by RDSO/Purchaser based on overall cost benefit and technical superiority of the design proposal, simplicity in design, construction and operational reliability etc.

17.0 TEST PROGRAMME

This test program has been prepared for type/routine/acceptance testing of complete assembly consisting of 3 phase AC small motor with built-in inverter for diesel locomotives.

18.0 TYPE, ROUTINE AND ACCEPTANCE TEST TABLE

S. No	Test	Nature of Test			Clause no
		Type Test	Routine Test	Acceptance test	
Test to be carried out with motor and inverter					
1	Preliminary checking	Yes	Yes	Yes	18.1
2	Direction of rotation	Yes	Yes	Yes	18.2
3	Measurement of cold resistance	Yes	Yes	No	18.3
4	Temperature rise test (Measurement by thermometer) a) One hour heat run b) Continuous heat run	 Yes Yes	 Yes No	 Yes* No	 18.4.2 18.4.3
5	Temperature rise test (Measurement by resistance method) a) One hour heat run b) Continuous heat run	 Yes Yes	 Yes No	 No No	 18.5 18.5
6	Over voltage protection test	Yes	Yes	Yes	18.6
7	Over voltage test	Yes	Yes	No	18.7
8	Over load protection test	Yes	Yes	Yes	18.8
9	Short time rating test	Yes	No	No	18.9
10	Insulation resistance test	Yes	Yes	Yes	18.10
11	Dielectric test	Yes	Yes	Yes	18.11
12	IR test after dielectric test	Yes	Yes	Yes	18.12
13	Reverse polarity test	Yes	Yes	Yes	18.13
14	Performance test	Yes	Yes	Yes	18.14
15	V/f control test	Yes	Yes	Yes	18.15
16	Efficiency test by Losses method	Yes	No	No	18.16
17	Endurance test	Yes	No	No	18.17
18	Vibration & shock test	Yes	No	No	18.18
19	Hose proof test	Yes	No	No	18.19
20	Ripple current test	Yes	No	No	18.20
21	Harmonic level test	Yes	No	No	18.21
Test to be carried with inverter only					
22	Dry heat test	Yes	No	No	18.22
23	Damp heat test	Yes	No	No	18.23
24	Cooling test	Yes	No	No	18.24
25	Combined dust humidity and heat test	Yes	No	No	18.25
26	Surge test	Yes	No	No	18.26
27	Short circuit test	Yes	No	No	18.27
Test to be carried out with motor only					
28	Over speed test	Yes	Yes	No	18.28
29	Locked Rotor Test	Yes	No	No	18.29
30	Inter turn short test	Yes	No	No	18.30
31	Blower Performance Test for AC Crank Case Motor & AC Cyclonic Filter Dust Exhauster Blower Motor	Yes	Yes	Yes	18.31

***** One out of 10 machines offered for inspection by random selection. In case the machine does not pass the test, all the machines will be subjected to this test for acceptance.

18.1 PRELIMINARY CHECKING

18.1.1 The motor shall be checked for proper terminal connections and free movement of the rotor without any noise in the bearings.

18.1.2 The radial play and axial play on the shaft shall be checked against design limits, with a dial gauge.

18.1.3 The stator shall be checked properly for loose connection of leads, inadequate clearance and any other visible defects.

18.1.4 Inverter shall be checked properly for the loose connections of the leads, heat sink fins and other visible defects.

18.1.5 All fasteners shall be checked for tightness.

18.1.6 Physical dimensions of the motors with built-in inverters shall be checked in accordance with the approved drawings.

18.2 DIRECTION OF ROTATION

The direction of rotation of the motors when started by applying a low voltage briefly with the connections as per the terminal markings shall be the same as that marked on the body.

18.3 MEASUREMENT OF COLD RESISTANCE

The resistance of the various windings, when cold, shall be measured by bridge or voltage drop method in accordance with IS: 4029-1991. For the purpose of this test, the motor shall be left in standstill conditions for 24 hours before the measurement. It shall be ensured that temperature of the windings of the motor is within 2 deg. C of the mean temperature of the ambient air. The method of test, voltage, current, resistance values and the winding temperature for each phase (UV, VW, UW) shall be recorded.

18.4 TEMPERATURE RISE TEST (Measurement by thermometer)

18.4.1 The heat sink separately shall be heated from the side it is connected to the device base (device base end). The temperature shall be measured at both the sides of the heat sink (fin end and device base end) at every 5 deg rise of device base end temperature. A graph between the temperature at fin end and device base end shall be plotted. The temperature impedance of the heat sink shall be the slope of the graph so plotted.

18.4.2 Three phase inverter driven motor shall be arranged for normal operation at 72 V DC input to inverter at full load. The temperature rise test shall be carried out in the following sequences:-

18.4.3 <u>One hour Heat Run Test:</u> The motor inverter set shall be allowed to run at 72 V DC input and at full load for one hour. Following parameters shall be recorded after every 15 minutes during the run.

Ambient temperature before start---------

Time	Ambient temp.	Body Temperature of motor	Heat Sink Fins Temp.	Temp. Rise	
				Body	Heat Sinks

The maximum value of temperature rise as recorded on body of motor shall not exceed 80 deg. C with class H insulating material. The maximum heat sink fin temperature shall be noted. The maximum temperature at the device base end shall read from the graph plotted in clause 18.4.1. Manufacturer shall provide the device junction temperature calculations and the value of device junction temperature obtained by calculation shall be 25deg C less than the declared device junction temperature of device manufacturer.

18.4.4 Continuous Heat Run Test: The motor inverter set shall be allowed to run at 72 V DC input and at full load for continuous heat run for maximum temperature rise of the machine. The motor shall run continuously till the motor temperature is stabilized i.e. when last three readings are same. Following parameters shall be recorded after every half an hour-

Time	Amb. Temp.	Body Temperature of motor	Heat Sink Fins Temp.	Temp. Rise	
				Body	Heat sink

The maximum value of temperature rise as recorded on body of motor shall not exceed 80 deg. C with class H insulating material. The maximum heat sink fin temperature shall be noted. The maximum temperature at the device base end shall read from the graph plotted in clause 18.4.1. Manufacturer shall provide the device junction temperature calculations and the value of device junction temperature obtained by calculation shall be 25deg C less than the declared device junction temperature of device manufacturer.

18.5 TEMPERATURE RISE TEST (Measurement by resistance method)

18.5.1 At the end of each test given in clause 18.4.3 and 18.4.4 i.e. one hour heat run and continuous heat run, the temperature rise of each of the stator windings of motor shall be calculated by the resistance method given below.

18.5.2 The hot resistance of the stator windings shall be measured immediately after switching off the motors (in any case, not later than 30 seconds) and subsequent measurement shall be carried out at intervals not exceeding 15 seconds for the first 2 minutes and 20 seconds for the next 3 minutes.

Time		**Hot resistance between UV**	**Time**		**Hot resistance between VW**	**Time**		**Hot resistance between UW**
Min.	**Sec.**		**Min.**	**Sec.**		**Min.**	**Sec.**	

18.5.3 The maximum temperature rise of the winding shall be just after switching off the motor. Thus the hot resistance has to be found out immediately after the motor is

switched off. But it is practically not possible to measure the hot resistance immediately after the motor is switched off. To overcome the above difficulty the temperature rise shall be calculated for all the readings recorded above and for all the three phases (UV, VW, UW) a graph between time and temperature rise calculated shall be plotted. The temperature rise at the zero time shall be found by extrapolating the curve so plotted to zero time point. The temperature rise so obtained at zero time for each winding shall not exceed 80 deg C.

18.5.4 Method of calculation of Temperature Rise by Hot Resistance Method

Formula: $\frac{\text{Hot Resistance per Phase}}{\text{Cold Resistance per Phase}} \times (235 + \text{Tamb.}) = 235 + \text{Tamb.} + \text{Trise}$

Tamb. = Ambient temperature

Trise = Temperature rise

18.5.5 The continuous heat run test shall be done again on the motor (without inverter) fed by industrial AC supply and temperature rise of the each of the stator winding of motor shall be calculated by the resistance method. The difference in temperature rise of winding with and without inverter shall not be more than 2 ºC.

18.6 OVER VOLTAGE PROTECTION TEST

The motor inverter set shall trip at 100 V DC input voltage. The unit shall work satisfactorily after completion of this test.

18.7 OVER VOLTAGE TEST

The inverter driven motor working at full load shall be subjected to an input DC voltage of 100 volts for a period of five minutes. This test shall be done after bypassing the over voltage protection of inverter. The unit shall work satisfactorily after completion of this test.

18.8 OVER LOAD PROTECTION TEST

The motor inverter set shall trip at 1.5 times the rated current. It shall work satisfactorily after completion of this test.

18.9 SHORT TIME RATING TEST

The motor inverter set shall satisfactorily withstand for 10 sec at rated voltage, a current equal to minimum of 1.5 times the rated current or the short time current value as declared by manufacturer. This test shall be done after bypassing the overload protection of inverter. The motor inverter set shall work satisfactorily after completion of this test.

18.10 INSULATION RESISTANCE (IR) TEST BEFORE DIELECTRIC TEST

Insulation resistance value of the motor with inverter shall be measured and recorded. It should not be less than 10 mega ohms.

18.11 DIELECTRIC TEST

This test shall be carried out on motor and inverter separately. The test voltage shall be alternating sine wave, frequency being 50 Hz to 60 Hz. For motor a test voltage of RMS value of 1.2 KV shall be applied for a period of one minute between AC winding of each phase and the frame. For inverter a test voltage of RMS value of 1.2 KV shall be applied for a period of one minute between shorted connections and frame. The motor/inverter shall be connected at a voltage of less than one third of test voltage and shall be increased gradually to the full test voltage. The test shall be considered satisfactory if neither a disruptive discharge nor a flash over occurs.

18.12 IR TEST AFTER DIELECTRIC TEST

Insulation resistance of the motor with inverter shall be measured after the dielectric test and there shall be no appreciable difference between the two values, one before the test and one after the test.

18.13 REVERSE POLARITY TEST

The motor inverter set shall be connected to 72 volts DC input supply in reverse polarity for a period of 2 minutes. This shall be followed by 100 ON and OFF cycles (each cycle consisting of 90 sec ON and 30 sec OFF). At the end of the test, the motor inverter set shall work satisfactorily when the connections at the input are restored to correct polarity.

18.14 PERFORMANCE TEST

The motor inverter set shall be mechanically loaded according to its rating. The performance characteristics shall be observed at 65 V, 72V and 90 V DC input to inverter. The following parameters shall be recorded:-

a) Input DC voltage to inverter (Vdc).
b) Input DC current to inverter (Idc).
c) Output AC volts of inverter (Vac).
d) Output AC current of inverter (Iac).
e) RPM
f) Input frequency in Hz.
g) Torque in Kgm.
h) Power factor
i) HP(of motor) to be calculated by formula $HP = \frac{2\pi \times RPM \times Torque(in\ Kgm)}{4500}$

j) Efficiency of complete set to be calculated by formula $\eta = \frac{746 \times HP \times 100}{Vdc \times Idc}$ %

k) Calculate Inverter efficiency= $\sqrt{3}\frac{Vac \times Iac \times Power\ factor}{Vdc \times Idc}$

The output AC volts of inverter, input frequency, power factor recorded at 65 V, 72V and 90 V DC input to inverter shall be within the design limits. The HP (of motor), efficiency of complete set, inverter efficiency calculated at 65 V, 72V and

90 V DC input to inverter shall not be less than the design values.

18.15 V/f CONTROL TEST

The inverter motor set shall be mechanically loaded according to its rating. The voltage shall be varied from 20V to 65V (17 V to 65 V for AC Fuel Pump Motor) in steps of 10 Volts. The following parameters shall be recorded:-

1. Output AC volts of inverter (Vac).
2. RPM
3. Input frequency in Hz.
4. Torque in Kgm.

The ratio Vac/f shall be calculated. The values so obtained shall be within $\pm$20% of nominal value. The torque measured shall not be less than 70 % of full load torque.

18.16 EFICIENCY TEST BY LOSSES METHOD

A. The motor inverter set shall be mechanically loaded according to its rating at 72V DC. The following parameters shall be recorded:-

   a. Input DC voltage to inverter (Vdc).
   b. Input DC current to inverter (Idc).
   c. Input AC volts to motor (Vac).
   d. Input AC current to motor (Iac).
   e. RPM (N)
   f. Power factor

B. The motor inverter set then shall be run without load at 72V DC. The following parameters shall be recorded:-

   a. No load Input DC volts to inverter (Vnl dc).
   b. No load Input DC current to inverter (Inl dc).
   c. No load Input AC current to motor (Inl ac)

Following calculations shall be done-

Inverter η	$= \sqrt{3}\frac{Vac \times Iac \times powerfactor}{Vdc \times Idc}$
Input power to inverter	=Vdc X Idc
Input power to motor	= out put power of inverter = Input power to inverter X Inverter η
Friction & winding loss (F&W loss)	= 5 % of rated HP
No load input power	$= V_{nl}$ dc X I_{nl} dc
No load losses	= No load Input power x Inverter η
Rc	=Average Hot resistance per phase (as calculated in clause 18.5.3)
Total No load I^2R loss	$= 3/2(I_{nl} ac)^2 \times Rc$
Fixed losses	= No load losses-Total No load I^2R loss-F&W loss

Total I^2R stator loss	= 3/2 (Iac) ^{2}xRc
Total stator loss	= Total I^2R stator loss +Fixed losses
Rotor Input	=Input power to motor –Total stator loss
Slip	=(Ns-N)/Ns
Rotor loss	= Rotor input X Slip
Output power	=(Rotor input-Rotor loss-Friction & winding loss)
Efficiency of complete set	= Output power/Input power to inverter

The efficiency of complete set calculated shall not be less than design value.

18.17 ENDURANCE TEST

The motor with inverter at 72 V with its driven load shall be kept in a heat chamber for subjecting it to endurance test at 55 degree centigrade for a period of 100 hours. After completion of this test, it should be checked for any adverse sign.

18.18 VIBRATION, SHOCK& BUMP TEST

18.18.1 The motor with inverter shall be subjected to this test in three orthogonal planes, under ambient temperature condition of the testing area, the maximum acceleration of shocks shall be equal to 3g in each of three directions, longitudinal, transverse and vertical. For this test, the equipment is secured in a suitable position to a machine producing vibrations of sinusoidal form with adjustable amplitude and frequency. The method of carrying out these tests is as per clause 18.18.2

18.18.2 Determination of resonant frequencies:

In order to determine the possible existence of critical frequencies producing resonance, the frequency shall be varied progressively from 1Hz to 100 HZ within a time of not less than 4 min. The amplitude of the oscillations ‘a’ expressed in mm shall be given as a function of ‘f’ by the equations

a = 25/f for values of ‘f’ between 1 Hz to10 Hz.
a = 250/f^2 for values of ‘f’ between 10 Hz to100 Hz.

If resonance is produced, the corresponding frequency shall be maintained for 4 minutes in each case.

18.18.3 Test with Sustained Vibrations:

The equipment with power applied shall be subjected with sustained vibrations for a

period of a minimum 8 hours in all the three directions at the frequency:

- Either at the critical frequencies, if any such well-defined frequency has been detected
- Otherwise at a frequency of 10 Hz

In both the cases, the amplitude of the vibrating table shall be adjusted to the value corresponding to the frequency concerned.

18.18.4 Test to simulate the effect of shunting shocks:

The equipment with power applied shall be subjected to a series of three successive shocks at 50 Hz vibrations each corresponding to a maximum acceleration of 3g in all the three direction.

18.18.5 Results of tests:

The tests are considered to be satisfactory if there is no resulting damage or abnormality in operation. The equipment shall be able to withstand successfully the performance test and dielectric test as per clause 18.14 and 18.11.

18.19 HOSE PROOF TEST

The inverter shall be tested as per IS 4691 and shall conform to IP65. Motor shall be tested as per IS 4691 and shall conform to IP54. Inverter and motor shall work satisfactorily after completion of this test.

18.20 RIPPLE CURRENT TEST

The inverter motor set shall be loaded according to its rating at 72V. The ripple current at input DC shall be measured. The ripple current recorded shall not be more than 5%.

18.21 HARMONIC DISTORTION LEVEL TEST

The inverter motor set shall be loaded according to its rating at 72V. Harmonics generated at the inverter output shall be measured and harmonic distortion level in % shall be less than 5% up to 20^{th} harmonic (up to 1000 hz) on current.

18.22 DRY HEAT TEST (Clause 5.6 of IEC-571-1)

The inverter with power applied shall be placed in a test chamber where the temperature is progressively raised from the ambient to 70 ± 2 deg centigrade over a period of half an hour. The unit shall be kept in this condition for 6 hours. At the end of this period, performance test shall be carried out and the requirements specified in the clause 18.14 should be met.

18.23 DAMP HEAT TEST (Clause 5.7of IEC-571-1)

The inverter without power applied shall be placed in a test chamber where the temperature is progressively raised from the ambient to 55 ± 2 deg centigrade over a period of 1.5 to 2.5 hours, the relative humidity being between 95% and 100%. The

unit shall be kept in this condition for 10 hours. At the end of this period, the temperature is lowered to the ambient temperature over a period of 3 hours, relative humidity being between 95% and 100%. After the end of this period, the performance test and dielectric test shall be carried out and the requirements specified in the clause 18.14 and 18.11 should be met.

18.24 COOLING TEST (Clause 5.5 of IEC-571-1)

The inverter shall be placed in a chamber where the temperature is progressively lowered from the ambient to –10°C over a period of at least half hour. The inverter shall be kept in this condition for 2 hours. After this test, the performance test shall be carried out and the requirements specified in the clause 18.14 should be met.

18.25 COMBINED DUST HUMIDITY AND HEAT TEST (Clause 5.9 of IEC-571-1)

The inverter with power applied shall be placed in a test chamber where the temperature is progressively raised from the ambient temperature to 70$\pm$2 °C in a period of time between 1.5 hr. and 2.5 hr. with a relative humidity of 95% to 100%. Quantity of dust mutually agreed shall then be sprayed over the equipment. At the end of this test, the performance test and dielectric test shall be carried out and the requirements specified in the clause 18.14 and 18.11 should be met.

18.26 SURGE TEST (Clause 5.4 of IEC-571-1)

Inverter shall be subjected to transient non repetitive surge between the supply points at 1.8 KV for 45µsec duration (using capacitor discharge circuit). The surge voltage shall be applied in both positive and negative direction. The test shall be considered satisfactory if the equipment continues to operate without malfunction or damage both during and following application of the voltage surge. After this, the performance test shall be carried out and the requirements specified in the clause 18.14 should be met.

18.27 SHORT CIRCUIT TEST

The inverter shall be loaded according to its rating. A short circuiting contactor shall be connected in parallel with the load. The short circuiting contactor shall be closed after the normal current through the load has been recorded for one minute. The resulting fault current shall be detected and cleared by the protective circuit of inverter. Inverter shall work satisfactorily after completion of this test.

18.28 OVER SPEED TEST

The motor shall be run at a speed of 1.25 times the rated speed for a period of 2 minutes. The motor shall work satisfactorily after completion of this test.

18.29 LOCKED ROTOR TEST

Locked rotor test shall be conducted at 38V, 40V, 42V AC input supply to motor. This test shall be done with four position of rotor 90 degree apart. Input Current drawn by

motor and Torque available shall be recorded. The value of Input Current drawn by motor shall not be more than the declared value of starting current given by manufacturer. The value of starting torque obtained shall not be less than the declared value of starting torque given by manufacturer.

18.30 INTER TURN SHORT TEST

The motor stator winding shall be tested for inter turn short (without its rotor in position) at test voltage of 2 KV (peak to peak). There should not be any interturn short on the stator.

18.31 BLOWER PERFORMANCE TEST:

Air velocity at the outlet will be measured; it should not be less than under mentioned data:

Motor	Static Head	Blower Output
AC Crank Case Motor	100 mm	Should not be less than 175 CF/ M (18.2 m/sec air velocity)
AC Cyclonic Filter Dust Exhauster Blower Motor		Should not be less than 650 cubic met/hour (10.96 m/sec air velocity

Annexure

Data to be furnished by Manufacturer / Tenderer

INVERTER

1 Continuous rating (voltage , current, output power)
2 Short time rating for 10 sec duration
3 Protections provided
4 Ripple current at input
5 Output wave shape and % harmonics at full load
6 Switching device
-type
-make
-rated voltage & current
- characteristics curve
-maximum permissible junction temp for the device as given by device manufacturer
-Maximum heat sink temperature
7 Type of protection of cabinet
8 DC output of DC chopper (if applicable)

MOTOR

1 Application
2 Type of induction motor
3 Rated voltage, current
4 Type of connection -Star/Delta
5 Frequency
6 Speed
7 Continuous rating HP
8 Short time rating
9 Slip at full load in percentage at rated voltage
10 Class of insulation of winding
11 Type of enclosure
12 Method of ventilation
13 Type of protection
14 Frame size
15 Overall dimension of complete motor inverter set
16 Type and make of bearing
17 Size of bearing and their estimated L10 life
18 Rotor construction
19 Starting current and torque in kgm
-at 38V AC
-at 40VAC
-at 42 VAC
20 Type of Enameled wire used as per IS 13730 Pt 13
21 Brand name of insulating material proposed to be used
22 Overall efficiency of motor inverter set
23 Weight of inverter motor set