TECHNICAL SPECIFICATION

ELECTRICAL MACHINES - CAGE-INDUCTION TYPES
(AMENDMENTS/SUPPLEMENTS TO IEC 60034-1)

DEP 33.66.05.31-Gen.

January 1999

DESIGN AND ENGINEERING PRACTICE

PREFACE

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Shell International Oil Products B.V. (SIOP)
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The Hague, The Netherlands,

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They are based on the experience acquired during their involvement with the design, construction, operation and maintenance of processing units and facilities, and they are supplemented with the experience of Group Operating companies. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

The objective is to set the recommended standard for good design and engineering practice applied by Group companies operating an oil refinery, gas handling installation, chemical plant, oil and gas production facility, or any other such facility, and thereby to achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual operating companies to adapt the information set forth in DEPs to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use DEPs they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will expect them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the DEPs. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal or its technical advisor.

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NOTE: In addition to DEP publications there are Standard Specifications and Draft DEPs for Development (DDDs). DDDs generally introduce new procedures or techniques that will probably need updating as further experience develops during their use. The above requirements for distribution and use of DEPs are also applicable to Standard Specifications and DDDs. Standard Specifications and DDDs will gradually be replaced by DEPs.

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APPENDICES

PART I INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for electrical machines of the cage-induction type. It applies to both induction motors and induction generators. This DEP is a revision of the DEP of the same number dated November 1995.

IEC 60034-1 shall apply to all induction machines.

Part II of this DEP gives amendments and supplements to IEC 60034-1 (tenth edition plus Amendment 1, 1997-06). Clauses shall apply to all machines except where the heading identifies that they apply to low voltage machines only or to high voltage machines only.

Part III gives amendments and supplements to IEC 60034-14 (second edition, 1996-11).

This DEP:

(i) makes selections from the options given in IEC 60034-1

(ii) specifies additional or modified requirements considered necessary for the machine to be suitable for operation and maintenance in continuously operating plants.

NOTES:
1. A bullet (•) in the margin indicates where a decision by, and/or information from, the Principal is required. These decisions and this information will be indicated in the requisition.

2. An asterisk (*) in the margin indicates where design alternatives may be acceptable. In certain cases these alternatives are subject to approval by the Principal.

3. A diamond (♦) in the margin indicates where information from the Manufacturer is required. This information shall be indicated in the requisition.

The minimum performance requirements specified in this DEP refer to constant speed operation and direct-on-line starting of the machines. For variable speed drives, DEP 33.66.05.33-Gen. shall also apply. Where a unit transformer is used with the motor, the combination shall comply with this DEP and DEP 33.65.40.31-Gen.

In case of conflict between documents relating to the enquiry/order the following priority of documents shall apply:

1. purchase order;
2. requisition and project specification (refer to the definition of ‘requisition’ in section 2);
3. this DEP.

SI units shall be used throughout.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP and SIEP, the distribution of this DEP is confined to companies forming part of or managed by the Royal Dutch/Shell Group. It may be distributed to Contractors and Manufacturers/Suppliers nominated by them (i.e. the distribution code is "F", as defined in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants, gas plants, exploration and production facilities and supply/marketing installations.

National and/or local regulations may exist in which some of the requirements may be more stringent than in this DEP. The Contractor shall determine by careful scrutiny, which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

See Part II, Section 2.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (Part III).

PART II GENERAL

2.1 STATEMENT OF COMPLIANCE

♦ By submitting the quotation the manufacturer is deemed to have agreed to comply with this DEP and the requisition. If the manufacturer has any deviations, **concerning both requirements and recommendations,** these shall be identified in writing at the time of quotation.

● Deviations from the requirements shall always be approved by the Principal. The approval shall state specifically the approved deviation.

The equipment shall be tested at the Manufacturer's works to prove its capability and compliance with this DEP.

2.2 LIFETIME AND RELIABILITY

The machine and all individual items forming part of it, including, if applicable, the unit transformer, shall comply with this DEP and shall have an expected lifetime of at least 20 years. They shall be suitable for at least 4 years of uninterrupted operation under the conditions specified. Rolling element bearings are exempted from the expected lifetime requirement.

2.3 EFFICIENCY AND LIFE-CYCLE COST

The minimum expected values for efficiency and power factor of machines rated up to 1 000 kW shall be as given in Annexes D and E, respectively. Machines rated at more than 1 000 kW shall have efficiencies and power factors not less than the following, related to full load operation of the machine:

Efficiency, (%)		Power Factor	
2-pole	4-pole	2-pole	4-pole
96.5	96.6	0.91	0.88

While reliable operation is of first importance, machines which also offer high efficiency and power factor at both full and three-quarter loads will be preferred. Where there is a need to deviate from this clause for special applications, the Manufacturer shall discuss the requirements with the Principal.

For machines which require separately driven auxiliary devices, like ventilators for method of cooling IC61A6A1, the Manufacturer shall list the power consumption of these devices.

● If stated in the requisition, the Manufacturer shall submit a calculation which enables the Principal to compare the Total All-in Costs (TAC) per annum of the machines offered, using the formula given below, and the factors and cost data stated in the requisition:

$$TAC = (C.C_{apc}/100) + (P.K_{ot}/E_{man}) \,.\, ((8760 \,.\, E_{cost}) + (12 \,.\, MDC/PF_{man}))$$

Where:

C = Capital Expenditure

C_{apc} = Capital Charge (%)

P = Rated output of machine (kW)

K_{ot} = Operating time per annum (e.g. 100% for single drive, 50% for duty/standby arrangement)

E_{man} = Efficiency guaranteed by the manufacturer (%)

E_{cost} = Energy unit cost per kWh

MDC = Maximum demand charge per month (cost/kVA)

PF_{man} = Power factor guaranteed by the manufacturer

An example of this calculation is given in Annex F.

2.4 GENERAL FEATURES OF DESIGN

2.4.1 Degree of protection

- The degree of protection (to IEC 60529) shall be at least:

Land and coastal installations	IP54 for the machine and auxiliaries IP55 for the terminal box and bearing housings
Offshore installations	IP56 for the machine, auxiliaries, terminal boxes and bearing housings
Submerged electric motors and electric drives of seal-less pumps	IP68 for the applicable parts

NOTE: For large machines, especially low speed machines, a lower degree of protection, e.g. IP44, may be acceptable if approved by the Principal. Terminal boxes and bearing housings shall always have a degree of protection of at least IP55.

The enclosure of the machine shall be equipped with a normally open drain hole in accordance with IEC 60034-5 to IP44. Attention shall be paid as to the correct location of the drain hole, especially for vertical motors. Not applicable for Ex d machines.

Vertical machines with a downward drive-end shaft shall be provided with a canopy over any upward facing air inlets to prevent entry of water or any other contaminant.

2.4.2 Methods of cooling

Unless otherwise specified, machines shall be air cooled with methods of cooling IC 4A1A1, IC 5A1A1 or IC 6A1A1 in accordance with IEC 60034-6.

- If specified in the requisition, air-to-water, self-cooled machines with method of cooling IC 8A1W7 in accordance with IEC 60034-6 shall be supplied

- Separately cooled machines are only permitted with the approval of the Principal. Attention shall be paid to sparing of auxiliaries of separately cooled machines.

2.4.3 Type of construction and mounting

The type of mounting for standard machines shall be either IM B3 (IM 1001), IM B5 (IM 3001), IM V1 (IM 3011), or IM V6 (IM 1031) in accordance with IEC 60034-7.

Bearing housings, especially for vertical machines with upwards drive-end shaft, (mounting arrangement IM V3 [IM 3031] and IM V6 [IM 1031] to IEC 60034-7) shall be sealed to prevent water entry to the machine via the shaft. Water and dirt collecting on the upper bearing end-shield shall not reduce performance or lifetime of the machine.

For special applications (e.g. reciprocating compressor drives) a different type of mounting may be preferred.

- The mounting required will be indicated in the requisition.

Frame sizes shall be in accordance with IEC 60072-1 and IEC 60072-2.

Dimensions of foot mounted machines and mounting flange dimensions shall be in accordance with IEC 60072-1 and IEC 60072-2.

PART III AMENDMENTS/SUPPLEMENTS TO IEC 60034-1

In this Part, certain sections of IEC 60034-1 (1997-06) are amended or supplemented, or new sections are added. Sections of IEC 60034-1 that are not mentioned shall remain applicable as written.

Section 2 Definitions

Add new clause:

2.30 *General definitions*

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant, authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

Add new clause:

2.31 *Additional specific definitions*

Air-to-air cooled machine
A closed machine with integral or machine mounted heat exchanger, using air as the primary and secondary coolant.

Air-to-water cooled machine
A closed machine with a heat exchanger using air as primary coolant and water as secondary coolant.

Allowable running-up time (ART)
The time for a machine to complete one start with rated voltage and frequency applied and coupled to a load with the actual running-up characteristics, but with the maximum moment of inertia so that when full speed is reached the most critical part of the machine has reached the highest permissible temperature.
The initial machine temperature is to be its full load working temperature. The coolant temperature is to be the maximum specified.

Capital Charges
The Capital Charge is a means of expressing a once off expenditure in the form of a cost per unit of time or quantity over the assumed lifetime of the asset i.e. motor. It represents the required net cash flow in real terms before tax to cover e.g. return on capital, payment of tax and inflation. These are dependent on local circumstances and can be obtained from e.g. the refinery economist.

Certificate of conformity
Certificate stating that the machine complies with the relevant standards for machines for potentially explosive atmospheres.

Coastal installation
An installation located within 1 km of open salty water. This may include jetties etc. that project into the water.

Critical speed
A finite speed at which resonance exists, regardless of the cause of the resonance.

NOTE: A critical speed can be caused by a number of factors such as electrical/magnetic asymmetry, oil whirl or torsion between shaft components.

Declaration of compliance (IEC 60079-15)
Document issued by the Manufacturer stating that the machine complies with IEC 60079-15.

Expected lifetime
The expected lifetime of a machine is the time during which the machine remains suitable for the application for which it was made when regularly inspected, examined and serviced in accordance with the Manufacturers instructions, with replacement of lubricants and of parts subject to wear.

Frame-surface cooled machine
A closed machine with its surface cooled by means of surrounding medium.

Hazardous area (IEC 60079-10)
An area in which an explosive gas mixture is present, or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of machines, cables and accessories.

Land installation
An installation located at sufficient distance from open salt water to minimise the effects of a salt laden atmosphere.

Limiting temperature (IEC 60079-7)
The maximum permissible temperature for machines, or parts of machines, determined by:
- The danger of ignition of the explosive atmosphere.
- The thermal stability of the materials used.

Low voltage (LV)
A voltage not exceeding 1 000 V.

Non-hazardous area (IEC 60079-10)
An area in which an explosive gas atmosphere is not expected to be present in a quantity such as to require special precautions for the construction, installation and use of machines, cables and accessories.

Non-sparking machine
A machine meeting a recognised standard for industrial equipment which in normal service does not arc or spark or produce ignition-capable hot surfaces.

Offshore installation
An installation located in open salt water, at a location remote from the nearest land.
The requisition is the vehicle used for information exchange between the Principal and the Manufacturer prior to order placement, using requisition form DEP 33.66.05.93-Gen. and, if necessary, the blank requisition form DEP 30.10.00.94-Gen.

Room temperature (IEC 60894)
The reduced range standard ambient (18 °C to 28 °C) stated in footnote 5 of Table I of IEC 212.

Running-up time (RT)
The time for a machine to complete one start with rated voltage and frequency applied and coupled to the actual load.

Self-cooled machine
A machine where the cooling is obtained by means of its own rotation.

Separately-cooled machine
A machine where the cooling is obtained by other means than its own rotation.

Site conditions
The external factors, e.g. altitude, air temperature, wind velocity, vibrations, earthquakes, relative humidity, voltage and frequency variations etc., which may influence the operation of a machine.

Stalling time
The time taken for any part of the machine, when it is energised at rated voltage and in the stalled condition, to be heated up from the temperature reached under full load and maximum coolant temperature conditions to the highest temperature which does not impair its subsequent performance.

Starting load torque
The torque required by the load over the starting period from zero speed to load speed.

NOTE: The starting torque includes, if applicable, compression torque and bearing friction torque.

Time t_e
The time t_e is the lesser of the times defined below:
- For the AC windings, when carrying the locked rotor current with the motor in the stalled condition, to be heated up, from the temperature reached under full load and maximum coolant temperature conditions, to the limiting temperature.
- For any other part of the machine in stalled condition, and with the AC windings carrying the locked rotor current, to be heated up, from the temperature reached under full load and maximum coolant temperature conditions, to the limiting temperature.

Type of protection 'd' (IEC 60079-1)
A type of protection of electrical apparatus in which the enclosure will withstand an internal explosion of a flammable mixture which has penetrated into the interior, without suffering damage and without causing ignition, through any joints of structural openings in the enclosure, of an external explosive atmosphere consisting of one or more of the gases or vapours for which it is designed.

Type of protection 'e' (IEC 60079-7)
Type of protection applied to electrical apparatus that does not produce arcs or sparks in normal service, in which additional measures are applied so as to give increased security against the possibility of excessive temperatures and of the occurrence of arcs and sparks.

Type of protection 'n' (IEC 60079-15)
A type of protection applied to electrical apparatus such that, in normal operation, it is not capable of igniting a surrounding explosive gas atmosphere and a fault capable of causing ignition is not likely to occur.

Type of protection 'p' (IEC 60079-2)
The concept of achieving safety by means of a protective gas.

Un IEC 60894
The rated rms phase-to-phase voltage by which the system is designated and to which certain operating characteristics of the system are related.

Vibration severity (ISO 2372)
The vibration severity is the root-mean-square value of the vibration velocity.

Section 3 Duty

3.1 Declaration of duty

Add to this clause:

Periods of running may alternate with idle (standstill) periods of maximum six months. At the end of such an idle period the machine shall be suitable for another running period without requiring additional inspection.

Section 4 Rating

4.5.2 *AC generators*

Add to this clause:

- The required generator rating and speed shall be stated in the requisition.

  All insulation materials shall be class F, as defined in IEC 60034-18. The rating of the machine offered by the manufacturer shall be based on a class B temperature rise for all parts of the machine windings.

- ◆ The Manufacturer shall provide advice regarding the optimum generator rating with respect to the prime mover capabilities and the specified operating and site conditions.

4.5.3 *Motors*

Add to this clause:

All insulation materials shall be class F, as defined in IEC 60034-18. The rating of the machine offered by the manufacturer shall be based on a class B temperature rise for all parts of the machine windings.

Section 5 Site operating conditions

5.1 General

Add to this clause:

The atmosphere is to be considered salty, sulphurous and dusty, as commonly encountered in oil refineries, chemical plants or other such facilities located close to open water.

Where operating conditions are not specified, it is deemed that the Principal accepts the default conditions stated in IEC 60034-1 and in this section.

5.3 Maximum ambient air temperature

Add to this clause:

The maximum ambient air temperature of 40 °C is taken to be the 'Mean Annual Extreme' as defined in IEC 60721-2-1 for a warm, damp climate.

5.3.1 *High voltage machines*

- The Principal may select the 'Mean Annual Extreme' which correlates with his site statistics.

'Absolute Extremes' shall not be selected.

5.5 Water coolant temperature

Replace this clause by:

The temperature of the water at the inlet to the heat exchanger shall not exceed 30 °C. The minimum cooling water temperature is 5 °C.

Add new clause:

5.8 Additional design data for air-to-water cooled heat exchangers

The following design data shall apply:

- maximum cooling water outlet temperature	37 °C
- maximum temperature rise for cooling water	7 K
- maximum static water pressure	8 x 10^5 Pa
- minimum static water pressure	3 x 10^5 Pa
- minimum cooling water velocity in tubes	1 m/s
- fouling resistance	???

Add new clause:

5.9 Additional operating conditions

- exposure to direct sunlight	Yes
- relative humidity	90%
- maximum wind velocity for offshore installations	45 m/s
- maximum shocks experienced on offshore installations	20 m/s^2
- maximum vibration transmitted from adjacent operating equipment	0.4 mm/s (rms)

Section 6 Electrical operating conditions

Add new clause:

6.3 Voltage and frequency variations during operation

6.3.1 *Low voltage machines*

Machines shall be suitable for operation on a supply voltage within the limits as specified in IEC 38.

6.3.2 *High voltage machines*

As a result of switching activities in the supply system, steep fronted transient voltage waves can be expected at the terminals of HV machines.

Add new clause:

6.4 Three-phase a.c. machines operating on unearthed systems

Replace the second paragraph by the following:

The machines shall be suitable to operate for periods of up to 8 hours on an unearthed system with an earth fault on one phase. The maximum cumulative hours of operation in this mode will be restricted to 500 hours over the machine lifetime.

Section 7 Thermal performance and tests

7.9 Measurement of bearing temperature

Add to this clause:

For both rolling element and sleeve bearings, the bearing temperature rise as measured by ETD, fitted in the bearing housing, shall not exceed 55 K at the end of the heat run.

For sleeve bearings with forced lubrication the lubricating oil temperature rise with the minimum allowable oil flow shall not exceed 28 K at the end of the heat run. However, the oil temperature shall not exceed 82 °C (API 617, 6th Edition 1995). For oil ring lubricated bearings the sump temperature shall not exceed 82 °C (API 610, 8th Edition 1995).

Section 8 Other performance and tests

8.5 Overspeed

Replace the second paragraph of this clause with the following:

Generators above 1 000 kW shall be subjected to an overspeed test at 1.2 times rated speed for a duration of 2 minutes. Before the overspeed test the rotor shall be balanced to quality grade G1 as specified in ISO 1940. After the overspeed test the rotor balance condition shall be verified to be still within the G2.5 limits. If the rotor fails to comply with these requirements the overspeed test may be repeated once more after re-balancing, subject to the approval of the Principal.

Add new clause:

8.10 Starting, re-starting and re-acceleration

8.10.1 *General*

Machines shall be suitable for direct-on-line starting or re-acceleration with any voltage between 80% and 100% of the rated voltage applied at the machine terminals.

Motors shall be capable of re-acceleration under full load conditions following a power interruption not exceeding 0.2 seconds. (A quadratic torque-speed characteristic for the driven equipment may be assumed)

* If this requirement cannot be met, and for other driven equipment torque-speed characteristics, the manufacturer shall provide detailed information regarding the re-acceleration ability of the motor.

8.10.1.1 *High voltage machines*

* For machines supplied via a dedicated unit transformer, different requirements may prevail. In these situations the design of the machine-transformer combination shall be optimised with respect to the maximum allowable voltage drop at the busbar and the start/restart performance of the machine.

8.10.2 *Number of sequential starts*

At any voltage between 80% and 100% rated voltage, machines (including their unit transformers if applicable) shall be capable of:

- three successive starts with the machine initially at maximum ambient temperature
- two successive starts with the machine initially at full load operating temperature.

Between successive starts the machine may be assumed to decelerate under operating conditions.

After a cooling period of 30 minutes at standstill, another starting sequence of at least two successive starts shall be possible.

8.10.2.1 *High voltage machines*

For machines with a rated output in excess of 1 600 kW deviations from this requirement may be acceptable. In these circumstances, approval to deviate shall be obtained from the Principal.

8.10.3 *Number of starts per year*

● Machines (including unit transformer if applicable for HV machines) shall be suitable for one of the duties listed below:

Normal : maximum 1 000 starts per year

Heavy : maximum 3 000 starts per year (e.g. conveyors, drain pumps)
Extra heavy : maximum 20 000 starts per year (e.g. cranes, hoists – LV only).

Add new clause:

8.11 Starting characteristics

8.11.1.1 *Starting current - LV machines*

The locked rotor apparent power shall comply with IEC 60034-12. However, for machines with a rated output in excess of 55 kW the starting current shall not exceed 7.0 times the rated current of the machine.

8.11.1.2 *Starting current – HV machines*

- The starting current shall not exceed 6.5 times the rated current of the machine, unless there is a more stringent limitation in the requisition.

8.11.2 *Starting performance*

8.11.2.1 *Low voltage machines*

The starting performance shall comply with IEC 60034-12. For driven equipment which exhibits a quadratic torque/speed characteristic Design N shall apply. For equipment with other characteristics Design H shall apply.

8.11.2.2 *High voltage machines*

The starting performance of cage induction machines at rated voltage shall be not less than the values listed in the table below:

	Poles								
	2			4			6		
Rating (kW)	T_1	T_u	T_b	T_1	T_u	T_b	T_1	T_u	T_b
Up to 250	0.8	0.6	1.8	0.9	0.7	1.8	0.9	0.7	1.8
250 - 500	0.7	0.6	1.8	0.7	0.6	1.8	0.7	0.6	1.8
500 - 1600	0.6	0.5	1.8	0.6	0.5	1.8	0.6	0.5	1.8
Over 1600	*	*	*	*	*	*	*	*	*

* To be agreed by Principal.

T_1 = locked rotor torque

T_u = pull-up torque

T_b = breakdown torque

All values are per-unit based on the rated torque.

8.11.3 Torque-speed characteristic

The torque-speed characteristic of the motor with rated frequency and 80% rated voltage applied at the motor terminals shall be adequate for starting the driven load under the most severe conditions, e.g. pump with open discharge. Under these conditions the accelerating torque shall be not less than 10% of the full load torque at any point.

* The above applies for driven equipment that exhibits a quadratic torque-speed characteristic. For other types of driven equipment, it may not be possible to comply with this requirement. For these situations the start conditions shall be discussed with the

Principal.

Add new clause:

8.12 Transient air-gap torques

The bracing of all machine end windings shall be suitable to withstand a three-phase short circuit at the machine terminals. Their shaft and active iron core systems shall withstand two-phase short circuits.

• Unless the Principal confirms that the starter arrangement specifically reduces reconnection torques, machines shall be suitable for re-start with full residual voltage in total phase opposition. The shaft and active iron core systems shall be suitable for supply reconnection onto the full residual voltage at 120 degree phase difference.

8.12.1 *High voltage machines*

• For HV machines the Manufacturer shall state the maximum transient air-gap torque in the cases of:
  – two and three phase short circuit at the machine terminals
  – reconnection after a power interruption of duration as stated in the requisition.

Add new clause:

8.13 Running-up time

♦ The Manufacturer shall state the running-up time with 80% and 100% rated voltage applied at the machine terminals.

The manufacturer shall also state the maximum allowable running up time at 80% and 100% rated voltage applied at the machine terminals.

8.13.1 *Low voltage machines*

For machines up to and including 660 V the initial value of the external (load) inertia used in this calculation may be based on the data given in IEC 60034-12, Table III.

8.13.2 *High voltage machines*

These calculations shall be made using the actual load inertia and driven equipment torque-speed characteristics.

Add new clause:

8.14 Critical speeds

Machines shall have a rigid, under critical rotor-bearing system with the first rotor bending critical speed not lower than 125% of the synchronous speed.

Where the driven equipment vendor is to perform a torsional vibration analysis of the complete motor/driven equipment train, the motor manufacturer shall provide the physical data required for the torsional analysis.

8.14.1 *High voltage machines*

• Machines with flexible, over-critical rotor bearing systems shall comply with the following:
  – the first critical speed shall be less than 80% of the machine synchronous speed
  – the second critical speed shall be greater than 125% of the machine synchronous speed
  – at any critical speed, the bearing vibration of the machine shall not exceed twice the values specified in Part III of this DEP.

Add new clause:

8.15 Noise control

8.15.1 *General*

ISO 1680-2 shall apply, with conditions as in the following paragraphs:

If the machine produces noise with tonal components, the maximum sound pressure levels shall be 5 dB(A) less than the values stated below or in the requisition.

NOTE: A tonal component is considered to exist if the level of any octave band exceeds the level of the adjacent bands by 5 dB with the sound meter set to linear response.

8.15.1.1 *Noise limits - LV machines*

The sound pressure level of the loaded machine shall not exceed 77 dB(A) in the work area, measured in accordance with ISO 1680-2.

8.15.1.2 *Noise limits – HV machines*

The sound pressure level of the loaded machine shall not exceed 82 dB(A) in the work area, measured in accordance with ISO 1680-2.

8.15.2 *Noise abatement*

Machines shall meet the maximum allowable noise limits by design and not by corrective measures. If this is not possible, the Manufacturer shall state the proposed corrective measures for the approval of the Principal.

Where the use of internal soundproofing material is unavoidable, such liners shall be fixed using retaining mesh.

The acoustic measures shall not obstruct routine inspection and maintenance activities such as lubrication of bearings and inspection of oil levels. The maximum allowable temperature rise of the machine windings and bearings shall not exceed the limits specified in this DEP.

Add new clause:

8.16 Pulsating stator current

Motors driving equipment which requires a variable torque during each revolution, e.g. reciprocating compressors or pumps, shall have sufficient inertia to limit the variations in the motor stator current to a value not exceeding 40% of the full load current for cage induction machines.

The additional inertia necessary to comply with the current variation and speed irregularity requirements shall be added to the rotating mass of the machine.

If this requirement cannot be met, approval shall be obtained from the Principal for an alternative design.

Add new clause:

8.17 Unit transformer – HV machines

Unit transformers shall comply with DEP 33.65.40.31-Gen., and shall be rated for direct-on-line starting of the loaded machine under the sequences specified in (8.10.2).

♦ The Manufacturer shall indicate in his quotation the short time rating and continuous rating of the transformer together with the applicable impedances.

Section 9 Rating plates

9.1 General

Replace the first sentence of this clause with the following:

Every electrical machine shall be provided with a rating plate or plates. Rating plates shall be made of stainless steel and shall be securely fixed to a non-removable part of the frame.

9.2 Marking

Add to the list of data to be supplied at the end of the clause:

27. Principal's purchase order number

28. Efficiency at full load

29. Locked rotor current at rated voltage and frequency

30. Locked rotor torque at rated voltage and frequency

31. Allowable running-up time (ART) at rated voltage and 80% rated voltage.

9.2.1 *Low voltage machines*

The data marked on the nameplates may be taken from a type test on an identical machine.

9.2.2 *High voltage machines*

The values provided shall, as far as possible, be those actually measured and shall be based on the specified operating conditions.

Add to the end of clause 9.2:

For machines with rated outputs exceeding 250 kW, the following bearing information shall be provided on a separate rating plate:

32. Bearing type, size, clearance, shaft and housing fit for DE and NDE bearings.

33. Type of lubricant, relubrication interval, mimimum and maximum allowable quantity of lubricant for the DE and NDE bearings.

34. Oil pressure required, for force lubricated bearings.

Add new clause:

9.3 Machines in hazardous areas

For machines to be used in hazardous areas the following information additional to that in clause 9.2 shall be provided:

- The type of protection of the following components in accordance with IEC 60079:

  Machine
  Terminal box
  Auxiliary devices

- The temperature group and gas group in accordance with IEC 60079

- The number of the test certificate or registered mark of the testing authority.

- For machines with type of protection 'e' - the t_e time

- For machines with type of protection 'd' - any information essential to ensuring the flameproof character of the enclosure

- For machines with type of protection 'p'

The minimum and, if applicable, maximum pressure during operation, or the minimum rate

of flow of protective gas.

The internal free volume, and the minimum volume of protective gas necessary for purging the enclosure.

Section 10 Miscellaneous requirements

Add new clause:

10.3 Machine housing

10.3.1 *General*

Materials that are hygroscopic, carcinogenic or release environmental toxicity shall not be used. The materials used shall be selected to prevent contact corrosion.

Machines with a mass greater than 25 kg shall have eye bolts, lugs or extension pieces clearly identifiable to be used for hoisting. The degree of protection specified in (2.4.1) shall be attained regardless of such eye bolts.

Machines weighing over 600 kg shall have jacking bolts or facilities to lift the machine with the aid of a mechanical jacking device, to facilitate alignment of the machine with the driven equipment.

10.3.2 *Stator frame*

All frames and bearing end-shields shall be made of ferrous materials. The frames shall have machined feet, which shall have supporting surfaces at four sides of each foot, if the foot is hollow.

Corresponding mounting surfaces for horizontal machines shall be in the same plane and within a tolerance of 0.15 mm per meter distance between surfaces.

The frame and interior of air-to-water cooled machines shall be constructed so that water leaking from the cooler, or condensation, will collect and drain from the machine without dripping onto the windings.

10.3.2.1 *Stator frame – LV machines*

Aluminium frames may be used for machines complying with the following conditions:-

Rating 22 kW or less.

Sited in a non-hazardous area.

Used in non-vital or non-essential services.

10.3.3 *Coolers - air/air and air/water*

If cooling air inlets are protected by a mesh screen, it shall be of corrosion resistant material or coated metal. Galvanised steel mesh shall not be used.

The cooler tube assembly shall be designed such that the natural frequency of vibration of the tubes is not excited by the motor's running frequency or its harmonics.

10.3.3.1 *Air to water heat exchangers – HV machines*

- Unless otherwise stated in the requisition, heat exchangers for air-to-water cooled machines shall be of the single tube design and shall have a 20% surplus number of tubes to allow for plugging of leaking tubes over the lifetime of the machine.

  They shall have collection trays to prevent water leaking onto vulnerable parts.

  If no chemically treated cooling water is available, the layout shall be such that the machine is able to carry 100% of the rated load for a period of at least eight hours with a heat exchanger taken out of service. During this period, the temperature rise of the machine windings shall be in accordance with the maximum allowable for Class F materials.

  The water box/header construction of heat exchangers shall be such that leaking tubes can be readily plugged and all tubes are accessible for cleaning.

  After dismantling a heat exchanger, it shall be possible to provide the machine with a cover plate to maintain a degree of protection of at least IP 54.

Provisions shall be made to drain the heat exchanger and to release air trapped in the heat exchanger during filling.

10.3.4 *Anti-condensation heaters*

Heaters shall be of a fully insulated design.

Heaters shall be arranged to provide uniform heating of the stator and, if applicable, the rotor windings, and shall maintain the temperature of the windings at approximately 5 K above ambient temperature.

The surface temperature of the heater element, or the machine enclosure, shall not exceed the limiting temperature specified.

The connecting leads of the heater elements shall be brought out to terminals in a separate heater terminal box mounted on the machine frame. A prominent warning label shall be provided to indicate that the circuit may be live when the motor is stationary.

10.3.4.1 *Low voltage machines*

On machines up to including 75 kW it is acceptable, with the prior consent of the Principal , to site the heater terminals in the main terminal box provided there is ample space to connect all cables. A prominent warning label shall be provided to indicate that there are two different supplies in the terminal box.

10.3.4.2 *High voltage machines*

Anti-condensation heaters shall be provided unless otherwise specified in the requisition.

Add new clause:

10.4 Windings

10.4.1 *Stator windings – LV machines*

- When requested by the Principal, the Manufacturer shall provide evidence that the insulation system used has been tested in accordance with IEC 60034-18-1 and IEC 60034-18-21.

10.4.2. *Stator windings - high voltage machines*

10.4.2.1 *All machines*

Stator windings shall be star connected.

Coils shall be made using rectangular copper conductors, covered by a mica tape or other insulation material of similar dielectric strength and ageing properties. Wire windings are not acceptable.

All stator coils shall have identical insulation levels irrespective of the electrical location of the coil (e.g. star-point side or line end coil).

All windings shall be adequately supported, braced and wedged to limit coil and end winding vibration and subsequent cracking of the winding insulation. Bracing, blocking and wedging shall be positively secured to allow for the vibration and forces experienced during the expected 20 year service life of the machine.

Windings shall be able to withstand the dynamic forces which result from frequent starting and from re-starting against full opposite residual voltage.

10.4.2.2 *Machines for voltages of 6 kV and above*

The following shall apply additionally:

The main insulation material shall be mica.

All coils shall have anti-corona protection, achieved using a semi-conducting tape, in the slot part of the coil.

Where the rated voltage is in excess of 7 kV, all coils shall, in addition to anti-corona protection, have stress grading.

10.4.2.3 *Slot wedges*

* Magnetic slot wedges are only acceptable if the manufacturer:-

- positively demonstrates at least 5 years of satisfactory running on past installations

AND

- guarantees against failure of wedges for at least 5 years after commissioning of the machine.

Add new clause:

10.5 Terminal boxes

10.5.1 *General*

- A terminal box of sturdy construction shall be provided, with sufficient internal space for connecting the cables as specified in the requisition. At the request of the Principal, the manufacturer shall demonstrate that the specified cable(s) can be terminated safely and correctly.

- The type of cable glands, if any, to be supplied by the manufacturer will also be indicated in the requisition.

- Unless otherwise stated in the requisition, the terminal box shall be located at the top or at the right hand side of the machine facing the driving end. The design shall allow the box to be rotated to accommodate cable entry from three positions 90 degrees apart, not facing the driving end.

  Inside the terminal box an earthing clamp or bolt of adequate dimensions shall be provided for connection of the cable earthing. The earthing facility shall be clearly marked with the appropriate symbol.

  The design of the terminal box shall be such as to prevent small parts from dropping into the machine housing.

  Auxiliary equipment and instrumentation fitted to the machine shall be wired to auxiliary terminal boxes fitted to the side of the machine. These boxes shall comply with the preceding two requirements.

10.5.1.1 *Terminal boxes – LV machines*

Terminal boxes shall be made of cast iron or steel, except where an aluminium frame is permitted.

10.5.1.2 *Terminal boxes – HV machines*

The main terminal box and, if applicable, the star point box shall be made of steel. Cast iron is not acceptable.

The main terminal box shall be of a non compound filled design.

Terminal boxes in which the protection of the phase conductors against electrical failure within the terminal box is achieved mainly by solid insulation, or in which faults are limited to earth faults by earthed metal barriers, are both acceptable.

Additional Terminal box requirements:

1. The products of an electrical breakdown within the terminal box shall be relieved through

a pressure relief diaphragm to the outside of the box. (This does not apply to Ex'd' terminations)

2. Pressure relief shall be arranged and located such that the potential for injury to personnel is minimized.
3. Main terminal boxes should be constructed such that that the cable can be connected without a requirement for pulling the cable through a fixed opening in the box.
4. Where single core supply cables are used, all gland plates and glands shall be of non-magnetic materials.
5. The lowest part of the terminal box, including cable gland and other miscellaneous parts, shall not be lower than the lowest part of the machine.
6. If applicable, the starpoint box shall be located at the opposite side of the machine from the main terminal box, and shall be sized to accommodate the current transformers for differential protection.

- The Principal will either:

  – Provide all necessary details of the current transformers and will make such current transformers available for the manufacturer to install in the terminal box.

  or

  – Will request the manufacturer to supply the full set of current transformers

  Any certificate of conformity or declaration of compliance shall specifically allow for such star point boxes and current transformers which may be separately certified or included in the overall certification.

Add new clause:

10.6 Bushings and terminations

10.6.1 *All machines*

Terminal marking of the main cable connections, and the direction of rotation, shall be in accordance with IEC 60034-8.

Terminal marking of auxiliary cable connections shall be in accordance with the relevant machine wiring diagrams.

Terminal connections shall be constructed such that direct contact between screws, bolts or nuts and the conductor is avoided. Connections shall be secured against loosening and the arrangement shall be such that the contact pressure is maintained over the life of the machine.

10.6.1.1 *Bushings and terminations – LV machines*

Terminal blocks shall be made of synthetic resin, unless the motor certification specifies otherwise.

10.6.1.2 *Bushings and terminations – HV machines*

All machines shall be provided with synthetic resin bushings and/or post insulators for the termination of the main cables. The use of porcelain for these components is not permitted.

Bushings and insulators shall be rated for the rated machine voltage and shall be able to withstand the dynamic and thermal effects of a through going short-circuit current for at least 0.2 seconds. The expected short-circuit current shall be based on the maximum supply fault level specified in the requisition.

The distance between bushings and between bushings and earthed parts of the terminal box shall be based on the applicable distances for an air insulated installation.

Cable termination materials, e.g. cable lugs, stress-relieving materials and other terminating

components are excluded from the manufacturers scope of supply.

Clamping devices shall be provided inside the main terminal box of HV machines to separate and support the cable conductors and, if applicable, the winding end-tails, thereby ensuring that the ability to withstand the short-circuit current will be maintained after completion of the non-compound filled type of termination. Materials used for clamping devices shall be non-hygroscopic.

Add new clause:

10.7 Rotor, fans and coupling

10.7.1 *Rotor*

The shaft shall be made of one-piece, heat treated steel.

Welding on finished shafts is not allowed. Shafts and spiders subjected to welding shall be post-weld heat treated.

Where non-contacting eddy current proximity probes are to be fitted, the surface finish of the shaft at the fitting point shall be as specified in API 670.

For all machines with flexible, over-critical rotor bearing systems, balancing shall be done at nominal speed. All machines shall be balanced with a half-key fitted in the keyway.

The shaft end shall be permanently marked with the indication 'H' to identify this procedure.

Lead or similar ductile material shall not be used for balance weights.

If metal is to be removed to achieve static or dynamic balance, it shall be removed in a manner that maintains the structural integrity of the rotor and does not result in hot spots liable to distort or otherwise harm the rotor.

Rotors shall be balanced to a minimum quality grade G2.5 as specified in ISO 1940.

10.7.2 *Fans*

The external fan and, if applicable, the separately mounted internal fan(s) shall be individually balanced. External fans shall be keyed to the shaft.

The external fans shall be of non-corroding material or shall be treated with a corrosion resistant coating.

Fan covers shall be made of metal and treated with a corrosion resistant coating. (Any deviation from this requires the specific approval of the Principal.)

The flow of cooling air shall be in the direction of the driven equipment.

Machines with unidirectional fans shall be provided with an engraved arrow permanently indicating the direction of rotation. Indication by means of a painted or adhesive arrow is not acceptable.

10.7.2.1 *Fans – LV machines*

For machines rated below 30 kW there is an exemption from the following requirements:

- Individual balancing of the external fan and, if applicable, any separately mounted internal fans.
- Keying of the external fan to the shaft.

10.7.3 *Coupling*

The shaft ends shall be provided with a suitably threaded hole or holes to facilitate the assembly or removal of the coupling and bearing races.

Shaft extensions, keys and keyways shall be in accordance with IEC 60072-1 and IEC 60072-2.

For motors intended to drive directly loads which require a variable torque during each revolution, e.g. reciprocating compressors, the shaft end design and coupling shall be matched to the driven equipment.

10.7.3.1 *Couplings – HV machines*

- Unless otherwise stated in the requisition, machines with a rated output in excess of 1 000 kW shall be designed with either an integrally flanged shaft end or a tapered shaft end for a hydraulically fitted coupling. Where no design is specified, the manufacturer shall indicate in his quotation which of these options is proposed.

Add new clause:

10.8 Protective systems

10.8.1. *Winding temperature detectors – HV machines*

- Machines in excess of 1 000 kW shall be provided with embedded temperature detectors in the stator windings.

  At least six detectors shall be installed, two for each stator phase. Detectors shall be located at the positions most likely to show the highest temperatures. The detectors shall be PT-100 Platinum resistance elements to IEC 60751. The elements shall be wired to a separate terminal box mounted on the machine frame. The terminals and control amplifier shall be suitable for 3-wire or 4-wire systems.

  NOTE: RTD elements can be of the two wire type up to the terminal box mounted on the machine frame.

  The manufacturer shall confirm whether the insulation system is such that no over-voltage surge arrestors are required for RTD elements. If this cannot be confirmed by the manufacturer, RTD elements shall be provided with short-circuit type over-voltage surge diverters installed in the auxiliary terminal box.

10.8.2 *Differential protection – HV machines*

Differential protection shall be provided on machines with rated outputs in excess of 3 500 kW, and on machines supplied by a dedicated unit transformer. On these machines, the star point connections shall be brought out to a star-point terminal box in accordance with (10.5.1.2).

10.8.3 *Air temperature detectors – HV machines*

For air-to-air cooled machines, with cooling methods IC6A1A1 and IC6A1A6, a cooling air RTD temperature detector shall be provided to measure the temperature of the internal cooling air leaving the heat exchanger.

Air-to-water cooled machines shall be provided with the following auxiliary devices:

- Resistance temperature detector (RTD) elements to measure the temperature of the internal cooling air as it enters and leaves the heat exchanger.
- A water leakage detector for each heat exchanger unit.

10.8.4 *Bearing temperature monitoring*

- When indicated on the requisition, RTDs shall be provided to measure bearing temperature. Care shall be taken that the RTD element does not violate the integrity of the bearing insulation.

  The RTDs shall be PT-100 resistance elements in accordance with IEC 60751. The elements shall be wired to a separate terminal box mounted on the machine frame. Terminals and control amplifiers shall be suitable for 3-wire or 4-wire systems.

  NOTE: RTD elements may be of the 2-wire type up to the terminal box mounted on the machine frame.

Add new clause:

10.9 Bearings

10.9.1 *Bearing selection*

Bearings may be selected from the following types:

- Grease lubricated rolling element bearings. Two deep groove ball bearings shall be used except where high thermal expansion or radial loads dictate the use of roller, or a combination of ball and roller, bearings at the drive end.
- Oil lubricated sleeve bearings

Grease lubricated rolling element bearings shall be used when the following conditions apply:

1. The product of rated output and shaft speed complies with the formula:

   $P \times n \leq 1\,000\,000$ where P = rated output (kW) and n = speed (r/min)

2. The product of bearing bore diameter and shaft speed complies with the formula:

   $D_b \times n \leq 255\,000$ where D_b = bearing bore diameter (mm) and n = speed (r/min)

3. The minimum re-lubrication interval shall be 4 000 hours for horizontal machines and 2 000 hours for vertical machines.

Where any of these criteria cannot be met, the preferred option is to use sleeve bearings.

10.9.2 *Bearing insulation*

Whenever the shaft voltage measured across the ends of the shaft exceeds 250 mV (rms) for rolling element bearings or 400 mV (rms) for sleeve bearings, bearing insulation shall be provided

Bearing insulation, if required, shall comply with the following:

It shall be provided on all bearings.

The method of insulation shall be permanent and non-deteriorating during assembly and dis-assembly of the bearing.

An earthing connection, removable for test purposes, shall be provided at the drive end bearing. Care shall be taken not to bridge the insulation by any other connection.

For single pedestal bearing machines, the insulation system shall be of 'sandwich' construction with two separate insulating layers. A removable earthing connection shall bridge one layer to ensure equipotential bonding of the middle conducting block.

Insulation layers which must be kept non-conducting during normal running shall bear a prominent warning label reading:

Caution : Bearing Must Be Kept Insulated

♦ Where bearing insulation is used, the manufacturer shall submit with the quotation drawings detailing the proposed insulation arrangement.

10.9.4 *Axial forces*

If a gear type or other type of coupling which may exert axial force on the machine is fitted, the maximum expected external axial force will be as calculated by the following formula:

(Refer to API 617, 6th edition)

$$\frac{0.25 \times 9550 \times P}{n \times D}$$

where:

F = external axial force (kN)
P = rated output of motor (kW)
n = synchronous speed (r/min)
D = shaft end diameter (mm)

Machines used for these applications shall be able to operate continuously with the above calculated maximum axial thrust while complying with all other applicable requirements of this DEP.

Where such forces are excessive, the motor manufacturer may negotiate the use of limited-end-float couplings with the driven equipment manufacturer. However, the motor manufacturer shall cater in his design for uncoupled running.

10.9.5 *Rolling element bearings*

Bearings shall be in metric sizes and comply with ISO 15 and ISO 1132.

Vertical motors driving direct coupled pumps shall have the thrust bearing at the non-drive end.

The use of angular contact bearings shall be restricted to vertical machines where the bearings have to accept high axial forces.

All rolling element bearings shall have a metallic cage unless otherwise approved by the Principal.

Bearings shall have a rated L10 lifetime in excess of 40 000 hours under the worst case operating conditions as specified in the requisition and in this DEP. The lifetime shall be calculated in accordance with ISO 281.

Rolling element bearings shall have grease relief systems where new grease displaces the old grease which, together with any surplus, is automatically ejected to the outside of the machine casing. Unless otherwise specified by the Principal, lithium based greases such as Shell Nerita HV shall be used in the bearings. However, selection of bearings shall be based on the use of Shell Alvania R3 (RL3) to attain the above lifetime and relubrication intervals. Non-compatible greases, such as those based on polyurea, shall not be used.

Relubrication shall be possible with the motor in operation and without dismantling parts..

Ball bearings shall have a C3 internal radial clearance. Roller bearings may have a normal or C3 internal radial clearance.

- If stated in the requisition, rolling element bearings shall be provided with testing points for shock pulse monitoring (SPM)

All rotors shall be secured during transport to avoid damage to the bearings.

10.9.5.1 *Rolling element bearings – LV machines*

Machines with rated outputs up to and including 37 kW may be equipped with sealed-for-life bearings pre-charged with Shell Nerita HV grease. Alternative grease options must first be approved by the Principal. The Manufacturer shall ensure that such bearings are selected to meet the above L10 lifetime.

10.9.6 *Sleeve bearings – HV machines*

Only sleeve bearings of a proven design shall be used.

Sleeve bearings shall be of the spherical seated, self-aligning type.

Radial sleeve bearings shall have replaceable liners or shells.

The bearing design shall suppress hydrodynamic instabilities and provide sufficient damping to limit rotor vibration to the maximum specified amplitudes at both operating and critical speeds.

The bearing housing design shall permit replacement of the bearing liners without disassembly of coupling or other machine parts.

Disc and wiper lubricated bearings may be used. The oil change interval for these bearings shall be at least 12 months.

- The Manufacturer shall state in the quotation the minimum oil change interval for the lubricating oil based on the most adverse operating conditions.

For force-lubricated bearings, the Manufacturer shall state in the quotation both the minimum and normally recommended oil flow rates.

Where common lube-oil systems are used, the driven equipment manufacturer is responsible for supplying the common lube-oil console. The motor manufacturer is responsible for informing the driven equipment manufacturer of the lubrication requirements for the motor bearings. All oil piping shall be flanged or studded, and/or welded. Screwed connections and unions shall not be used in pressure containing lines and connections.

Bearings shall be equipped with an oil level or flow indicator

Bearings with a ring lubricating system shall allow visual inspection of the oil ring operation while the machine is running.

Bearings shall be suitable to start the machine without the aid of oil jacking.

The bearing design shall limit axial float either during uncoupled running or due to unbalanced axial forces during start-up. The free float allowed by the bearings shall be a minimum of ± 3 mm, and a maximum of ± 6 mm, from the magnetic centre.

White metal liners and shells shall be protected against corrosion during transport and storage. Products used for protection shall not require mechanical or manual cleaning of the bearings prior to commissioning of the motor.

Rotors shall be secured during transport to avoid damage caused by axial or radial movement of the rotor.

Add new clause:

10.10 Special constructions

10.10.1 *Close-coupled pumps*

The combined shaft of the electric motor/pump shall be machined from one solid piece of heat treated steel unless the material requirements for the pump require special non-magnetic shaft material.

The material of the shaft and the sealing elements of the electric motor shall comply with the product specification given in the pump data/requisition sheet. In the absence of such specification for the shaft material, the shaft shall be of the steel type SAE 1035.

The shaft run-out shall be as per IEC 60072-1, Table 5 precision class.

The maximum permissible change in indicator reading of the concentricity of spigot diameter and perpendicularity of flange to shaft shall be precision class (Reference Table 6 of IEC 60072-1).

The motor shall have its thrust bearing located at the non-drive end.

The motor shall be able to carry in both directions double the maximum thrust that the pump may develop while starting, stopping or operating at any point on its characteristic, or while being tested with water. This requirement shall not result in inadequate loading of the bearings during normal operation.

10.10.2 *Submerged motors and electrically driven seal-less pumps*

The electric motor shall, as far as practically possible, comply with the requirements specified in this DEP.

Parts, including cables, which are in contact with the product pumped, shall be chemically and thermally resistant to this product over the lifetime of the motor. Windings shall also be designed to resist the effects of likely solid or liquid contaminants in the fluids in the pump or motor.

The windings, and connections to them, shall be designed to minimise the number of joints submerged in the process or filling fluids. Coils shall be secured so as to prevent winding movement and chafing on other parts inside the motor.

The windings shall be tested in accordance with the submerged stator test outlined in NEMA MG 1-20.49.

Add new clause:

10.11 Mass

- The manufacturer shall state in the quotation the total mass of the machine. The final mass shall not deviate by more than 10% from this value.

Add new clause:

10.12 Surface finish

Machines shall have a internal and external surface finish which provides adequate protection against corrosion in the specified site conditions (section 5).

- Where tropical treatment is specified in the requisition, the manufacturer shall provide a finish that is type tested for the likely daily fluctuations in temperature and humidity.
- Where special treatment is needed because of extreme environmental conditions, additional information will be provided in the requisition.

Add new clause:

10.13 Unit transformer (HV machines)

The construction of the unit transformer shall be in accordance with DEP 33.65.40.31-Gen.

The unit transformer shall be able to withstand the thermal and dynamic stresses imposed on the core and windings during repeated direct-on-line starts of the machine. It shall also withstand the transient overvoltages specified in Annex C.

The neutral of the unit transformer shall be resistance earthed. the rating of the resistor shall be such as to limit the maximum earth fault current to 10 A or the total capacitive current, whichever is the greater. (The capacitive current is that due to the machine, unit transformer LV winding, and machine main connections.)

The quotation shall specify the neutral earthing resistor separately.

Add new section:

Section 12 Additional requirements for machines in hazardous areas

12.1 Bonding straps

Machines shall be fitted with bonding straps across joints within or between the main enclosure, the bed plate and the heat exchanger. Bonding across the main frame and terminal box is necessary unless the manufacturer can demonstrate the absence of circulating current effects. Internal steelwork, e.g. air guides, shall be such that no sparking can occur across joints.

12.2 Requirements for external cooling fans

In addition to (10.7.2), external cooling fans shall comply with EN 50014:1992, Clause 17 Rotating electrical machines.

12.3 Requirements for machines of Type of Protection ‘e’

The machine shall comply with IEC 60079-7. Listed below are the options to be selected where IEC 60079-7 gives alternatives:

- wire insulation used for machine windings shall comply with IEC 317 and be tested in accordance with IEC 60851;
- winding and rotor temperatures shall under no operating condition exceed the limiting temperature determined by the temperature group applicable - usually T3
  Winding temperatures shall not exceed the maximum temperatures specified for Class B insulation materials as specified in table 5 of IEC 60079-7;
- the t_e time shall be at least 5 seconds;
- testing of all thermal characteristics of the motor shall be carried out in accordance with Appendix B of IEC 60079-7.

For machines equipped with noise reduction measures, the certification procedure shall take this into account.

12.4 Requirements for machines of Type of Protection ‘d’

The machine shall comply with IEC 60079-1. Listed below are the options to be selected where IEC 60079-1 gives alternatives:

- A flameproof gland shall be provided wherever a shaft passes through the wall of a flameproof enclosure.
- The length of flame path in a flameproof shaft entry associated with a sleeve bearing shall not be less than the diameter of the shaft, provided that the length of the flame path does not exceed 25 mm.
- For shafts fitted with ball or roller bearings, the radial clearance in the flameproof shaft entry shall not exceed the maximum diametrical clearance allowed for shaft entries used with sleeve bearings.

Terminal boxes fitted to the motor should have type of protection 'e'.

12.5 Requirements for machines of Type of Protection ‘p’

The machine shall comply with IEC 60079-2.

For machines with type of protection 'p' the temperature limitations specified in clause 7.10 of IEC 60034-1 shall apply. However, the temperature of any surface to which the potentially explosive atmosphere has access under normal operating conditions shall not exceed the limiting temperature of temperature group T3.

Terminal boxes fitted to the machine shall be of type of protection 'e' or ‘p’

A minimum over-pressure of 0.05 kPa shall be maintained relative to the external atmospheric pressure at every point within the enclosure.

12.6 Requirements for machines of Type of Protection ‘n’

The machine shall comply with IEC 60079-15.

For machines used in Zone 2 areas the same temperature limitations apply as for machines in non-hazardous areas.

In addition, to prevent thermal ignition, the temperature of any external or internal surface to which the potentially explosive atmosphere has access shall not exceed the limiting temperature of Class T3 temperature group under normal operating conditions.

Auxiliary devices mounted on the machine for protective, alarm or other purposes shall comply with the appropriate standard for the type of protection of electrical equipment used in hazardous areas.

- The equipment shall be suitable for an area characterized by class T3 temperature group and class IIA gas group, unless otherwise specified.
- For Type ‘n’ machines a Certificate of Conformity shall be supplied, except that, subject to the prior approval of the Principal, a Declaration of Compliance may be issued by the Manufacturer.

Add new Section:

Section 13 Inspection and tests

13.1 Tests During Production – HV machines

The following test shall be performed, registered and made available to the Principal's inspector or representative.

- Rotor balancing;
- Pressure test on water coolers, if applicable.

- If specified in the requisition, the Principal will witness some or all of the production tests.

13.2 Final tests

13.2.1 *General*

Before leaving the manufacturers works, each machine shall be inspected and tested, and the results shall be recorded in the test reports.

Machines offered for final inspection shall be complete and ready for shipment, with the possible exception of the final paint finish.

Tests shall be carried out in accordance with this DEP and the referenced external standards, unless otherwise agreed.

- The Manufacturer shall state in his quotation if his normal test arrangements are not adequate, or if he is not capable of carrying out the specified tests. Performing alternative tests (e.g. Testing under reduced load conditions or using a two-frequency method) shall be approved by the Principal before the order is awarded.
- The Principal shall specify in the requisition whether, and to what extent, he will witness the final tests.

13.2.2 *Performance test*

The performance test as specified in (13.3) shall be made on at least one machine of each group of identical machines being supplied.

For LV machines a Type Test on an identical machine is acceptable.

13.2.3 *Routine test*

A routine test shall be carried out on every HV machine not subjected to a performance TEST. The Manufacturer shall certify that each machine is identical to the one that was subjected to the performance or type test.

For LV machines, the manufacturers routine/production tests will be acceptable.

13.2.4 *Type tests and measurements*

The Manufacturers' type test will be acceptable for the following:

- Complete performance test on identical LV machines;
- Winding temperature rise measurements on identical HV machines;
- Locked rotor current and torque tests on identical HV machines;
- Impulse tests and Tan Delta tests on sample coils (see Annex C).

13.2.5 *Special tests*

Machines for special duties or equipped with special protection equipment may require additional tests.

These tests will be specified in the requisition or agreed between the Manufacturer and the

Principal.

13.2.6 *Sample coil test*

- The Principal shall indicate in the requisition whether a sample coil test (see 13.3.6) shall be performed and whether he will witness it.

13.3 Test specification

13.3.1 *Performance test*

The performance test shall include at least the tests and measurements below. The requisition may specify additional tests (see 13.3.6).

1) Winding resistance (cold)
2) Calculated winding resistance at 20 °C
3) Full load heat run
4) Winding resistance (hot)
5) Calculated winding temperature rise
6) Bearing temperature rise
7) Slip at full load and 3/4 load
8) Efficiency at full load and 3/4 load
9) Power factor at full load and 3/4 load
10) Current unbalance at full load
11) Locked rotor current – at reduced voltage
12) Locked rotor torque – at reduced voltage
13) No-load current
14) No-load losses
15) Vibration severity
16) Dielectric tests on machine windings, heaters and built-in temperature detectors
17) Insulation resistance test on:
    - machine windings (a) before heat run
      (b) after heat run and dielectric test
    - heater(s)
    - built-in temperature detectors
    - bearing insulation
18) Polarization Index test on stator windings (HV)
19) Shaft voltage at no-load
20) Noise test
21) Run-up (speed-time) curve
22) Sleeve bearing inspection (if applicable)
23) Physical inspection for compliance with this DEP and the requisition

13.3.2 *Performance test – HV machine in combination with unit transformer*

The motor of such a combination shall be subjected to the performance test as specified in 13.3.1 or 13.3.2, as applicable.

The transformer shall be subject to the type tests as specified in DEP 33.65.40.31-Gen. and IEC 60076-1.

In addition to these tests, the transformer shall be subjected to the following:

1) Lightning impulse test on the primary windings, IEC 60076-3 item 12.
   The rated lightning impulse withstand voltage shall be in accordance with Table II, list 1 of IEC 60076-3, unless otherwise specified.
2) Measurement of reactance and resistance.
3) Calculated resistance and reactance at 20 °C
4) Noise test
5) Short-circuit test, IEC76-5 item 2.

If no short-circuit type test certificate for an identical transformer is available, a simulated transformer/motor on-load start test, with the transformer at its normal operating temperature, shall be performed. The test procedure shall be:

- ♦ Measurement of reactance at normal operating temperature
- ♦ Three tests with a current corresponding to the motor starting current. The duration of the test shall be equal to the running-up time of the motor.
- ♦ Measurement of reactance after the simulated starts. The measured value shall not deviate by more than 2% from the value prior to tests.
- ♦ If the requisition also requires an out-of-tank inspection, the transformer shall be given a routine test as specified in DEP 33.65.40.31-Gen. and IEC 60076-1 after it is re-installed in the tank.

13.3.3 *Routine test*

The test shall comprise at least the following:

1) Winding resistance - cold.
2) Calculation of winding resistance at 20 °C for stator (and rotor for synch. motors)
3) No-load current
4) No-load losses
5) Vibration severity
6) High voltage test on:
   - Machine windings
   - Heater(s)
   - Built-in temperature detectors
7) Insulation resistance test on:
   - Machine windings
   - Heater(s)
   - Built-in temperature detectors
   - Bearing insulation
8) Sleeve bearing inspection.
9) Physical inspection for compliance with this DEP and the requisition.

13.3.4 *Routine test for HV machine in combination with unit transformer*

The motor of such a combination shall be given a routine test as specified in 13.3.3.

The transformer shall be subjected to the routine test specified in DEP 33.65.40.31-Gen. and IEC 60076-1.

13.3.5 *Special tests*

- ● Where specified in the requisition, the performance or routine tests may also include additional special tests, examples of which are included in the following list:

1) No-load saturation test
2) Rotor open-circuit test
3) Rotor inertia test
4) Overspeed test
5) Type test for applicable type of hazardous area protection, in accordance with IEC 60079
6) Submerged stator test to NEMA MG-1, 20.49
7) Surge immunity test to EN 61000-4-5
8) Any other test that may have been agreed upon.

13.3.6 *Sample coil test*

In order to confirm the quality of the winding insulation used in machines with rated voltage Un > 5 kV (and lower ratings if specified in the requisition), two additional coils shall be manufactured identical to the coils made for the machine. From the total number of coils, two coils shall be selected at random for test purposes. If the vacuum pressure impregnation method is applied for the insulation system, these two coils shall be impregnated and processed together and under the same conditions as the complete stator winding.

If one of the coils fails the test shall be repeated on a further set of two coils. If both coils fail the entire batch shall be rejected.

The test procedures and the criteria to evaluate the test results are provided in Annex C.

Add new section:

Section 14 Documentation

14.1 Manufacturers technical information

The following drawings and data shall be submitted for all machines.

- Outline drawings showing main dimensions, arrangement of components, terminal boxes, foundation loading.
- Schematic and connection diagrams covering all equipment pertaining to the motor.
- Additional information shall be provided for HV motors over 250 kW as follows:
- Torque-speed curves.
- Bearing arrangement/alignment drawing with data outlining bearing/bearing shell replacement procedure.

14.2 Test reports

The Manufacturer shall provide test reports giving the results of all tests carried out on the machines supplied. These reports shall also include the Manufacturers Type Tests and Routine/production tests, if applicable.

PART III AMENDMENTS AND SUPPLEMENTS TO IEC 60034-14

In this Part, sections of IEC 60034-14 are amended or supplemented. Sections of IEC 60034-14 that are not mentioned shall remain applicable as written.

Section 1 Scope and object

Replace the second paragraph of this section by the following:

It is applicable to three-phase a.c. machines, with shaft heights 56 mm and higher and a rated output up to 50 MW, at all nominal speeds up to and including 3 600 r/min.

Section 8 Limits of bearing housing vibration

8.1 Limits of vibration severity

Add to this clause:

All machines, at any speed, shall comply with Vibration grade N for rigid mounting in Table 1 in this paragraph.

The maximum allowable vibration levels shall apply to all operating temperatures of the motor between ambient and maximum operating temperature and to all operating conditions between no-load and full load.

8.2 *Limits of vibration velocity with twice line frequency for a.c. machines*

Add to this clause:

The contribution of the twice supply frequency component to the overall vibration shall not exceed 1.4 mm/s (rms)

8.3 *Axial vibration*

Add to this clause:

The vibration severity of the motor frame, including main terminal boxes, (excluding bearings) shall not exceed 4.5 mm/s (rms)

Section 9 Limits of relative shaft vibration

Replace this section by the following:

- If stated in the requisition, each bearing of a motor equipped with sleeve bearings shall be provided with two non-contacting eddy current proximity probes in accordance with API 670.

  The type and model number of the probes will be advised by the Principal.

  For bearings fitted with proximity probes, the unfiltered double amplitude of shaft vibration (peak-to-peak) including shaft run-out, relative to each radial bearing, with rated voltage and frequency applied, and at any load condition between no-load and full load, shall not exceed 50 µm for all machines

  NOTE: Shaft run-out is the total indicator reading in a radial direction when the shaft is rotated in its bearings. The total mechanical and electrical run-out combined shall not exceed 25% of the maximum allowable peak-to-peak vibration.

  The above limits are additional to Section 8.

Add new section:

Section 10 Vibration tests

The aim of the vibration test is to obtain at the Manufacturers test bed sufficient information concerning the vibration characteristics of the machine under normal site operating conditions.

1. For all tests (except as below) the machine shall be mounted as permitted by Section 6 and conditions of measurement shall be as Section 7 of IEC 60034-14.
2. For machines subject to a *Performance Test*, vibration measurements shall be taken during a no-load run at near ambient conditions, and also after the heat run with the machine at full operating temperature.
3. For two-pole machines where a test to establish the twice supply frequency component is to be performed, the machine shall be rigidly mounted as specified in Paragraph 6.2, and a broad band frequency analysis shall be carried out.
4. For machines which are subject to a *Routine Test*, the test is only required during a no-load run at near ambient conditions.

PART IV REFERENCES

In this DEP, reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments, supplements or revisions thereto.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Data/requisition - general	DEP 30.10.00.94-Gen.
Data/requisition sheet - equipment noise limitation	DEP 31.10.00.94-Gen.
Power Transformers (amendments/supplements to IEC 60076 and IEC 726)	DEP 33.65.40.31-Gen
Electrical variable speed drive systems	DEP 33.66.05.33-Gen.
Requisition sheet - electric motors	DEP 33.66.05.93-Gen.

AMERICAN STANDARDS

Centrifugal compressors	API 617
Non-contacting vibration and axial position monitoring systems	API 670

Issued by:
American Petroleum Institute
Publication and Distribution section
2101 L Street, NW
Washington DC 20037, USA.

Motors and generators	NEMA MG 1

Issued by:
National Electrical Manufacturers Association
2101 L Street, NW
Washington DC 20037
USA.

BRITISH STANDARDS

General requirements for rotating electrical machines: Part 144: Specification for the insulation of bars and coils of high voltage machines, including test methods	BS 4999-144

Issued by:
British Standards Institution
389 Chiswick High Road
London W4 4AL
UK

EUROPEAN STANDARDS

Electrical apparatus for potentially explosive atmospheres - General requirements	EN 50014:1992
Electromagnetic compatibility (EMC) - Part 4: Testing and measurement techniques - Section 5: Surge immunity test	EN 61000-4-5

INTERNATIONAL STANDARDS

Rotating electrical machines		
Part 1:	Rating and performance	IEC 60034-1: tenth edition plus Amendment 1 (1997-06)
Part 2:	Methods for determining losses and efficiency of rotating electrical machinery from tests	IEC 60034-2
Part 4:	Methods for determining synchronous machine quantities from tests	IEC 60034-4
Part 5:	Classification of degrees of protection provided by enclosures of rotating electrical machines (IP code)	IEC 60034-5
Part 6:	Methods of cooling (IC code)	IEC 60034-6
Part 7:	Classification of types of constructions and mounting arrangements (IM code)	IEC 60034-7
Part 8:	Terminal markings and direction of rotation of rotating machines	IEC 60034-8
Part 12:	Starting performance of single speed three-phase cage induction motors for voltages up to and including 660V	IEC 60034-12
Part 14:	Mechanical vibration of certain machines with shaft heights 56 mm and higher. Measurement, evaluation and limits of the vibration severity	IEC 60034-14: second edition (1996-11)
Part 15:	Impulse voltage withstand levels of rotating AC machines with form-wound stator coils	IEC 60034-15
Part 18:	Functional evaluation of insulation systems	IEC 60034-18
High voltage test techniques		IEC 60060
Dimensions and output series for rotating electrical machines		IEC 60072
Part 1:	Frame numbers 56 to 400 and flange numbers 55 to 1080	IEC 60072-1
Part 2:	Frame numbers 355 to 1000 and flange numbers 1180 to 2360	IEC 60072-2
Power transformers		IEC 60076
Electrical apparatus for explosive gas atmospheres		IEC 60079
Degrees of protection provided by enclosures (IP code)		IEC 60529
Classification of Environmental Conditions: Part 2-1: Environmental conditions appearing in nature; temperature and humidity		IEC 60721-2-1
Industrial Platinum Resistance Thermometer Sensors		IEC 60751
Methods of test for winding wires		IEC 60851
Guide for test procedure for the measurement of		IEC 60894

loss tangent on coils and bars for machine windings

Issued by:
Central Office of IEC (Sales Dept.)
3, Rue de Varembé
1211 Geneva 20
Switzerland

Copies can also be obtained from national standards organizations.

Rolling bearings - radial bearings - boundary dimensions	ISO 15
Rolling bearings - dynamic load ratings and rating life	ISO 281
Rolling bearings - tolerances - definitions	ISO 1132
Acoustics - Test code for the measurement of airborne noise emitted by rotating electrical machinery	ISO 1680-2

Part 2: Survey method

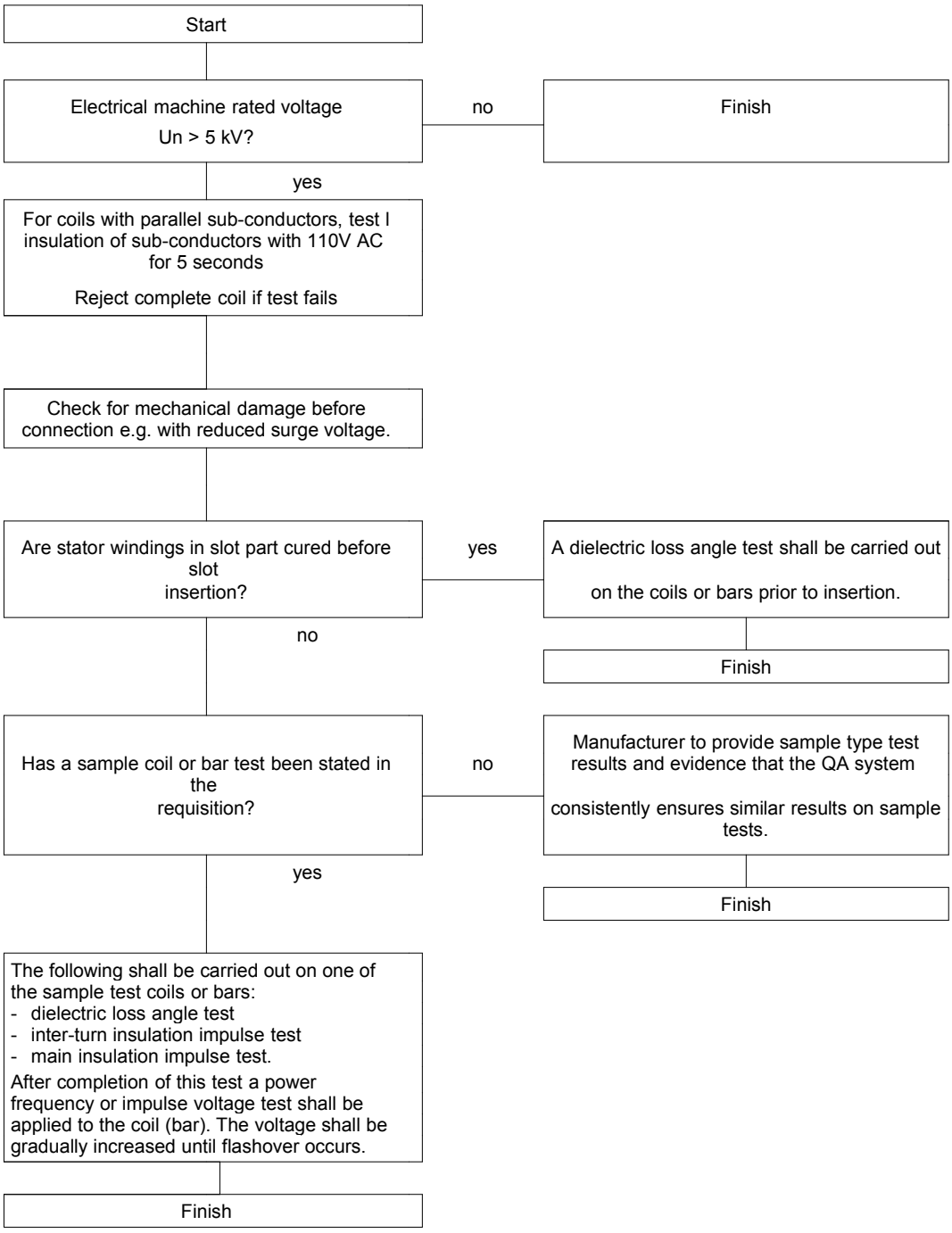
Mechanical vibration - balance quality requirements of rigid rotors	ISO 1940
Mechanical vibration of machines with operating speeds from 0-200 r/s - Basis for specifying evaluation standards	ISO 2372

Issued by:
International Organisation for Standardisation
1, Rue de Varembé
P.O. Box 56
CH -1211 Geneva 20
Switzerland

Copies can also be obtained from national standards organizations.

ANNEX C INSULATION QUALITY TEST

To verify the integrity of the insulation system, the following tests as shown in the diagram below shall be performed as a minimum. Criteria to evaluate the test and test results are provided thereafter.



Assessment of insulation quality

1. DIELECTRIC LOSS ANGLE TEST

The measurement of the dielectric loss angle (δ) of the insulation of coils for machine windings shall comply with the guidelines as laid down in IEC 60894. If stress grading is applied before curing, Appendix B of IEC 60894 shall be followed.

The results shall be within the highest permissible values as specified in BS 4999-144. The delta-tan-delta values shall be within the highest permissible 95% sample values.

For one of the sample coils the test shall be carried out after the coil has been heated to 155 °C followed by cooling to ambient temperature.

2. INTER-TURN INSULATION IMPULSE TEST

This test is applicable for sample coils and shall be conducted to IEC 60034-15 with the following conditions:

The inter-turn test voltage shall be generated by a damped oscillatory discharge of a capacitor. The number of capacitor discharges shall be 5, unless otherwise agreed between the Manufacturer and the Principal.

The front time of the first voltage peak shall be 0.3 µs $\pm$ 0.2 µs. The decay time to half the peak voltage shall be between 3 µs and 10 µs. The shape of the waveform shall be recorded by means of a photograph or equivalent method.

The voltage peaks between the terminals of the sample coil shall be equal to at least 0.65 x $(4U_n + 5)$ kV.

3. MAIN INSULATION IMPULSE TEST

This test is applicable for sample coils and shall be conducted to IEC 60034-15 with the following conditions.

The impulse withstand level of the main insulation is tested by applying either a power frequency voltage or an impulse voltage.

* Testing of the main insulation shall be carried out after the coil has been heated to 155 °C followed by cooling to ambient temperature.

3.1 POWER FREQUENCY VOLTAGE TEST

An rms voltage of $(2U_n+1)$ kV shall be applied for 1 minute between coil terminals and earth. The voltage shall then be increased at a rate of 1 kV/s up to 2 x $(2U_n+1)$ kV and shall then immediately be reduced at a rate of at least 1 kV/s to zero, without a failure.

3.2 IMPULSE VOLTAGE TEST

The impulse test of the main insulation shall be performed by applying a voltage between the coil terminals and earth.

The main insulation test voltage shall be generated by an impulse generator applying approximately the standard lightning impulse specified in IEC 60060-2, i.e. wave front rise time of 1.2 µs and a decay time of 50 µs to half the peak voltage.

The number of pulses shall be 5, unless otherwise agreed between the Manufacturer and the Principal.

The shape of the wave form shall be recorded by means of a photograph or equivalent method.

The voltage peaks between the coil terminals and earth shall be at least equal to $(4U_n+5)$ kV.

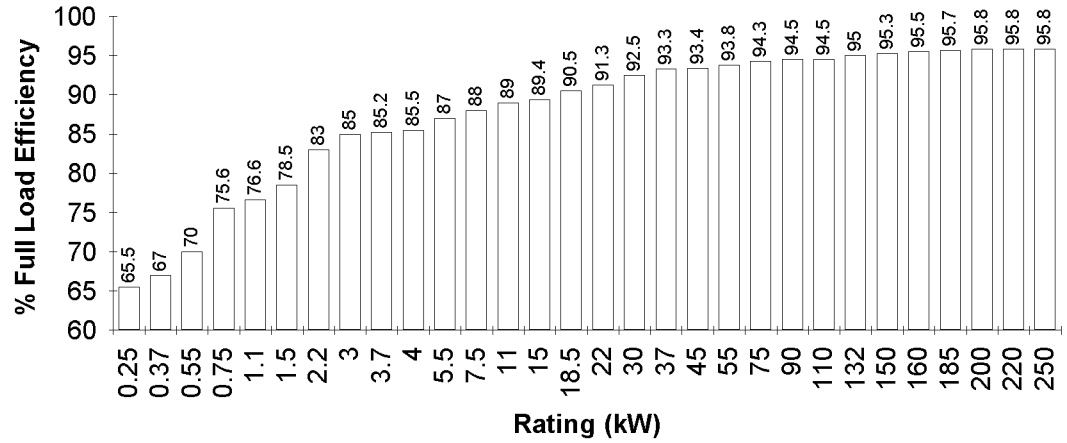
The winding is considered sound and acceptable if no voltage collapse has occurred and the results are identical with each other.

ANNEX D MINIMUM EXPECTED FULL LOAD EFFICIENCY OF MACHINES

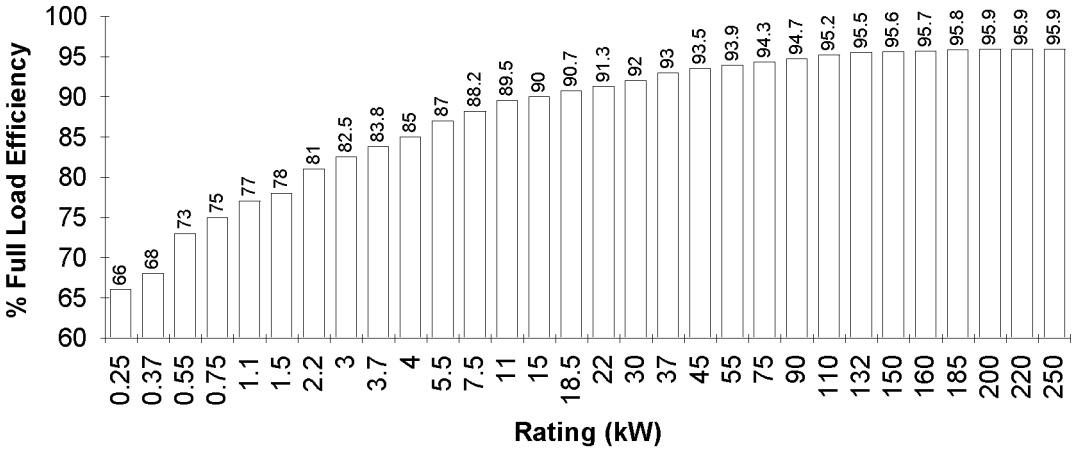
The minimum expected values for efficiency of motors are shown in the charts below. Motors with higher efficiency at both full load and three quarter loads will be preferred.

Manufacturers are requested to quote all their alternative ranges offering equivalent or higher efficiencies.

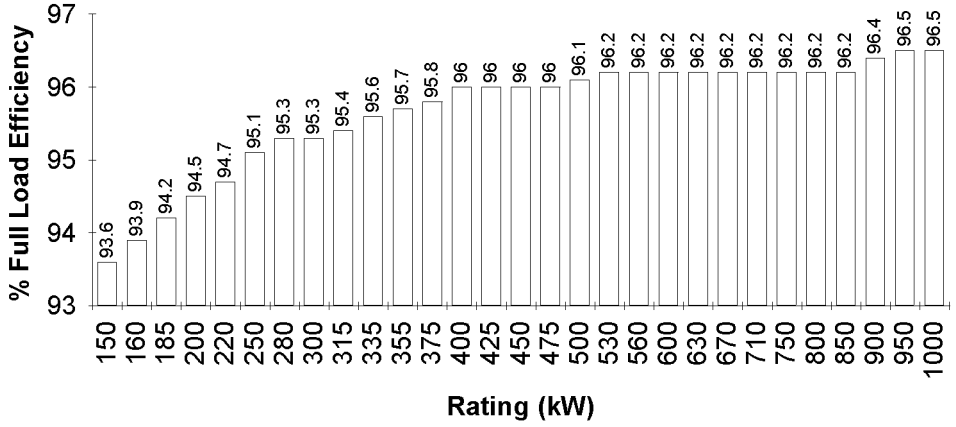
MINIMUM EXPECTED FULL LOAD EFFICIENCY OF 2-POLE LV MOTORS



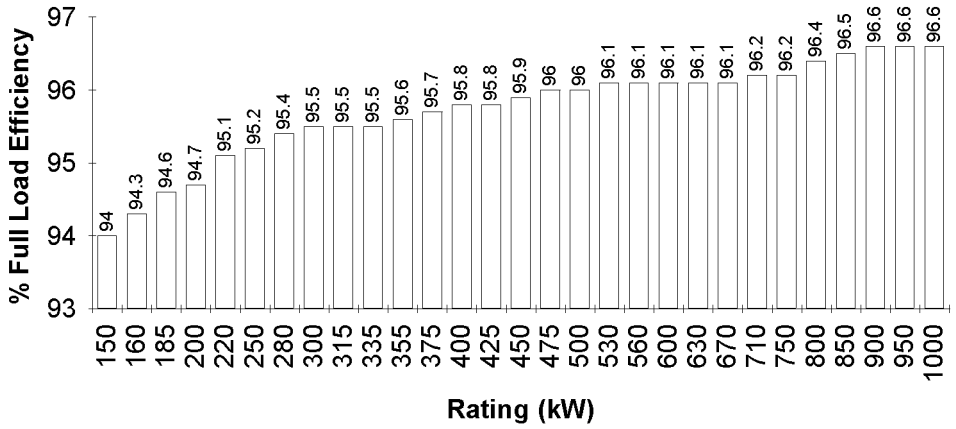
MINIMUM EXPECTED FULL LOAD EFFICIENCY OF 4-POLE LV MOTORS



MINIMUM EXPECTED FULL LOAD EFFICIENCY OF 2-POLE HV MOTORS



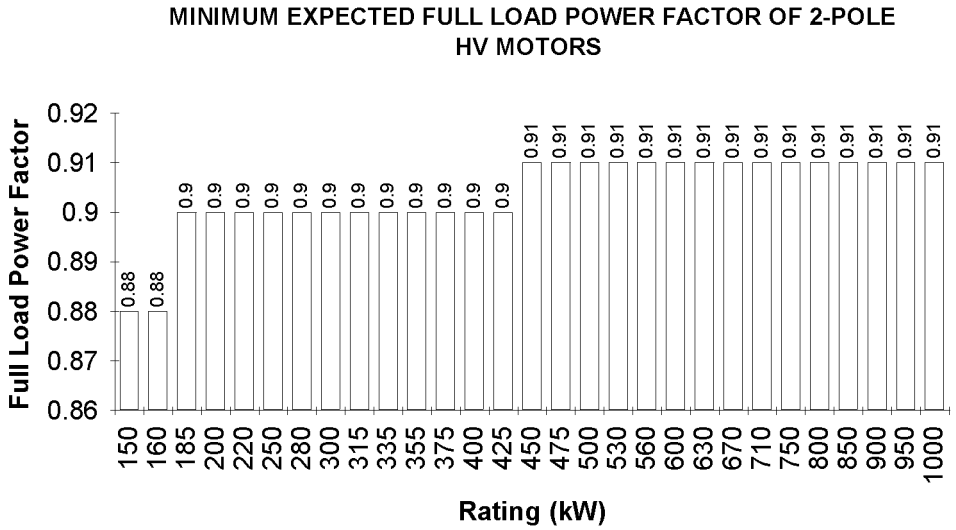
MINIMUM EXPECTED FULL LOAD EFFICIENCY OF 4-POLE HV MOTORS

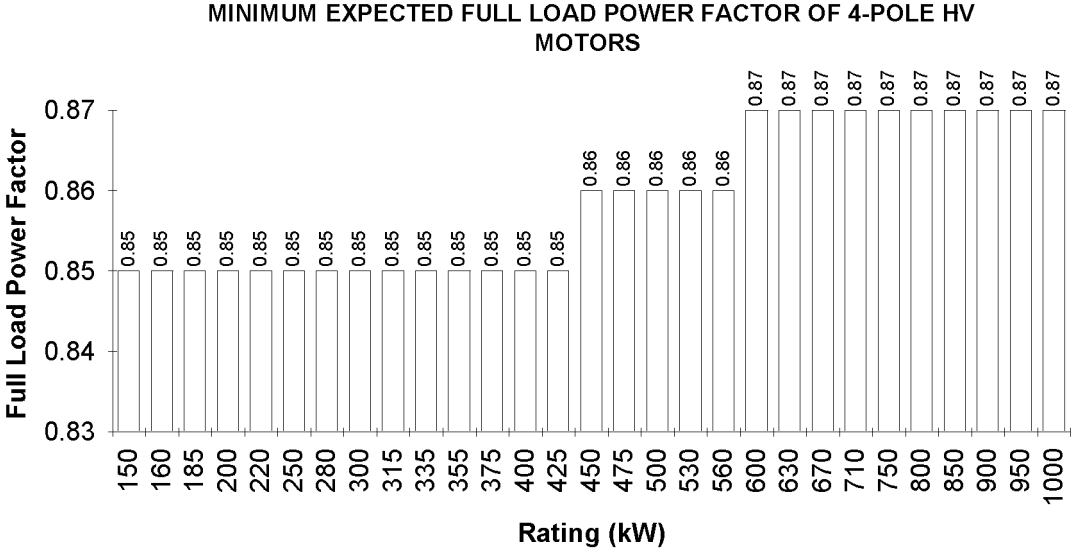


ANNEX E MINIMUM EXPECTED FULL LOAD POWER FACTOR OF MACHINES

The minimum expected values for the power factor of motors are shown in the charts below. Motors with higher power factor at both full load and three quarter loads will be preferred.

Manufacturers are requested to offer 'high power factor' motors as an alternative.





ANNEX F EXAMPLE OF ALL-IN COST CALCULATION

	P (kW)	Number of poles	E_{man} (at full load)	PF_{man} (at full load)	C (USD)
Motor A	160	4	95.7	0.87	13,500
Motor B	160	4	94.6	0.87	12,500

C_{apc} = 20%

E_{cost} = USD 0.06 per kWh

MDC = USD 1/kVA,

K_{ot} = 100 %

	Motor A	Motor B
Capital charge (USD)	2,700	2,500
Electricity cost (USD)	90,181	91,229
Total All-in Cost, TAC (USD)	92,881	93,729

In the above table the capital charge and the electricity cost are calculated as follows:

$$\text{Capital charge (USD)} = \frac{C \cdot Capc}{100}$$

$$E \quad \frac{P \cdot K_{ot}}{E_{man}} \quad x \quad \left(8760 \cdot E_{cost} + \frac{(12 \cdot MDC)}{PF_{man}}\right)$$

In the example it is assumed that the maintenance costs are identical for both motors.

This example indicates that the Total All-in Cost of motor A is USD 848 less than that of motor B.

All other factors being equal, motor A would be the preferred option.