TECHNICAL SPECIFICATION

SYNCHRONOUS AC MACHINES
(AMENDMENTS/SUPPLEMENTS TO IEC 60034-1)

DEP 33.65.11.31-Gen.

January 1999

DESIGN AND ENGINEERING PRACTICE

PREFACE

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PART I INTRODUCTION

1.1 SCOPE

This DEP specifies requirements for three-phase, air-cooled, synchronous AC machines, and their excitation systems and auxiliary equipment.

IEC 60034-1 shall apply to all synchronous AC machines.

This DEP supplements IEC 60034-1 for all synchronous machines, both motors and generators, with ratings of 1 250 kVA and higher.

This DEP does not apply to synchronous machines with ratings lower than 1 250 kVA, except for Section 12, which applies to synchronous machines of any rating sited in zone 2 areas.

Part II of this DEP amends and supplements IEC 60034-1 (tenth edition plus Amendment 1,1997-06).

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.

This DEP is a revision of the DEP of the same number dated July 1997.

NOTES:
1. A bullet (•) in the margin indicates where information from the Principal Is required. This information shall 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.

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.

If national and/or local regulations 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 document 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 document 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).

2. 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 four years of uninterrupted operation under the conditions specified.

♦ Unless otherwise stated in the requisition, the machine Manufacturer shall include provisions for condition monitoring where relevant in order to maximize intervals between maintenance.

The unit transformer of the machine, if applicable, shall comply with this DEP and DEP 33.65.40.31-Gen.

2.3 EFFICIENCY

High voltage synchronous machines shall have efficiencies not less than the following:

2-pole	4-pole
98.0%	97.5%

• These values are related to full load operation at the power factor specified in the requisition, and include the power consumption of the excitation system.

For machines which require separately driven auxiliary devices, like ventilators for method of cooling IC6A6A1, the Manufacturer shall list the power consumption of these devices.

2.4 GENERAL FEATURES OF DESIGN

2.4.1 Degree of protection

- The minimum degree of ingress protection, in accordance with IEC 60529, shall be as follows:

			Minimum degree of protection
Land and coastal installations	Machine and auxiliaries	indoor installation	IP 44
		outdoor installation	IP 54
	terminal boxes and bearing housings		IP 55
Offshore installations	Machine and bearing housing.		IP 55
	Auxiliaries and terminal boxes		IP 56

Add new clause:

2.4.2 Methods of Cooling (IEC 60034-6)

- Unless otherwise specified, machines shall have air-to-air, self-cooling with cooling method IC 5A1A1, IC 6A1A1 or IC6A1A6 in accordance with IEC 60034-6.

  Air-to-water, self-cooled machines shall be supplied with cooling method IC 8A1W7 in accordance with IEC 60034-6.

* Separately-cooled machines may be supplied only for special applications and only with the approval of the Principal. Attention shall be paid to the sparing of auxiliaries of separately-cooled machines.

* The cooling air for the exciter shall be taken from the cooling air circuit of the machine (cooling method IC 3A1 in accordance with IEC 60034-6), except that for larger exciters where the above cooling method is no longer practical, exciter cooling shall be independent of the main machine cooling. In the latter situation the exciter cooling method shall be IC 6A1A1 or IC 8A1W7 in accordance with IEC 60034-6.

The coolers shall be pressure-tested at 1.5 times the maximum working pressure for 15 minutes to demonstrate the withstand capability. If the water pressure in the cooler is controlled by a valve or pressure-reducing device connected to a water supply of higher pressure than the working pressure of the cooler, the cooler shall be designed for the higher pressure, and tested at 1.5 times the higher pressure value.

- The Principal shall submit to the Manufacturer the relevant data regarding the cooling water.

PART II AMENDMENTS/SUPPLEMENTS TO IEC 60034-1

In this Part, certain sections of IEC 60034-1 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.

Add new clause:

2.31 ADDITIONAL SPECIFIC DEFINITIONS

Air-to-air cooled machine
A closed machine with an 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 the secondary coolant.

Certificate of conformity
A 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 salt 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
Document issued by the Manufacturer stating that the machine complies with the requirements of IEC 60079-15.

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

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

Limiting temperature
The maximum permissible temperature for apparatus or parts, determined by:

- The danger of ignition of the explosive atmosphere
- The thermal stability of the materials used.

The lower of these two temperatures is the limiting temperature.

Non-hazardous area (IEC 60079-10)

An area in which an explosive gas mixture is not expected in a quantity such as to require special precautions for the construction and use of electrical apparatus, cables and accessories.

Offshore installation
An installation located in open salt water at a location remote from the nearest land.

Relative harmonic content
The ratio of the rms value of the harmonic content to the rms value of the total non-sinusoidal periodic waveform

i.e. relative harmonic content = $\sqrt{1-(g_1/g)^2}$

where:

g_1 = rms value of the fundamental component of voltage

g = rms value of the total voltage waveform

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 means other 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.

Turbine-type machine
A cylindrical rotor machine designed for operation at high peripheral rotor speed.

Type of protection 'e' (IEC 60079-7)
A 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 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.

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 6 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, speed and power factor shall be stated in the requisition.

  The rating of the generator offered by the Manufacturer shall have class F insulation but shall be used only for class B temperature rise for all parts of the generator, e.g. stator, rotor and exciter 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:

- The required motor rating, speed and power factor 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.

Section 5 Site operating conditions

5.1 GENERAL

Add to this clause:

The atmosphere shall be assumed to be 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. The Principal may select the 'Mean Annual Extremes' which correlate with their 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 HEAT EXCHANGERS FOR AIR-TO-WATER COOLED MACHINES

The following design data shall apply for heat exchangers:

maximum cooling water outlet temperature	37 °C
maximum cooling water temperature rise	7 K
maximum static water pressure	8×10^5 Pa
minimum static water pressure	3×10^5 Pa
minimum cooling water velocity in tubes	1 m/s
fouling resistance	in accordance with DEP 20.21.00.31-Gen.

Note: If the requisition indicates that sea water needs to be used, the design of the cooler including materials shall be suitable for those characteristics.

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 expected from adjacent operating equipment with the generator running or standing idle	0.4 mm/s (rms)

Section 6 Electrical operating conditions

6.1 ELECTRICAL SUPPLY

Add to this clause:

- The rated values of the system voltage, frequency and minimum and maximum fault level shall be stated in the requisition.

  Synchronous generators shall be suitable for:
  - island operation; and
  - parallel operation with other generators; and
  - parallel operation with an external grid.

- Details regarding the external grid or other generators operating on the system shall be made available by the Principal.

6.2.2 *AC generators*

Add to this clause:

When tested on open circuit and at rated speed and voltage the wave-form of the line-to-line terminal voltage shall be sinusoidal with a relative harmonic content not exceeding 3% for generators with ratings up to 5 000 kVA and 1.5% for generators with ratings exceeding 5 000 kVA.

6.2.3 *Synchronous machines*

Add to this clause:

During operation under these conditions the maximum permissible temperature rise may be exceeded by maximum 5 K.

6.3 VOLTAGE AND FREQUENCY VARIATIONS DURING OPERATION

Add to this clause:

Machines connected to the grid via a unit transformer shall be capable of supplying their rated output (kVA) at rated speed and power factor and at voltage and frequency variations for zone A of Figure 11. Machines directly coupled to the grid shall be capable of supplying their rated output at rated speed and power factor at voltages ranging from +10% to -10% of the rated value.

In cases of continuous operation at the extreme voltage limits specified above, the maximum permissible temperature rise may be exceeded by maximum 10 K.

Where the machine is a generator, the output voltage shall be adjustable between +10% and -10% of the rated value. Adjustment shall be possible during normal operation.

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

6.4 THREE PHASE A.C. MACHINE OPERATING ON UNEARTHED SYSTEMS

Add to this clause:

The machine shall be suitable to operate:

- continuously on an unearthed system;
- for periods of up to 8 hours on an unearthed system with an earth fault on one phase. The maximum cumulative time in this mode shall be restricted to 500 hours over the machine lifetime.

Add new clause:

6.6 MACHINE NEUTRAL EARTHING

The requirements for machine neutral earthing are laid down in DEP 33.64.10.10-gen.

The earthing resistor and cubicle shall be supplied by the Manufacturer.

Section 7 Thermal performance and tests

7.9 MEASUREMENT OF BEARING TEMPERATURES

Add to this clause:

The bearing temperature rise measured by the ETDs 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 never exceed 82 °C. (API 617, 6th. Edition, 1995) For oil ring lubricated bearings the sump temperature shall not exceed 82 ^{o}C (API 610, 8^{tth} Edition 1995).

Section 8 Other performance and tests

8.5 OVERSPEED

Add to this clause:

Generator rotors shall be subject to the same overspeed test(s) as specified for their prime-movers.

* Before the overspeed test the rotor shall be balanced at nominal speed 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.

8.6 SHORT-CIRCUIT CURRENT FOR SYNCHRONOUS MACHINES

Add to this clause:

Machines shall be designed to withstand without suffering injurious effects a short circuit at its terminals, while operating at full load and at voltage and frequency limits in accordance with Zone A Figure 11.

The duration of the short-circuit shall be limited to 3 seconds.

- The machine sub-transient reactance may be higher than the standard specified value depending on switchgear constraints and with regard to (8.11). The Principal shall specify such requirements, if necessary.

Add new clause:

8.9 TELEPHONE HARMONIC FACTOR (THF) FOR SYNCHRONOUS MACHINES

8.9.2 *Limits*

Replace this clause by:

The machine shall be suitable for electrical loads having non-linear characteristics as specified in DEP 33.64.10.10-Gen.

Add new clause:

8.10 EXCITATION SYSTEM

8.10.1 *Generators*

- Unless otherwise specified, the excitation system of the generator shall be designed for continuous operation at a generator power factor of 0.8 lagging at rated output and a generator terminal voltage between 90% and 110% of the rated voltage.

  The steady-state voltage variations from no-load to full load shall be limited to ± 0.5% of the rated voltage during island operation.

  The excitation system shall be equipped with an automatic power factor controller. When operating in parallel with a connected grid, the power factor controller shall maintain the power factor within a margin of +2.5% to –2.5% of the set power factor.

- Unless otherwise specified, the voltage regulation grade of the AVR shall be VR 2.33 in accordance with BS 4999-140.

8.10.2 *Motors*

- Unless otherwise specified, synchronous motors shall be designed for continuous operation at a power factor of 0.9 leading at rated output and a voltage applied at the motor terminals

of between 90% and 110% of the rated voltage.

If the motor loses synchronism with the supply voltage, the solid state protection system shall protect the field windings against excessive over-voltage and the excitation shall be disconnected immediately. Such protection shall operate in the event of undervoltage.

A synchronous operation of the motor with the excitation voltage applied shall be avoided to the greatest possible extent. The Manufacturer shall clarify the protection being offered in this respect. In any case, he shall provide a stability curve identifying maximum allowable operating time versus remnant voltage.

The excitation system shall be equipped with an automatic power factor controller. This power factor controller shall maintain the power factor within a margin of + 2.5% to - 2.5% of the set power factor.

Add new clause:

8.11 TRANSIENT AIR-GAP TORQUES

The end-winding supports of all machines shall cater for three-phase short-circuit currents and system reconnection at total phase opposition. Their shaft and active iron core systems shall cater for two-phase short-circuit.

The manufacturer shall ensure that the shaft and active iron core systems are suitable for system reconnection at 120 degree phase difference, having regard to the impedance of the connected system.

NOTE: If the Manufacturer cannot readily calculate the above quantities other than rated and three-phase short-circuit torques, the following assumptions may be made:
- the two-phase short-circuit torque is 1.2 times the three-phase short-circuit torque;
- the 180 degree reconnection will result in an end-winding current 20 times the rated current;
- the 120 degree reconnection will result in a reconnection torque 2.6 times the three-phase short-circuit torque.

♦ For generators, the Manufacturer shall state the maximum transient airgap torques during two and three phase short-circuits and reconnection at the generator terminals.

♦ For synchronous motors, the Manufacturer shall state the maximum transient air-gap torques during:

- asynchronous start
- two and three phase short-circuit at the motor terminals
- reconnection after power interruption

Add new clause:

8.12 CRITICAL SPEEDS

Machines shall have a rigid, undercritical rotor-bearing system, with the first rotor bending critical speed not lower than 125% of the synchronous speed. If this is not possible, machines may have a flexible, overcritical rotor-bearing system, with the first critical speed below 80% of the rated synchronous speed and the second critical speed shall be not lower than 125% of the rated synchronous speed.

♦ The mechanical equipment Manufacturer shall perform a torsional vibration analysis of the complete train. It shall be the responsibility of the machine Manufacturer to provide the physical data required for the torsional analysis.

Add new clause:

8.13 NOISE CONTROL

8.13.1 *General*

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

If the machine produces noise with tonal components, the maximum sound pressure levels

shall be 5 dB(A) less than the values stated above or in the requisition.

8.13.2 *Noise limits*

The sound pressure level of the machine at full load shall not exceed 82 dB(A) in the work area, measures in accordance with ISO 1680-2

8.13.3 *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:

8.14 UNIT TRANSFORMER

Unit transformers shall comply with DEP 33.65.40.31-Gen.

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

Add new clause:

8.15 STARTING, RE-STARTING AND RE-ACCELERATION OF SYNCHRONOUS MOTORS

8.15.1 *Number of sequential starts*

Motors shall be suitable for direct-on-line asynchronous starts.

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

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

Between successive starts the motor will 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.

• For motors with a rated output in excess of 1600kW, the manufacturer may separately quote their standard start option.

The proposed driven machine inertia and torque/speed data shall be used.

8.15.2 *Number of starts per year*

Motors including, if applicable, the unit transformer, shall be suitable for a maximum of 1000 starts per year, unless otherwise specified.

8.15.3 *Starting current*

For HV motors, the starting current during an asynchronous start shall not exceed 6.5 times the rated current of the motor.

• More stringent limitations, if applicable, shall be specified in the requisition.

8.15.4 *Pull-in torque*

The pull-in torque shall be at least 60% of the rated torque for two, four and six pole machines. For machines with eight or more poles the pull-in torque shall be at least 45% of the rated torque.

8.15.5 *Running-up time*

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

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

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

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 motor stator current to a value not exceeding 40% of the full load current.

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

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

Section 9 Rating plates

9.1 GENERAL

Add to this clause:

The rating plates shall be made of stainless steel and be fixed to a non-removable part of the frame.

9.2 MARKING

Add to the beginning of this clause:

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

Add to the end of this clause:

27. Principal's purchase order number
28. Efficiency at full load
29. Subtransient reactance (not applicable to exciter)
30. Transient reactance (not applicable to exciter)
31. Rated exciter field current.
32. Bearing type, size, clearance, shaft and housing fit for DE and NDE bearings
33. Type of lubricant, relubrication interval, minimum and maximum allowable quantity of lubricant for the DE and NDE bearing
34. Oil pressure required, for force-lubricated bearings

Bearing information shall be provided on a separate rating plate.

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 for hoisting. The degree of protection specified in (2.4.1) shall be attained regardless of such eye bolts.

Machines 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 mechanical 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 shall be in the same plane and within a tolerance of 0.15 mm per metre 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.

10.3.3 *Heat exchangers*

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

The heat exchanger's tube assembly shall be designed so that the natural frequency of vibration of the tubes is not excited by the machine's running frequency or its harmonics.

- 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 throughout the lifetime of the machine. They shall have collection trays to prevent water leaking onto vulnerable parts.

  For air-to-water cooled machines, if there is no chemically treated cooling water available, then the layout shall be such that the machine can carry 100% of the full load for a period of at least 8 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.

  Heat exchangers shall have provisions to drain the heat exchanger and 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, rotor windings and shall maintain the temperature of the machine windings at approximately 5 °C 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.

Add new clause:

10.4 WINDINGS

10.4.1 *Stator windings*

Stator windings shall be star connected.

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

All stator windings shall have identical insulation levels regardless of the electrical location of the winding, e.g. star-point side or HV side.

The main insulation material used for machines with a rated voltage higher than 6 kV shall be mica.

The windings of machines with rated voltages higher than 6 kV shall have anti-corona protection achieved by means of semi-conducting tape covering the slot part of the winding. Semi-conducting paint shall not be used for anti-corona protection.

The windings of machines with rated voltages higher than 7 kV shall have stress grading as well as anti-corona protection.

All windings shall be adequately supported, braced and blocked to provide sufficient rigidity and to limit end-winding vibration and subsequent cracking of the winding insulation.

Windings shall be capable of withstanding the dynamic forces which result from system fault conditions and mis-synchronisation.

Inter-coil packing blocks shall be positively secured to the coils by binding with cord or tape. Varnish or tight initial wedging shall not be relied upon for holding the blocks in place.

Stator coils shall be tightly fitted in the slots. The wedging method shall be suitable for thermal cycling and vibration over the specified 20 years.

10.4.2 *Exciter*

The windings shall be fully impregnated to restrict the movement of the coils and to achieve an adequate heat dissipation. Coating or painting is not recognised as impregnation.

10.4.3 *Terminal boxes*

- A terminal box of sturdy construction shall be provided, with sufficient space for connecting the cable(s) as indicated 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 used and to be supplied by the Manufacturer shall also be indicated in the requisition.

  Gland plates and glands to be used for single-core cables shall be made of non-magnetic material.
- 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.

  An earthing clamp or bolt of adequate dimensions shall be provided inside the terminal box for connecting the cable earthing.

  The earthing facility shall be clearly marked with the appropriate symbol.

The terminal box shall be designed 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 and shall comply with the above requirements.

The main terminal box and, if applicable, the star-point box shall be made of steel.

* The main terminal box shall be 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.

Additionally, each type of terminal box shall be designed so that the products of an electrical breakdown within the terminal box are relieved through a pressure relief diaphragm to the outside of the terminal box. Pressure relief shall be located to minimise the potential for injury to personnel.

Main terminal boxes shall be constructed so that the cable can be connected without needing to pull the cable through a fixed opening in the box.

The lowest part of the terminal box, including the cable gland and other miscellaneous parts, shall not be lower than the lowest part of the machine.

The star-point box shall be located on the opposite side of the machine from the main terminal box. The size of the terminal box shall be sufficient to accommodate the current transformers for the differential protection.

• The Principal will either:

- Provide all necessary details of the current transformers and shall make the 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 cover such star-point boxes and current transformers, which may be separately certified or included in the overall certification.

10.4.4 *Bushing and terminals*

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.

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.

Terminal connections shall be constructed such that there is no direct contact between the conductor and screws, bolts or nuts. Connections shall be secured against loosening and, if cable lug connections are used the arrangement shall be such that the contact pressure is maintained.

The bushings and insulators shall be fully rated for the machine voltage and shall be capable of withstanding both the dynamic and thermal effects of a short-circuit current for at least 3.0 seconds. The expected short-circuit current shall be based on the maximum system 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 Manufacturer's scope of supply.

Clamping devices shall be provided inside the main terminal box of the machine to separate and support the cable conductors, thereby ensuring that their ability to withstand the short circuit current will be maintained after the non-compound filled type of termination has been completed. Materials used for clamping devices shall be non-hygroscopic.

Add new clause:

10.5 ROTOR, FANS AND COUPLING

10.5.1 *Rotor*

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

Welding on finished shafts is not allowed. Shafts and/or 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.

Rotor retaining rings of turbine type machines shall be of materials which are not susceptible to stress corrosion.

- For salient pole machines the Manufacturer shall, if requested by the Principal, provide information to verify that the rotor design is such that the poles are mounted securely to the shaft and the windings are fixed securely to the poles.

Rotors of turbine type machines, and other machines with flexible, over-critical rotor bearing systems, shall be balanced at nominal speed.

Rotors shall be equipped with provisions to allow for multi-plane balancing.

Rotors shall be balanced to quality grade G1 as specified in ISO 1940. All shaft components such as fans, retaining rings, coupling, etc. shall be individually balanced.

Lead, or similar ductile materials, 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.

10.5.2 *Fans*

The external fan and any internal fans 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 durable corrosion resistant coating.

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

The flow of external cooling air shall be in the direction of the coupling.

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.

10.5.3 *Coupling*

* The coupling shall be in accordance with API 671 or, if approved by the Principal, an equivalent standard. The full nominal torque transmission shall be by friction only.

The coupling design shall be able to withstand without permanent deformation the maximum transient torques that can be expected at the coupling in a fault condition e.g. two-phase short circuit, missynchronisation, etc. at the machine terminals. Unless otherwise advised by the Principal (8.11) the coupling shall also be suitable for reconnection torque.

Stiff couplings shall be used wherever possible.

Add new clause:

10.6 MACHINE PROTECTIVE DEVICES

10.6.1 *Stator winding temperature protection*

At least six embedded temperature detectors shall be installed in the machine, two for each stator phase. The detectors shall be PT-100 platinum resistance elements in accordance with 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 may be of the 2-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.

10.6.2 *Differential protection*

Differential protection shall be provided on machines with rated outputs exceeding 3500kW, and on machines supplied by dedicated unit transformers. On these machines, the star-point connections shall be brought out to a separate star-point box in accordance with (10.4.3).

10.6.3 *Bearing temperature monitoring*

When indicated on the requisition, each sleeve bearing shall be furnished with two RTD elements, measuring the bearing temperature as near as possible to the loaded area of the white metal. 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.

10.6.4 *Air temperature detectors*

For air-to-air cooled machines, 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 furnished with the following auxiliary devices:

- resistance temperature detector (RTD) elements to measure the internal cooling air temperature before and after the heat exchanger;
- a water leakage detector.

For air-to-air cooled machines, an RTD shall be provided to measure the temperature of the internal cooling air after the heat exchanger.

All RTDs shall be PT-100 elements in accordance with IEC 60751, and shall be connected in accordance with the requirements listed in (10.6.3).

Add new clause:

10.7 BEARINGS

- Machines and exciters shall be equipped with self-lubricated or force-lubricated hydrodynamic sleeve bearings. Anti-friction bearings may be offered as an alternative provided 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)

   (Items 1 and 2 apply to the main machine only).

3. The minimum re-lubrication interval shall be 4 000 hours (grease lubrication)

4. For exciters, the L10 life shall be 100 000 hours.

The bearing systems shall be arranged such that there will be no ingress of oil vapour into the machine and exciter housings or leaks to the outside.

Machines shall be able to run down safely if the forced lubrication fails or is switched off.

With the quotation the Manufacturer shall provide detailed data and drawings regarding the bearing arrangement. These data shall include at least the following:

- bearing data, e.g. type, size, clearance, maximum allowable thrust;
- installation instructions;
- bearing insulation details;
- minimum permissible luboil flow;
- normal luboil flow;
- required oil quality.

10.7.1 *Bearing insulation*

Whenever the shaft voltage measured across the ends of the shaft exceeds 250mV (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 coupling-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.

♦ The Manufacturer shall submit with the quotation detailed drawings showing the proposed insulation arrangement.

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

!! Caution: Bearing Must Be Kept Insulated !!

10.7.2 *Sleeve bearings*

Only sleeve bearings of a proven design shall be used.

***** Sleeve bearings shall be of the spherical-seated, self-aligning type. The Manufacturer shall submit details such as specific loading, stiffness, etc. regarding the proposed bearing arrangement to the Principal for information.

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 less than the maximum specified amplitudes at both operating and critical speeds.

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

♦ The Manufacturer shall state in the quotation the maximum replacement interval of

thelubricating oil based on the most adverse operating conditions.

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 whilst the machine is running.

Where common lube-oil systems are used, the lube-oil console for the complete train shall be supplied by the mechanical equipment Manufacturer. The electrical machine Manufacturer shall be responsible for informing the mechanical equipment Manufacturer of the lube-oil requirements for the machine bearings and any other special requirements.

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

Bearings shall be suitable for the machine to be started without the aid of oil jacking. However, oil jacking may be required for barring duty.

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 $\pm$3mm, and a maximum of $\pm$6mm, 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 machine.

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

Add new clause:

10.8 EXCITATION SYSTEM

The excitation system shall be either:

- the brushless type, comprising an AC main exciter and a rotating rectifier; or
- a system which uses permanent magnet pilot exciters; or
- (for generators) a system in which the excitation voltage is derived directly from the generator terminals (known as compound excitation with current boost).

The current rating of the semi-conductors in the diode bridge shall not be less than twice the maximum current flowing through the components at maximum continuous excitation current.

The repetitive reverse blocking voltage rating of the semi-conductors in the diode bridge shall be at least 200% of the maximum peak voltage generated by the main exciter. A failure of a diode shall be detected by a diode failure monitoring device.

10.8.1 *Generators*

The automatic voltage regulator (AVR) controlling the DC voltage for the main exciter field winding shall be of the electronic type and employ 3-phase sensing. The AVR shall be equipped with a manual control facility.

The AVR shall automatically switch over to manual control if a failure is detected in the automatic controller. The manual control setting shall automatically follow the setting of the automatic controller.

To minimise over-voltages if the generator is suddenly disconnected from the load, a fast-acting de-excitation system shall be provided for the main exciter.

♦ The Manufacturer shall provide information regarding the maximum transient over-voltage which may occur if the load is suddenly disconnected from the generator.

10.8.2 *Motors*

Synchronous motors shall be furnished with the following auxiliary devices, which shall be mounted in a motor excitation panel to be installed adjacent to the Principal's switchgear.

- DC voltage controller for the pilot field

- Manual DC voltage adjustment
- Door mounted meters for the pilot field voltage and current
- Rotating diode failure protection
- Slip/stall protection
- Power factor controller including adjustment

The manufacturer shall review the switchgear control and excitation schematic diagram to ensure that the motor protection and control designs are compatible with the motor requirements. These shall include field out-of-step and undervoltage schemes.
Add new clause:

10.9 CONTROL, METERING AND PROTECTION

All control, metering and protective devices required for the safe and reliable operation of the machine shall be supplied by the Manufacturer. The Principal shall provide information regarding the proposed lay-out of the system, the preferred location of the necessary current and voltage transformers and the location of the control, metering and protection cubicles.

All dielectrics and insulation in the control, protection and metering cubicles shall be fire-retardant to IEC 60332-3 category C.

The cubicle containing the electronic AVR shall be provided with a manual/automatic selector switch, a manual voltage adjustment and a door-mounted meter indicating the exciter field voltage.

Generators which are operated in parallel with an external grid shall be provided with an automatic power factor controller. If the connection with the external grid is broken, the excitation control shall change from power factor control to voltage control.

- Unless otherwise specified, limiting devices shall be provided which limit the excitation current once the generator stator or rotor current has been exceeded for a prolonged period.
- Unless otherwise specified, Standard Drawings S 67.047, S 67.055 and S 67.056 shall apply. The ultimate protection system shall be discussed in detail between the Manufacturer and the Principal.
- ♦ The Manufacturer shall prepare a setting proposal for the various protection relays involved. The final setting of the relays shall be agreed between the Manufacturer and the Principal.

The protection relays shall be of a digital type and installed in a free-standing cubicle near the Principal's switchgear. This cubicle shall also contain the dedicated power supply for the protection relays, AVR and miscellaneous equipment.

The power supply shall be backed up by batteries of sufficient capacity to supply the connected load for at least eight hours.

At least the following digital metering functions shall be available at the panel and shall have accuracy better than 0.5%:

- phase-to-phase and phase-to-neutral voltages;
- phase currents and neutral current;
- exciter field voltage and current;
- apparent, active and reactive power demand and power factor (see Note);
- frequency (see Note);
- winding temperature (see Note);
- cooling air temperature;
- cooling water temperature and pressure;
- DE and NDE bearing temperature (see Note);

- DE and NDE bearing vibration (see Note);
- lube-oil temperature and pressure (see Note);
- auxiliary power voltages and currents;
- emergency DC power voltages and current;

NOTE: These metering functions are normally displayed in the main control room.

Add new clause:

10.10 MASS

The Manufacturer shall state in the quotation the total mass of the machine and the mass of the individual components. The final mass shall not deviate by more than 10% from the quoted value.

Add new clause:

10.13 SURFACE TREATMENT

The machines shall have a surface finish which complies with the Manufacturer's standard for increased internal and external protection against corrosion in outdoor climates

The paint system applied shall provide adequate protection against the adverse effects of the humid, salty environment normally encountered in refineries, chemical plants or other such facilities.

Add new Section:

Section 12 Additional requirements for machines in zone 2 areas

12.1 BONDING STRAPS

Machines shall be fitted with bonding straps across joints within or between the main enclosure, the bedplate 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 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.

12.3 REQUIREMENTS FOR MACHINES OF TYPE OF PROTECTION qP'

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 0.05kPa shall be maintained relative to the external atmospheric pressure at every point within the enclosure.

12.4 REQUIREMENTS FOR MACHINES OF TYPE OF PROTECTION qD'

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 be type of protection 'e'.

Add new Section:

Section 13 Inspection and tests

13.1 TESTS DURING PRODUCTION

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

- pressure test on water cooler(s), if applicable;
- rotor balancing and overspeed test;

• 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 Manufacturer's works, each machine shall be inspected and tested, and the results shall be recorded in 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 the quotation if his normal test arrangements are not adequate or if he is incapable of carrying out a specified test.

Performing alternative tests (e.g. testing under reduced load conditions) shall be approved by the Principal before the order is awarded.

• The Principal shall indicate in the requisition whether, and to what extent, he will inspect the machine or witness the required tests.

13.2.2 *Performance test*

The performance test as specified in (13.3.1) shall be made on at least one machine for each group of identical machines being supplied.

13.2.3 *Routine test*

A routine test shall be carried out on every HV machine not performance tested.

The Manufacturer shall certify that each machine is identical to the one which was subjected to the performance test.

13.2.4 *Type tests and Measurements*

The Manufacturer's type test shall be sufficient for the following:

- winding temperature rise measurements on identical machines;
- impulse tests and tan delta tests (see Annex C) on sample coils.
- locked rotor current and torque tests on identical synchronous motors

13.2.5 *Special tests*

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

These tests shall be indicated 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 13.6) shall be

performed and whether he will witness it.

13.3 TEST SPECIFICATIONS

13.3.1 *Performance test-all machines*

For a detailed description of the various tests reference is made to IEC 60034-4.

Unless otherwise specified in the requisition, machine performance testing shall, include at least the following tests and measurements:

1. Winding resistance (cold)
2. Calculated rotor and stator winding resistance at 20 °C
3. Full load heat run

It is often impractical to make the test under full load conditions. Compromise methods to obtain the desired information are:

- synchronous feedback (back-to-back) if two machines are available (IEEE 115)
- superposition (open circuit and short-circuit loading (IEEE 115)
- zero power factor method (IEEE 115)

4. Winding resistance (hot)
5. Calculated windings temperature rise
6. Bearing temperature rise
7. Efficiency at full load and 3/4 load, both at rated power factor (IEC 60034-2)
8. No-load current
9. No-load losses (IEC 60034-2)
10. Vibration severity
11. Di-electric test on:
    - heater(s)
    - built-in temperature detectors
    - machine windings
    - exciter windings
12. Insulation resistance of:
    - machine windings:
      a) before heat run
      b) after heat run and di-electric test
    - exciter windings
      a) before heat run
      b) after heat run and di-electric test
    - heater(s)
    - built-in temperature detectors
    - bearing insulation
13. Polarisation index test of machine windings
14. Noise test
15. Shaft voltage at no-load
16. Sleeve bearing inspection
17. Physical inspection for compliance with this DEP and the requisition.

13.3.2 *Additional tests for synchronous motors*

In addition to the tests specified in 13.3.1, a performance test on a synchronous motor shall include the following:

1. Locked rotor current
2. Locked rotor torque
3. Torque-speed curve during start.

13.3.3 *Routine tests*

A routine test shall include at least the tests and measurements detailed below:

1. Winding resistance (cold)
2. Calculated rotor and stator winding resistance at 20 °C
3. No-load saturation test, IEC 34-4
4. Sustained three-phase short circuit test, IEC 34-4
5. Vibration severity, see Annex C for the test procedure
6. Di-electric test on:
   - heater(s)
   - built-in temperature detectors
7. Insulation resistance test on:
   - machine and exciter windings
   - heater(s)
   - built-in temperature detectors
   - bearing insulation
8. Polarisation index test on machine windings
9. Sleeve bearing inspection
10. Physical inspection for compliance with this DEP and the requisition.

13.3.4 *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. Sudden three-phase short-circuit test, IEC 60034-4
2. Rotor inertia test, IEC 60034-4
3. No-load saturation test, IEC 60034-4
4. Overspeed test in accordance with IEC 60034-1

   The impedance of the rotor winding shall be measured prior to and after completion of the overspeed test in order to detect loose connections.

NOTE: This test may be carried out as part of production testing (13.1) in the balancing machine.

5. AVR test, IEEE 421.2
6. Type test for applicable type of protection, in accordance with IEC 60079
7. Submerged stator test, NEMA MG1 20.49
8. Surge immunity test to EN 61000-4-5
9. Any other test that may have been agreed upon

13.3.5 *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 coil 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 Documents

14.1 GENERAL

All documents shall be marked in the bottom right-hand corner with the Principal's order and item number together with the Manufacturer's references.

All documents shall be the English language and shall be distributed as specified in the order.

14.2 MANUFACTURER'S TECHNICAL INFORMATION

The following drawings shall be submitted (refer also to the data specified in the requisition):

- outline drawings showing main dimensions, arrangement of components, terminal boxes and foundation loading;
- schematic and connection diagrams covering all equipment pertaining to the machine;
- bearing arrangement/alignment drawing with data covering replacement of the bearings/bearing lining.

14.3 TEST REPORTS

Test reports stating the results of all tests carried out on the machines supplied shall be provided by the Manufacturer. These tests shall also include the Manufacturer's type tests if applicable.

PART III AMENDMENTS AND SUPPLEMENTS TO IEC 60034-14

In this Part, sections of IEC 60034-14 (second edition, 1996-11) are amended or supplemented. Sections of IEC 60034-14 that are not mentioned shall remain applicable as written.

Section 1 Scope and object

Amend the second paragraph of this section to read:

It is applicable to three-phase a.c. machines, with shaft heights 56mm and higher and a rated output up to 50MW, at all nominal speeds up to 3600rev/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 clause.

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

8.2 LIMITS OF VIBRATION VELOCITY AT 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 FRAME VIBRATION

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 with the following:

- If stated in the requisition, each bearing of a machine 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 50mm 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

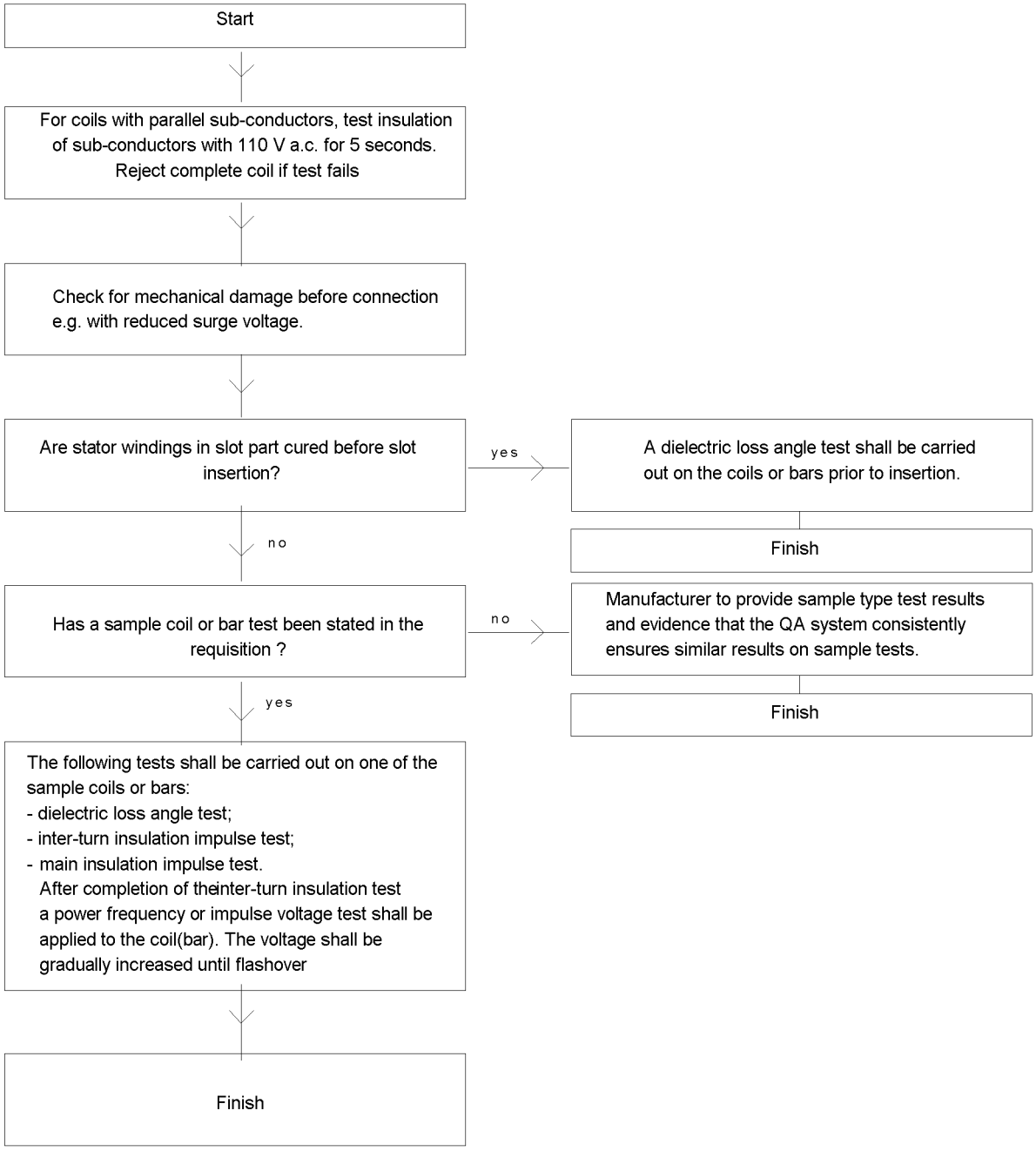
The aim of the vibration test is to obtain at the Manufacturers test bed sufficient information concerning the vibration characteristics of the machine under normal site operating conditions.

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 machines which are subject to a *Routine Test*, the vibration test is only required during a no-load run at near ambient conditions.
4. For two-pole machines where a test to establish the twice supply frequency component is to be performed, the machine is to be rigidly mounted as specified in (6.2), and a broad band frequency analysis shall be carried out.

Add new Annex:

Annex C Insulation quality test

To verify the integrity of the insulation system, for machines with rated voltage above 5kV, the following tests as shown in the diagram below shall be performed as a minimum. Criteria to evaluate the tests and their results shall be in accordance with Annex D.



Assessment of insulation quality

1. DIELECTRIC LOSS ANGLE TEST

The measurement of the dielectric loss angle (δ) of the insulation of machine winding coils shall comply with 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.

On 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 to sample coils and shall be conducted in accordance with IEC 60034-15 under the following conditions:

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

The front time of the first voltage peak shall be 0.3 µs ± 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 $0.65x(4U_n + 5)$ kV

3. MAIN INSULATION IMPULSE TEST

This test is applicable to sample coils and shall be conducted in accordance with 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 (2Un + 1) 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 (2Un + 1) kV and shall immediately thereafter be reduced at a rate of at least 1 kV/s to zero, without failure.

3.2 Impulse voltage test

The impulse voltage test of the main insulation shall be performed by applying a voltage between 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 of 50 µs to half the peak voltage.

There shall be five pulses 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 winding is considered sound and acceptable if no voltage collapse has occurred and the results are identical with each other.

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 amendments, supplements or revisions thereto.

SHELL STANDARDS

DEPs

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Fouling resistances for heat transfer equipment	DEP 20.21.00.31-Gen.
Requisitioning binder	DEP 30.10.01.10-Gen.
Lubrication, shaft sealing and control oil systems for special purpose applications	DEP 31.29.60.32-Gen.
Electrical engineering guidelines	DEP 33.64.10.10-Gen.
Power transformers (amendments/supplements to IEC 76 and IEC 726)	DEP 33.65.40.31-Gen.

DATA/REQUISITION SHEETS

Data/requisition - equipment noise limitation	DEP 31.10.00.94-Gen.
Requisition for synchronous ac machines	DEP 33.65.11.93-Gen.

NOTE: Data/requisition sheets are contained in the Requisitioning binder, DEP 30.10.01.10-Gen.)

STANDARD DRAWINGS

Typical HV single line diagram for generators directly connected (voltage $\leq$ 11 kV)	S 67.055
Typical HV single line diagram for generators with unit transformer (voltage > 11 kV)	S 67.056

AMERICAN STANDARDS

Vibration, axial position and bearing temperature monitoring systems	API 670
Special purpose couplings for refinery service	API 671

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

Guide: Test procedures for synchronous machines	IEEE 115
Guide for identification, testing, and evaluation of the dynamic performance of excitation control systems	IEEE 421.2
Recommended practice for excitation system models for power system stability studies	IEEE 421.5

Issued by:
Institute of Electrical and Electronics Engineers (IEEE)
PO Box 1331
445 Hoes Lane
Piscataway. NJ 08855 1331
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 140: Specification for voltage regulation and parallel operation of a.c. synchronous generators	BS 4999-140
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

Electromagnetic compatibility (EMC) Part 4: Testing and measurement techniques Section 5: Surge immunity test (IEC 1000-4-5)	EN 61000-4-5

Issued by:
CENELEC
Rue de Stassart 35
Brussels B1050
Belgium

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 (excluding machines for traction vehicles) measurement of losses by the calorimetric method	IEC 60034-2
Part 4: Methods for determining synchronous machine quantities from tests	IEC 60034-4
Part 6: Methods of cooling (IC code)	IEC 60034-6
Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher - measurement, evaluation and limits of vibration	IEC 60034-14: second edition (1996-11)
Part 15: Impulse voltage withstand levels of rotating a.c. machines with form-wound stator coils	IEC 60034-15

Part 18: Functional evaluation of insulation systems for rotating electrical machines	IEC 60034-18
High voltage test techniques	IEC 60060
Electrical apparatus for explosive gas atmospheres:	
Part 10: Classification of hazardous areas	IEC 60079-10
Part 15: Electrical apparatus with type of protection "N"	IEC 60079-15
Specifications for particular types of winding wires;	IEC 60317
Tests on electronic labels under fire conditions:	
Part 3: Tests on bunched wire or cables	IEC 60332-3
Degrees of protection provided by enclosures (IP code)	IEC 60529
Classification of Environmental Conditions:	
Part 2: Environmental conditions appearing in nature; Section 1: Temperature and humidity	IEC 60721-2-1
Industrial platinum resistance thermometer sensors	IEC 60751
Winding wires - Test methods	IEC 60851
Guide for test procedure for the measurement of loss tangent on coils and bars for machine windings	IEC 60894

Issued by:
Central Office of IEC (Sales Dept)
3, Rue de Varembé
P.O. Box 131
Geneva CH-1211
Switzerland

Copies can also be obtained from national standards organizations.

Acoustics - Test code for the measurement of airborne noise emitted by rotating electrical machinery	
Part 2: Survey method	ISO 1680-2
Mechanical vibration - balance quality requirements of rigid rotors	ISO 1940

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

Copies can also be obtained from national standards organizations.