WATER SUPPLIES DEPARTMENT

STANDARD SPECIFICATION E-51-01

LOW VOLTAGE SQUIRREL CAGE INDUCTION MOTORS OF 140 kW AND ABOVE

1 TECHNICAL REQUIREMENTS

1.1 General

This standard specification is for low voltage squirrel cage induction motors of rating 140 kW and above.

The motor shall comply with the following requirements:

(a) Type : Energy efficient squirrel cage induction motor to Class IE2 of IEC 60034-30 with the following minimum full load efficiency measured according to IEC 60034-2-1 :

Rated output (P)	Minimum motor efficiency
140 – 159 kW	94.7 %
160 – 199 kW	94.9 %
200 kW and Above	95.1 %

(b) Degree of protection : Totally enclosed IP 55 to IEC 60034-5.

(c) Duty rating : Maximum continuous rating (MCR), S1 duty to IEC 60034-1.

(d) Insulation : Class F design with temperature rise not exceeding the limit applicable to Class B in IEC 60034-1.

(e) Max. speed : 1500 rpm at 50Hz.

(f) Noise level : Mean sound power level (Lw) in dB(A) for airborne noise emitted by motor not to exceed the limits in Table 2 of IEC 60034-9.

(g) Vibration level : Grade A of IEC 60034-14

1.2 Operating Conditions

(a) Altitude : not greater than 1,000 metres

(b) Ambient temperature : 40 ^{o}C maximum continuous for 4 hours.
30 ^{o}C average over any 24 hours.

5 ^{o}C minimum.

(c) Humidity : Up to 98% relative humidity.

1.3 Electrical Conditions

(a) Electricity supply : 380V 3 phase, 50 hertz, 4-wire system with solidly earthed neutral.

(b) Voltage variation : ±6%.

(c) Frequency variation : ±2%.

1.4 Standards

The equipment supplied shall comply with the latest version of the relevant international Standards and Codes of Practice. In particular, the following Standards are applicable :-

(a) IEC 60072 Dimensions and output series for rotating electrical machines

(b) IEC 60034 Rotating electrical machines

(c) IEC 60085 Evaluation and thermal classification of electrical insulation

(d) IEC 60751 Industrial platinum resistance thermometer sensors

(e) ISO 281 Rolling bearings - Dynamic load ratings and rating life

1.5 Starting Performance

The motor shall be suitable for both direct-on-line and reduced voltage assisted starting. Direct-on-line starting current at rated voltage shall not exceed seven times the full load current.

The starting time (time taken to attain 90% of the rated speed) under the most arduous conditions shall be as follows:

85% rated voltage at motor terminals - not more than 4 seconds.

49% rated voltage at motor terminals - not more than 10 seconds.

At the lowest specified voltage across the motor winding (i.e. 49% rated voltage), the accelerating torque at any speed up to the peak torque point shall be not less than 10% of the motor rated full load torque.

The motor shall be suitable for two starts in succession followed by a cooling period of 30 minutes before attempting another starting sequence. The motor shall also be

capable of at least three starts per hour, equally spaced, under normal operating conditions.

1.6 Running

Motors shall be capable of operating continuously at any voltage in the range 94 - 106% of rated voltage and at any frequency between 49-51 Hz. The motor shall be capable of operation at full load with 75% rated voltage at 50 Hz for a period of 5 minutes without injurious heating.

1.7 Transient Recovery

The motor shall be capable of recovering normal operation in the event of a system disturbance causing temporary loss of supply voltage for periods of up to 0.2 seconds (fault clearance time) followed by a sudden restoration initially to 80% rated voltage. At this voltage, the motor shall be capable of accelerating to ultimate recovery under the most arduous load conditions, e.g. open fan vane, open pump discharge valve, speed controller in maximum speed position, etc.

2 RATING

The rated motor power output shall be not less than 120% for fresh water pumpset and 115% for salt water pumpset of the maximum power absorbed by the pump over the entire pump operating range specified. The foregoing power margin shall not be reduced by any factors such as tolerances of pumpset or accuracy of test equipment.

The uncorrected power factor of the motor shall be not less than 0.85 lagging at full load.

When used in conjunction with a variable speed drive (VSD) or inverter supply, the motor shall be suitably de-rated to account for the reduced cooling effect of the motor fan. Moreover, the motor shall be designed with reference to IEC TS60034-17 or other equivalent standards to withstand over-voltage, higher rate of rise of voltage, over-heating due to harmonics, flow of bearing current and other stressing effects arising from the pulse width modulated (PWM) waveform of the supply voltage.

3 DESIGN AND CONSTRUCTION

3.1 Enclosure

Dimensions and frame numbers of motors shall comply with IEC 60072.

Motors for driving pumpsets of the same capacity and supplied under the same contract shall be interchangeable.

The motors shall have cast iron casings. Acoustic enclosures shall not be used.

The frame design of motor shall facilitate easy removal of rotor assembly and allow motor stator winding repair/cleaning to be carried out. Lifting lugs and other lifting gear shall be provided for easy handling during erection or maintenance.

The colour of final coat of the motor shall be same as the pump.

3.2 Ventilation and Cooling

Motors shall be designed for method of cooling IC411 to IEC 60034-6.

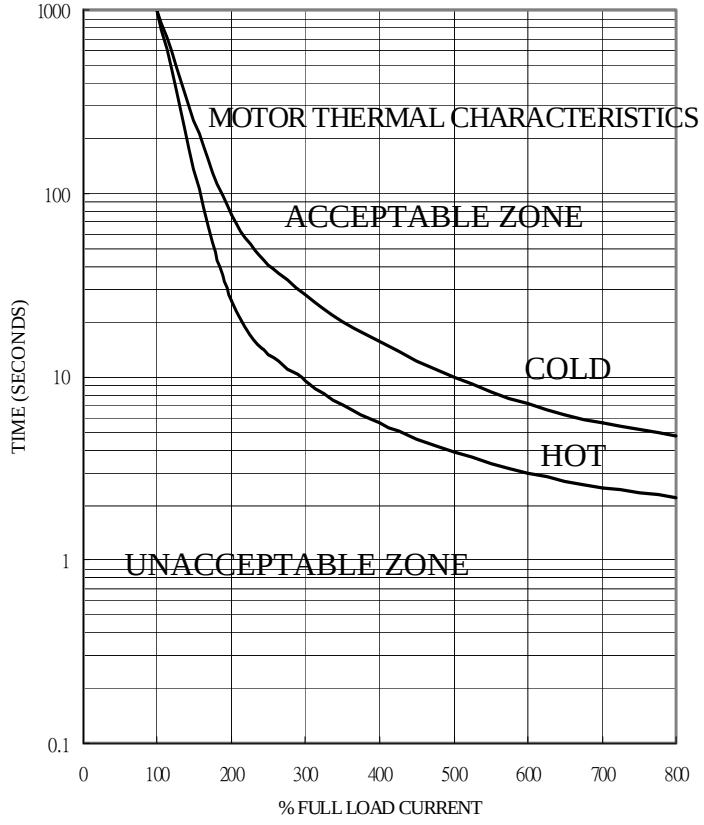
The motor air inlet shall normally be arranged to draw ventilating air directly from the surroundings.

The motor ventilating fan at non-drive end (NDE) shall be directly driven by the motor, i.e., with no auxiliary power supply required and complete with a detachable steel fan cover. The motor shall be designed such that at the worst operating condition and rated output, the maximum casing temperature is less than 35 ^{o}C above the ambient.

3.3 Class of Insulation and Thermal Characteristic

The motor windings and accessories shall be designed for Class F insulation with Class B maximum temperature rise limit to IEC 60034-1.

The motor thermal characteristic shall be within the acceptable zone as shown in the graph below. If the maximum temperature rise is limited by the rotor, this shall be stated.



Motor Short-time Overload Withstand Characteristic

3.4 Stator Winding

The stator winding shall be designed for a minimum life of 25 years of service at rated load and voltage. All winding coils shall be adequately supported, braced and blocked to provide sufficient rigidity during all conditions of service.

Motors shall be designed to permit high voltage tests to be conducted after erection on site in accordance with IEC 60034-1.

Natural rubber insulated cables shall not be used for connection between the stator winding and motor terminals.

The stator winding shall be insulated by vacuum pressure impregnation (VPI) process. Alternatively, trickle impregnation process shall be acceptable provided that the motor insulation complies with the functional requirements of the latest IEC 60034-18-1.

3.5 Rotor

3.5.1 Vibration Level

The limits of vibration during works testing shall not exceed the limits of Grade A specified in IEC 60034-14. The limits shall also be applicable to vertically mounted motors, notwithstanding that the standard applies normally to horizontally mounted motors only.

3.5.2 Dynamic Balancing

Each rotor shall be dynamically balanced to confirm that vibration levels are within the specified limit.

3.6 Bearings

Bearings shall be of metric sizes. Ball or roller bearings to ISO 281 shall be used. Vertical shafts shall have thrust and guide bearings of the approved types.

Consideration shall be given to bearing service life, noise, losses and maintenance convenience in the selection of bearings. The life associated with 90% reliability (L10 life) of the bearing shall be not less than 50,000 hours under the most onerous conditions.

Bearings shall be easily accessible for inspection and shall be liberally rated to ensure cool even running. Bearings shall be suitable for reverse rotation at the normal running speed.

Bearings shall be adequately lubricated by grease and sealed against leakage of lubricant along the shaft. Construction shall be such that bearings can be dismantled and reassembled without risk of damage.

The bearing assembly shall be designed to exclude the ingress of dust and water. It shall be provided with a grease relief device such that when the motor runs at its rated speed any surplus grease is ejected out of the motor casing.

Housing for ball/roller bearings shall be packed with suitable lithium-based grease at the time of delivery. The re-lubrication interval shall not be less than 4000 hours.

Nipples for lubrication purposes shall be in accordance with ISO 6392 or other industrial standards.

Grease nipples shall be readily accessible without removal of guarding. Where necessary, these may be remotely mounted at a point as near as practicable to the lubrication point.

3.7 Motor Foundation

A motor bedplate/foundation block shall be provided unless the motor is to be mounted on the soleplate of the pump. Provision shall be made for fitting jacking screws to facilitate alignment of the coupling.

Vertical motors shall be designed for flange mounting on a detachable motor stool to be supplied with the motor.

3.8 Lifting

The complete motor shall be capable of being dismantled or reassembled by the use of one electric overhead crane.

Heavy parts of the motors shall be provided with a suitable arrangement for lifting and handling during erection and overhaul. Details of the arrangements shall be included in the instruction manual. Components to be removed during maintenance which weigh 1,000 kg or more shall be marked with their respective weights.

3.9 Provision for Cabling

3.9.1 Cabling provision at bedplates

Where necessary, provision of a slot shall be made in the steel bedplate to facilitate vertical entry of cables to the bottom of the motor terminal box.

3.9.2 Cabling provision at cable boxes

The termination box for a horizontally mounted motor shall be positioned at the top of the motor with the cable end box angled downwards to facilitate cable entry from below. The terminal box shall be diagonally split to enable quick and easy installation and maintenance.

The orientation and the position of the cable box shall be confirmed prior to manufacture.

An earthing terminal, outside the cable box, with the same current carrying capacity as the line terminals but not smaller than that suitable for the termination of a 50 x 6.3 mm copper strip shall be provided. A tapped hole with screw external to the cable box would be acceptable.

Permanent terminal markings and direction of rotation in accordance with IEC 60034-8 shall be provided in the cable boxes.

3.9.3 Cabling Provision at Motor Casing

The terminal leads from the cable box to the winding shall be adequately braced to withstand the forces produced by maximum fault current.

3.9.4 Main Cable Termination

Motor terminations shall generally be suitable for use with the motor supply cable sizes given in Table 1 below (based on installation in enclosed cable trenches). The correct size of cable to be used shall be confirmed prior to manufacture of the motor.

Table 1 - Power Supply Cable and Terminations

Stranded Copper Size mm^2	Type of Cable	Max. Motor Full Load Current Amp.		Compression Fitting Palm Width (max.) mm	Terminal Stud Centre Lines (min.) mm	Stud to Gland Plate Dimension (min.) mm
		1 Cable	2 Cables			
70	XLPESWAPVC 3 core	-	278*	30	44	225
95		-	342*	35	49	255
120		-	394*	40	57	280
150		-	459*	45	62	315
185		302	524*	50	67	355
240		358	619*	52	72	400
300		408	-	57	77	450
300	XLPEAWAPVC 3 x 1 core	455	788	57	77	450
400		499	863	65	85	450
500		553	958	70	90	500
630		608	1050	75	95	500

*Note : This is applicable to star-delta starting motor for which each of the supply cables will share 0.577 of the motor rated full load current.

3.10 Cable Termination Box

3.10.1 General Construction

The cable termination box shall comprise an air insulated termination chamber and a cable end box. The degree of protection of the cable termination box shall be IP 55 to IEC 60529.

The cable termination box shall be fabricated from mild steel plate of minimum 4 mm thickness. Cast iron boxes are not acceptable.

Joints shall be machined flat and fitted with neoprene rubber gaskets.

The insulation of terminals, connectors, cables and conductors shall be of moisture-resistant homogeneous materials, e.g. butyl rubber, PVC, PVC thermo-shrinking tubing.

The cable termination box shall allow sufficient space for cable termination and be designed with clearance and mounting suitable for use with heat-shrinkable PVC cable termination for the incoming power supply cable.

3.10.2 Termination Chamber

Both ends of the three-phase winding shall be brought out and terminated on six insulated stud connectors in the termination chamber. Copper links shall be provided by the manufacturer and connected for direct-on-line starting. The terminal bases of the six-terminal cable box shall be in staggered, 2-tier, slanted or other suitable formation to facilitate easy cable termination.

Studs shall be so fixed as to prevent them from turning when the nuts are tightened down. Means shall be provided to prevent slackening of cable connections due to vibration.

The stud connector insulation shall be of epoxy resin, phenolic resin, glass-fibre polyester or other approved high-pressure moulding. Porcelain insulators are not acceptable.

Current carrying studs and sockets shall be of hard-drawn cadmium copper with the socket portion locally annealed for crimping.

Detachable polycarbonate plastic shrouds shall be fitted over each insulated connector. Polycarbonate plastic shrouds shall be of minimum wall thickness of 1.6 mm and minimum breakdown voltage of 1 kV.

The termination chamber shall be provided with a front access cover and shall be bolted to the motor frame with M10 high tensile steel studs and nuts. The minimum clearance from the stator casing shall be 130 mm to allow access to the rear fixing nuts.

3.10.3 Cable End Box

The cable end box shall be fixed to the termination chamber by means of M8 or M10 high tensile steel bolts or studs and nuts.

The cable end box shall be provided with a front access cover.

The cable box shall be arranged for bottom entry of cables and with a detachable brass gland plate.

Cable tails at the junction between the cable gland plate and the insulated stud connectors shall be held in place by a tufnol or laminated densified wood (permali) cable spacing block with bolts and nuts.

3.10.4 Clearance and Creepage Distances

Electrical clearance and creepage distances inside cable box shall comply with Table 2 below. These clearance and creepage distances shall also apply to terminals or connectors which have to be insulated on site, and shall apply even if the terminals or connectors are fully insulated but are not intended to apply to permanently insulated conductors.

Table 2 - Clearance & Creepage Distances

Motor Rating (kW)	Minimum Clearance between phases & to earth (mm)	Minimum Creepage Distances over Bushings and Surfaces Resistant to Tracking (mm)
up to 199	12.5	19.0
200 and above	19.0	25.0

3.10.5 Cable Lug

Cable lugs specifically designed for the motors shall be supplied for the motor supply cables.

3.11 Rotor Locking Device

A rotor locking device shall be fitted in the motor prior to shipment for protecting the bearings against damage during transport. The device shall be of robust design and be reusable for future maintenance.

3.12 Markings and Data Plates

An instruction plate and a data plate of stainless steel shall be provided. Lettering and numerals shall be either stamped or embossed. Data plates with lithographed or painted-on information are unacceptable.

The instruction plate shall give the connections and phase rotation for the required direction of rotation.

The data plate shall be stamped with all information required by IEC 60034-1. The minimum coolant (air) quantity shall also be marked.

The motor serial number shall be stamped with metal dies on the driving-end shaft face of the motor in addition to being stamped on the stator.

4 PROTECTIVE EQUIPMENT

4.1 Embedded Temperature Detectors (ETD)

A set of six Embedded Temperature Detectors complying with IEC 60034-11, complete with monitoring units shall be provided to afford Class II Protection for the motor.

3-wire Resistance Temperature Detectors (RTD) shall be used. The monitoring unit shall incorporate a winding temperature indicator in addition to the alarm and trip contacts.

The ETD monitoring units shall be mounted in the pumpset instrument panel provided per Clause 5.1 and shall incorporate the following features:

(a) Alarm contacts to operate at 120 ^{o}C
(contacts rated at 2A inductive, 220V a.c.)

(b) Trip contacts to operate at 140 ^{o}C
(contacts rated at 2A inductive, 220V a.c.)

(c) Power supply - 220V a.c.

(d) Terminal blocks for the necessary connections.

4.2 Bearing Temperature Detectors and Indicators

Thermometer pockets shall be provided on each bearing to enable insertion of a test thermometer, 3-wire RTD complying with IEC 60751 Grade 2 shall be provided to monitor the temperature of each motor bearing. The RTD shall be supplied with a 220V a.c. powered monitoring unit and provided with independent alarm and trip volt free contacts. The alarm and trip setting shall be adjustable. The monitoring unit shall be installed in the pumpset instrument panel and shall provide a suitable output for the temperature indication.

5. AUXILIARY EQUIPMENT

5.1 Pumpset Instrument Panel

An individual instrumentation panel shall be provided for each pumpset. The panel shall be rectangular, free floor standing, fabricated with sheet steel of a minimum thickness of 2 mm, suitably braced to afford rigidity. It shall have a rear or side hinged access door with chromium plated car-type handle. The degree of protection shall be IP 55 to IEC 60529. All indicating instruments shall be flush mounted with the front panel.

The panel shall be mounted adjacent to the motor.

The following equipment shall be mounted in this panel:

(a) Motor winding temperature indicators and monitoring units

(b) Motor bearing temperature indicators and monitoring units

(c) Pump bearing temperature indicators and monitoring units

(d) No-flow switch monitoring unit

(e) Emergency stop button (with two latched change-over contacts)

(f) Key-operated start and stop buttons for pumpset (with two sets of latched change-over contacts)

(g) Isolation switch and protection fuses for A.C. supply

(h) Anti-condensation heater complete with isolation switch and thermostat

(i) Motor running indication beacon (green – ‘running’, red – ‘stopped’)

(j) Sufficient terminals (including terminals for connection of start, stop and emergency stop buttons) for external cable connections

(k) A brass gland plate with cable glands for cable termination to the pumpset instruments

5.2 Auxiliaries

5.2.1 Spreader, Slings and Tools

General and special maintenance tools shall be supplied.

Special tools required for the dismantling, reassembly and maintenance together with the necessary slings and spreaders for transport of the motor and its components shall be supplied. All lifting gear shall be tested, examined and certified by competent personnel in accordance with statutory requirements prior to handing over to WSD.

5.2.2 Anti-condensation Heaters for Motor

Anti-condensation heaters suitable for operation on a 220V, single phase, 50 hertz, supply shall be fitted in the motor.

Motor anti-condensation heaters shall be designed to permit replacement of the unit. Heater elements shall be of a rating such that the temperature measured at the motor casing at any point shall be 2 ^{o}C – 15 ^{o}C above the ambient temperature. Heaters shall be designed to provide even heating to the motor winding.

A separate termination box shall be supplied for the anti-condensation heater. The box shall be provided with terminals for 2.5 mm^2 2-core PVCSWAPVC cable and a warning label “Separate Supply for Space Heater – Isolate Before Opening this Lid”.

5.2.3 Marshalling Box for Protective Devices

Protective devices mounted on the motor shall be wired to an IP 55 marshalling box mounted on the motor casing. Screen cables or special temperature compensation cables, where required, for connection between the box and the pumpset instrument panel shall be supplied in sufficient length and terminated to the motor.

5.2.4 Small Wiring

Wiring shall be in accordance with Waterworks Standard Specification E-00-01 except where modified herein.

High temperature insulation shall be provided on all wiring where contact with heated parts of the motor is anticipated.

Wiring in conduits shall not be used. Wiring shall be run in a manner which enables its being checked without the removal of cleats.

An allowance shall be made on the length of each wire at the point of connection to the terminal in order to permit the cutting off and re-making of the wire terminations without causing a disturbance to the main run of the wiring.

Wires shall be coloured black for a.c. connections, grey for d.c. connections and yellow/green for earth connections.

Ferrules shall be fitted for each wire core such that they would not be detached unintentionally when the wire is removed from the terminal.

6. INSPECTION AND TESTING

6.1 Inspection and Testing at the Manufacturer's Works - General

The motors shall be inspected and tested at the manufacturer’s works prior to shipment under the witness of the Independent Inspection Body.

Indicating meters (ammeter, voltmeter, wattmeter etc.) used during tests shall be of accuracy ±0.5% or better. The calibration results of these instruments shall be provided to the Independent Inspection Body for inspection and included in the test

report.

The inspection work shall in general cover the following:

(a) General inspection checks including physical dimensions, workmanship, quality, quantity, and standards.

(b) Check on model and nameplate data.

(c) Functional checks of correct operation, alarms, indications and setting of equipment.

(d) Routine and basic tests as specified in Clause 6.2 below.

(e) Packing and protection checks.

Inspection reports/certificates with description on test arrangement, circuits, calculations, and test results shall be forwarded to WSD immediately after the inspection.

Type tests on equipment and standard calibration tests on instruments/equipment by manufacturers shall not form part of the normal inspection and hence need not be witnessed by the Independent Inspection Body.

6.2 Motor Tests

6.2.1 General

Tests conducted at the manufacturer's works shall be in accordance with IEC 60034. No positive tolerance from specified limits shall be allowed for noise level, temperature rise and starting (locked rotor) current.

The following basic tests shall be conducted by the manufacturer on one of the motors of each size and design supplied under the contract which shall be used for the subsequent pump efficiency test:

(a)	Temperature rise	(IEC 60034-1)
(b)	Efficiency at rated load and at pump efficiency test duty points	(IEC 60034-2-1)
(c)	Power factor at rated load and at pump efficiency test duty points	
(d)	Locked rotor torque	
(e)	Starting (locked rotor) current (by transient recorder at rated voltage)	
(f)	Noise level	(IEC 60034-9)

The following routine tests shall be conducted on each motor supplied:

(a)	No load losses, current and power factor	(IEC 60034-2-1)
(b)	Withstand voltage	(IEC 60034-1)
(c)	Stator winding resistance measurement (cold) and direction of rotation	(IEC 60034-1)
(d)	Vibration	(IEC 60034-14)

6.2.2 Noise Level Test

The motor shall be tested at no load for noise level to IEC 60034-9. The measured sound power level value shall not exceed the limits stated in Table II of the Standard. Measurement details shall be prepared in the test report.

6.2.3 Efficiency Test

The efficiency figures for the motor shall be established by summation of losses in accordance with IEC 60034-2-1. Curves of efficiency against the motor output shall be prepared in the test report.

6.2.4 Power Factor Test and Temperature Rise Test

The power factor and temperature rise tests shall be conducted by direct loading at rated supply voltage and frequency. Curves of power factor against the motor output shall be prepared in the test report.

Temperature rise test shall be conducted in accordance with IEC 60034-1. The test shall be conducted for at least 4 hours and until the thermal equilibrium is reached, i.e. when the rise of temperature of the stator winding does not exceed 2 ^{o}C over a period of one hour.

The stator winding temperature shall be measured by an instrument which has been calibrated to an accuracy equivalent to 0.5^{o}C.

The motor casing temperature shall be measured during the temperature rise test to verify that the actual rise in temperature throughout the test is within the specified figure.

6.3 Test on ETD

Embedded temperature detectors shall be calibrated by suitable means before being fitted into the motor. The calibration need not be witnessed by the Independent Inspection Body but the calibration report shall be submitted for verification during the motor works test.

6.4 Test on Pumpset Instrument Panel

The monitoring and control functions of the panel shall be tested functionally to verify compliance with design requirements. ETDs and the monitoring units shall be tested in accordance with IEC 60034-11 and the test results shall be included in the test report.

7. INFORMATION FOR EQUIPMENT APPROVAL

7.1 Catalogues and Performance Data

Catalogues and performance data of the motor, motor cable box, instruments and the various protective equipment shall be submitted for assessment.

7.2 Pump and Motor Starting Characteristics

The pumpset starting characteristic shall be furnished for assessment and shall include the following:

(a) Pump torque characteristic at the most arduous load condition with closed valve.

(b) Pump torque characteristic at the most arduous conditions with delivery valve fully open.

(c) Motor torque characteristic at the lowest specified voltage across the motor terminals i.e. 49% nominal voltage.

The Y-axis shall be torque in N-m while the X-axis shall be the motor speed in r/min. Characteristic curves plotted on per unit values are not acceptable.

7.3 Motor Thermal Characteristics

The short-time overload withstand characteristics of the motor (both hot state and cold state) shall be submitted by plotting on a graph paper against the motor thermal characteristics as given in Clause 3.3.

- End of this Specification -