SEPS SP-1003

Subsea electric motors

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1 FOREWORD

The intent of this document is the development of a standard that will be accepted globally. Presently discussions are underway with IEC and IEEE about the possibility of their development of this document into a joint IEC/IEEE standard.

This, document, SEPS-SP -1003, has been compiled and approved by the following members of the SEPS JIP on behalf of their respective companies.

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1 SCOPE

This International Standard is applicable to three-phase subsea liquid filled motors and subsea gas filled motors with a minimum rated power of 375 kW and with rated voltages up to and including 13.8 kV. This standard includes induction motors, permanent magnet motors and machines having an integrated load (e.g. a pump or compressor). This standard is applicable to variable speed motors and to single speed motors (also called Direct On Line motors).

The intention is to specify additional requirements that are not covered by API standard 541 (for induction motors) and API standard 546 (for permanent magnet motors). The requirements are from API 541 or API 546, in conjunction with either IEC 60034, NEMA MG1 or IEEE standard 112.

The scope of the document excludes low voltage and subsea ESP motors.

2 NORMATIVE REFERENCES

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies. There are sections in this document where either a U.S. or an international equivalent normative reference standard may be used. The choice of which standard to be used shall be agreed in advance between the manufacturer and purchaser using the data sheet to communicate the chosen standard.

API standard 541:	*Form-wound squirrel cage induction motors – 375 kW (500 horsepower) and larger*
API standard 546:	*Brushless Synchronous Machines—500 kVA and Larger*
API standard 17F:	*Specification for Subsea Production Control Systems*
API standard 617:	*Axial and centrifugal compressors and Expander-compressors*
API standard 17N:	*Recommended practice for Subsea Production System Reliability, Technical Risk and Integrity Management.*
BS EN 50209:	*Test of insulation of bars and coils of high-voltage machines*
IACS	*International Annealed Copper Standard*
ICEA S-97-682	*Standard for Utility Shielded Power Cables Rated 5 Through 46 kV*
IEC 60034-1:	*Rotating electrical machines. Part 1 – Rating and performance*
IEC 60034-2-1:	*Rotating electrical machines – Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)*

IEC 60034-15: *Rotating electrical machines - Part 15: Impulse voltage withstand levels of form-wound stator coils for rotating a.c. machines*

IEC TS 60034-18-42: *Rotating electrical machines - Part 18-42: Partial discharge resistant electrical insulation systems (Type II) used in rotating electrical machines fed from voltage converters - Qualification tests*

IEC 60034-25: *Rotating electrical machines. Part 25: AC electrical machines used in power drive systems – Application guide*

IEC TS 60034-27-1: *Rotating electrical machines - Part 27-1: Off-line partial discharge measurements on the stator winding insulation of rotating electrical machines*

IEC TS 60034-27-2: *Rotating electrical machines - Part 27-2: On-line partial discharge measurements on the stator winding insulation of rotating electrical machines*

IEC 60034-27-3: *Dielectric dissipation factor measurement on stator winding insulation of rotating machines*

IEC 60034-27-4: *Rotating electrical machines: Measurement of insulation resistance and* polarisation index of winding insulation of rotating electrical machines

IEC 60034-29: Rotating electrical machines - Part 29: Equivalent loading and superposition techniques - Indirect testing to determine temperature rise

IEC 60038: IEC standard voltages

IEC 60060-1: High voltage test techniques – Part 1 General definitions and test requirements

IEC 60068-2-6: Environmental testing – Vibration sinusoidal

IEC 60085: Electrical insulation – Thermal evaluation and designation

IEC 60243-1: Electrical strength of insulating materials – Test Methods Part 1 – Tests at power frequencies

IEC 60270: High-voltage test techniques - Partial discharge measurements

IEC 61000-2-4: Electromagnetic compatibility (EMC) – Part 2-4: Environment – Compatibility levels in industrial plants for low-frequency conducted disturbances

IEC 61800-2: *Adjustable speed electrical power drive systems – Part 2: General requirements – Rating specifications for low voltage adjustable frequency a.c. power drive systems*

IEC 61800-4: *Adjustable speed electrical power drive systems – Part 4: General requirements – Rating specifications for a.c. power drive systems*

IEC 61800-8: *Adjustable speed electrical power drive systems – Part 8: Specification of voltage on the power interface*

IEC/IEEE 61886-1:	*Subsea equipment - Power connectors, Penetrators and Jumper assemblies with rated voltage from 3 kV (Umax = 3,6 kV) to 30 kV (Umax = 36 kV)*
ISO 14839-3:	*Mechanical vibration - Vibration of rotating machinery equipped with active magnetic bearings - Part 3: Evaluation of stability margin*
ISO 23936-1:	*Petroleum, petrochemical and natural gas industries – Non-metallic materials in contact with media related to oil and gas production Part 1: Thermoplastics*
ISO 23936-2:	*Petroleum, petrochemical and natural gas industries – Non-metallic materials in contact with media related to oil and gas production Part 2: Elastomers*
NACE SP0108:	*Corrosion Control of Offshore Structures by Protective Coatings*
NEMA MG1:	*Motors and Generators*
BS PD 5500:	*Specification for unfired fusion welded pressure vessels*
ASME BPVC :	*Boiler and Pressure Vessel Code*
DNV-RP-B401:	*Cathodic protection design*
Norsok M501:	*Surface preparation and protective coating*
Norsok M710:	*Qualification of non-metallic sealing materials and manufacturers*
IEEE 1:	*General Principles for Temperature Limits in the Rating of Electrical Equipment and for the Evaluation of Electrical Insulation*
IEEE 43:	*IEEE recommended practice for testing Insulation Resistance of Electric Machinery*
IEEE 112:	*IEEE Standard Test Procedure for Polyphase Induction Motors and Generators*
IEEE 115:	*Test procedures for synchronous machines*
IEEE 252:	*Standard test procedure for polyphase Induction motors having liquid in the magnetic gap*
IEEE 434:	*Guide for the Functional Evaluation of Insulation Systems for AC Electric Machines Rated 2300V and above.*
IEEE 454:	*Recommended practice for the detection and measurement of Partial Discharges (Corona) during dielectric tests.*
IEEE 522:	*Guide for Testing turn insulation of form-wound stator coils for A.C. electric machines.*
IEEE 1812:	*Guide for testing Permanent Magnet Machines*

3 TERMS, DEFINITIONS AND ABBREVIATED TERMS

For the purposes of this document, the terms and definitions given in API 541, API 546 and IEC 60034-1 and the following apply.

3.1 Terms and definitions

3.1.1 Cathodic Protection

Reduction or prevention of corrosion by making a metal the cathode in a conducting medium by means of a direct current (impressed or galvanic).

3.1.2 Connector Assembly

Any assembly of wet and/or dry mate connectors, penetrators, cable terminations, cable pigtails or jumper cables between subsea components – or any combination of these

3.1.3 Connector

Fully insulated termination permitting the connection and the disconnection of an electrical cable to other equipment

3.1.4 Differential Pressure

The difference between the two absolute values of pressure that are acting on either side of a wall or partition.

3.1.5 Extended Routine Test

A test to which each individual motor is subjected once all connector assemblies have been installed on to the machine.

3.1.6 Maximum Operating Speed

The maximum rotational speed (revolutions per minute) at which the motor is allowed to operate continuously.

3.1.7 Minimum Operating Speed

The minimum rotational speed (revolutions per minute) at which the motor is allowed to operate continuously.

3.1.8 Motor Assembly

The complete assembly required for the motor to be operational in given subsea conditions but does not necessarily include components related to the driven unit (i.e. pump/compressor).

3.1.9 **Motor Unit**

The electro-magnetic part of the motor assembly, to which motor performance data are related, but does not include pressure housing or components related to the driven unit (i.e. pump/compressor). Components related to circulation and cooling, which influence the losses and efficiency of the motor, are included in this definition.

3.1.10 **Overspeed Limit**

The maximum speed (revolutions per minute) above the maximum operating speed that the machine can withstand **for two minutes** without permanent damage.

Note 1: Permanent damage is defined as a change in the baseline vibration characteristics outside of the manufactures' acceptable limits and damage to any components that affects the component's ability to function within specification).

3.1.11 **Penetrator**

A device that enables one or several conductors to pass through a partition such as a wall or a tank and insulates the conductors from it. The means of attachment, flange or fixing device, to the partition forms part of the penetrator. Penetrators include bulkhead mounted connector assembly components.

3.1.12 **Rapid Gas Decompression**

An extreme depressurization event from high pressure (hundreds of bar) to low pressure (tens of bars down to atmospheric) in order of seconds, that can occur in a production system with presence of gas. The phenomenon is also known as explosive decompression.

3.1.13 **Rated Absolute Pressure**

The maximum absolute pressure that a motor has been designed to operate at under the specified conditions of use. For motors that are designed to operate under pressure balanced conditions, only one value of rated absolute pressure shall be specified. For motors that are designed to operate with different pressures on either side of the motor housing, two values of rated absolute pressure shall be specified. RAP-1 shall be used to refer to the maximum rated absolute pressure on the external or outboard side of the motor and RAP-2 shall be used to refer to the maximum rated absolute pressure on the internal or inboard side of the motor.

Note 1: The rated absolute pressure value shall be used to describe the pressure rating of the motor assembly and it should not be confused with the maximum design or test pressure to which the assembly must be subjected in order to qualify it for service.

3.1.14 **Rated Differential Pressure**

The maximum differential pressure that a motor has been designed to operate at under the specified conditions of use. For motors that are designed to operate under pressure balanced conditions, only one value of rated differential pressure shall be defined and shall be the same in both directions.

3.1.15 **Rated Insulation Level**

The maximum voltage that the electrical insulation of the system can withstand without a reduction in the design life of the machine in order to provide the required margin of safety when the system is operating at the rated voltage (normal working voltage).

Note 1: For clarity Rated Insulation Level is not the same as the voltage withstand level which is a short-term over-voltage to test the electrical strength of the insulation nor is it the same as the machine rated voltage.

3.1.16 **Rated Speed**

The maximum continuous rotational speed (revolutions per minute) that the motor can withstand.

Note 1: The rated speed and maximum operating speed may be the same value in some cases.

3.1.17 **Rated Voltage**

The line voltage (phase to phase voltage) at which the equipment is designed to operate continuously under specified operating conditions. This is the voltage that shall be displayed on the rating plate and the voltage at which the performance characteristics of the machine shall be established.

Note: Rated voltage is not the maximum voltage that the machine can withstand as margins of safety require the machine to tolerate an over-voltage as defined in the data sheet.

3.1.18 **Routine Test**

A test to which each individual machine or its subcomponents is subjected during or after manufacture to ascertain whether it complies with certain criteria.

3.1.19 **Single Speed Motor**

Motor fed at fixed frequency which is also referred to as Direct On Line motor.

3.1.20 **Special Test**

A type or routine test that is conducted by agreement between the machine manufacturer and purchaser in order to evaluate specific, non-standard aspects of the machine’s performance.

3.1.21 **Synchronous Motor**

The reference to synchronous motor in this document is for Permanent Magnet motors only.

3.1.22 **Trip Speed Limit**

The speed at which overspeed protective devices operate to remove power from the motor and protect the machine from surpassing the Overspeed limit.

3.1.23 **Type Test**

A test of one or more machines made to a certain design to show that the design meets certain specifications.

3.2 Abbreviated terms

3.2.1 **API**

American Petroleum Institute

3.2.2 **AMB**

Active magnetic bearing

3.2.3 **ASD**

Adjustable Speed Drive. See also VFD and VSD. For consistency the term ASD is used throughout this document according to Section 3.2 of API 541.

3.2.4 **CFD**

Computational Fluid Dynamics

3.2.5 **CP**

Cathodic Protection

3.2.6 **DOL**

Direct On Line

3.2.7 **ESP**

Electrical Submersible Pump

3.2.8 **ETD**

Embedded Temperature Detector

3.2.9 **FEA**

Finite Element Analysis

3.2.10 **FMECA**

Failure Mode Effect and Criticality Analysis

3.2.11 **HV**

High Voltage

3.2.12 **IACS**

International Annealed Copper Standard

3.2.13 **IEC**

International Electrical Committee

3.2.14 **IEEE**

Institute of Electrical and Electronics Engineers

3.2.15 **IR**

Insulation Resistance

3.2.16 **JIP**

Joint Industry Project

3.2.17 **LI**

Lightning Impulse

3.2.18 **LV**

Low Voltage

3.2.19 **MEG**

Monoethylene glycol

3.2.20 **PD**

Partial Discharge

3.2.21 **PI**

Polarization Index

3.2.22 **PM**

Permanent Magnet

3.2.23 **PREN**

Pitting resistance equivalent number

3.2.24 **RAP**

Rated Absolute Pressure

3.2.25 **RPM**

Revolutions per minute

3.2.26 **RTD**

Resistance Temperature Detector

3.2.27 **SC**

Starting current

3.2.28 **SEPS**

Subsea Electrical Power Standardisation

3.2.29 **TEG**

Triethylene glycol

3.2.30 **TRL**

Technical Readiness Level

3.2.31 **THD**

Total Harmonic Distortion

3.2.32 **Um**

Maximum allowed voltage for equipment

3.2.33 **Un**

Rated voltage for the equipment in normal use (i.e. Stator L-L voltage)

3.2.34 **VI**

Vacuum Impregnation

3.2.35 **VPI**

Vacuum Pressure Impregnation

4 SERVICE, TRANSPORTATION AND STORAGE CONDITIONS

4.1 Normal service conditions

The following service conditions apply:

a) Operational water depth:

As specified in the data sheet.

b) Rated electrical frequency:

As specified in the data sheet.

c) Ambient water temperature range: Unless specified differently in the data sheet, the following ambient water operational temperature range shall apply:

-5 to+10 °C

d) Ambient air storage, handling and transportation temperature range: Unless specified differently in the data sheet, the following temperature range shall apply:

-25 to +60 °C

e) Sea water current velocity for cooling calculation:

0 m/s

4.2 Transportation, handling and installation requirements

The requirements listed below apply to the motor unit. Unless otherwise agreed between purchaser and manufacturer, the requirements shall also apply to the motor-pump/compressor assembly:

a) Basis of design

The design requirements for the motor, casing, seals and bearing shall be according to ASME BPVC or BS PD 5500.

b) Maximum landing speed

0.5 m/s

c) Maximum acceleration (shock loading) during transportation

1g in three perpendicular axes

Note 1: It is acceptable for the subsea structure, onto which the motor unit is mounted, to have dampening features in order to achieve this requirement.

d) Maximum inclination at installation

3°

Note 1: The motor unit shall be capable of operating at inclinations from zero up to and including 3° to the horizontal plane.

e) Handling

Unless delivered as part of a structure, the machine shall have clearly identified lifting points that are rated for the weight of the machine. The manufacturer shall produce a document clearly outlining the correct procedures for transportation, receipt inspection, lifting, storage, installation, final inspection, deployment operation and retrieval.

Acceleration/shock recorders and any protective devices or locks should be installed during transport and installation up to the moment of final lifting of the subsea motor for deployment. It may be necessary for the subsea structure onto which the motor unit is mounted to have damping features in order to achieve the requirements

4.3 Documentation

The basis for communicating information between the purchaser and the manufacturer is the data sheet. This data sheet also specifies requirements for documentation covering design, testing, storage, installation, usage and recovery.

4.4 Storage

Unless specified differently in the data sheet, the electric motor shall be designed for a minimum of two years storage onshore and for minimum one-year storage subsea, in addition to the specified design service lifetime. The manufacturer shall present a procedure for the operation, handling and preservation required for the storage period including the use of any protective equipment.

5 DESIGN ANALYSIS

The subsea motor, including accessories (connector assemblies, instruments etc.), shall be subject to a design analysis covering as a minimum:

- Electromagnetic, thermal, fluid dynamic and mechanical analyses, covering type tests and intended operational conditions. The analyses shall verify that the worst-case design loads that have been identified in the data sheet do not exceed electromagnetic, thermal or mechanical limitations for any material. The analysis shall include:
    - All modelling assumptions for the analysis and design
    - A Failure Mode Effect and Criticality Analysis (FMECA) to identify possible failure modes, especially those with a safety, environmental or performance critical impact.
    - Worst case design loads (test, storage, handling, installation/retrieval and operation as defined in the data sheet) and demonstrate sufficient margin of safety against failure modes that have been identified.
    - Resonance, dynamic and torsional analysis across the operating speed range. Reference shall be made to Section 4.4.6 of API 541.
    - Thermal analysis. The complete motor shall be analysed and effect of speed, pressure, any marine growth, calcium deposits etc. shall be considered. An

ambient water current velocity of 0 m/s shall be used in the thermal analysis. The analysis shall be performed at different operating points and cover as a minimum:

- Maximum continuous temperatures of insulating materials and winding temperature rises.
- Maximum continuous winding hot spot temperature.
- Maximum temperatures at the surface of the motor cooler.
- For variable speed motors:
  - Thermal losses at full load resulting from both the fundamental and harmonic currents
  - operation at minimum (not applicable to PM machines) and maximum operating speed

- Possible nonlinear material properties. When linear material properties are used, technical assumptions that simplify the analysis shall be justified on the basis of prior test data. This shall include time dependent degradation of material properties. If this is not possible, non-linear modelling shall be used.

- Unless otherwise specified in the data sheet an allowance of 15% on both weight and thermal capacity of the machine shall be made to account for marine and calcareous growth.

  Note 1: The practical implications of this clause are that, unless otherwise specified, lifting points and supporting structures shall be designed to allow for a 15% increase in weight during service. Also, the thermal design of the machine shall allow for a 15% reduction in cooling efficiency during service. This is manifested by an increase in temperature by 15% that the motor shall be designed to withstand without a reduction in the design life.

- Impact of seismic activity shall be included as specified by the purchaser and shall include input from the manufacturer of the subsea structure so that amplification effects can be minimised.
- The material selection, material properties and limitations used in the analysis shall be identified and documented based on qualified, recognized and repeatable fabrication processes.
- A description of welding, sealing and corrosion protection, including surface treatment solutions.
- Analysis (such as FEA) for any hydraulic, press or thermal fit components to ensure geometries are within tolerance over the operating range of the machine
- Fluid dynamic analysis. For subsea liquid or gas filled motors, drag losses as a function of speed and process conditions should be calculated in the motor gap and its windings' end turn regions. If fluid dynamics analytical tools are used, their simplifying assumptions should be validated by experimentation, test data or by more detailed CFD models.

6 DESIGN REQUIREMENTS

6.1 General requirements

The manufacturer shall design, fabricate, and integrate a complete functional electrical motor unit into the subsea motor assembly. The complete motor assembly, with its accessories, shall fulfil the requirements set forth in this section. The appropriate standards as defined in this document shall be followed. |However, this document supplements those standards with specific requirements for subsea use. The datasheet shall state which of these requirements are to be used. For machines driven by an ASD, the motor manufacturer should liaise with the ASD manufacturer so that each party understands the effect that their equipment has on the electrical environment.

6.2 Induction motors

The motor shall be designed to fulfil the driven equipment load envelope, an example of which is shown in Figure 1. Any requirement to motor oversizing including requirements to performance during earth fault (if applicable) shall be defined in the data sheet. The motor rated speed shall meet or exceed the requirements of the driven equipment. The overspeed limit for ASD fed machines shall be 110% of the maximum operating speed. Referring to Section 4.4.2 of API 617, the manufacturer shall specify a Trip Speed Limit so that the overspeed limit cannot be reached in service.

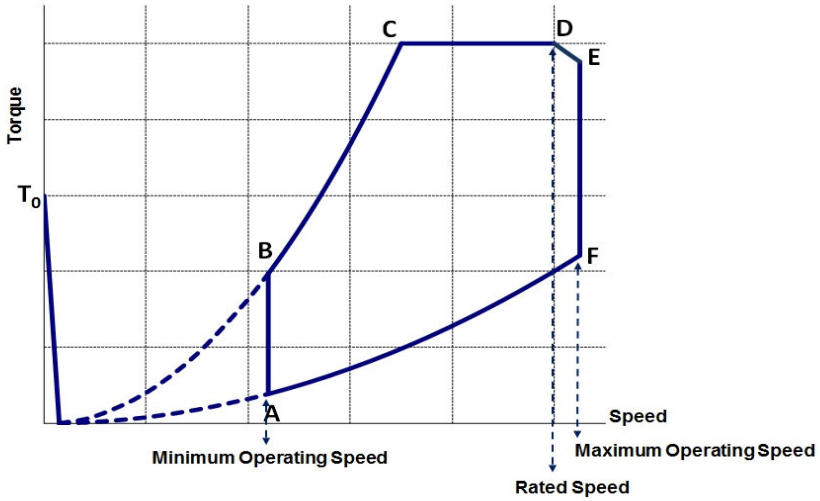

Figure 1: An example of a motor load envelope

6.2.1 Waveform and duty requirements

Unless otherwise specified in the data sheet, variable speed motors fed from an ASD shall be designed for duty type S1, S9 or S10 according to IEC 60034-1, with the overload requirement as specified in the data sheet. The motor shall be designed to operate from an ASD according to IEC 61800-2, IEC 61800-4, IEC 61800-8 such that its rated speed, rated voltage, rated current, rated torque and rated power are achieved where the electrical machine delivers its maximum power.

The motor manufacturer shall liaise with the ASD manufacturer to consider the ASD voltage stress (transient peak voltage values, peak rise time and repetition rate) on the motor winding insulation system. Reference shall be made to Section 11.5 of IEC 60034-25.

For induction motors that are connected DOL, the duty type shall be S1: continuous running duty as defined in IEC 60034-1.

Unless otherwise specified in the data sheet, the performance of the equipment shall not be affected by THD up to 8 % on the voltage waveform and each Individual Harmonic Distortion within the limits of class 2, tables 1, 2, 3, 4 and 5 of IEC 61000-2-4.

Note 1: This clause applies to all motor types fed by any supply type and is not limited to machines that are DOL, despite the clauses in IEC 60034-1 requiring that this applies to fixed speed machines only.

Should the limits of distortion and unbalance occur simultaneously in service at the rated load, this shall not lead to any deleterious temperature in the motor assembly and the excess resulting temperature rise or temperature related to be limits specified in IEC 60034-1 shall be not more than 10 K for both rotor and stator.

6.3 Permanent magnet motors

The overspeed shall be 110% of the maximum operation speed. Referring to Section 4.4.2 of API 617, the manufacturer shall specify a Trip Speed Limit so that the overspeed limit cannot be reached in service.

6.3.1 Waveform and duty requirements

Unless otherwise specified in the data sheet, single speed motors that are to be connected DOL shall be designed for duty type S1: continuous running duty as defined in IEC 60034-1. The motors shall be able to operate on an unbalanced system as defined in IEC 60034-1 paragraph 7.2 and NEMA MG-1 section 20.24.2.

PM motors that are to be supplied from an ASD shall be designed for duty type S1, S9 or S10 according to IEC 60034-1, with the overload requirement as specified in the data sheet. The motor shall be designed to operate from an ASD such that its rated speed, rated voltage, rated current, rated torque and rated power are achieved where the electrical machine delivers its maximum power.

Unless otherwise specified in the data sheet, the performance of the equipment shall not be affected by THD up to 8 % on the voltage waveform and each Individual Harmonic Distortion within the limits of class 2, tables 1, 2, 3, 4 and 5 of IEC 61000-2-4.

Note 1: This clause applies to all motor types fed by any supply type and is not limited to machines that are DOL, despite the clauses in IEC 60034-1 requiring that this applies to fixed speed machines only.

Should the limits of distortion and unbalance occur simultaneously in service at the rated load, this shall not lead to any deleterious temperature in the motor assembly and the excess resulting temperature rise or temperature related to be limits specified in IEC 60034-1 shall be not more than 10 K for both rotor and stator.

6.3.2 Starting capabilities

The starting capabilities of the machine shall be in accordance with API 546 Sections 2.2.4 and 2.2.5. The starting current and the number of hot and cold restarts in a given time period shall be specified in the data sheet.

6.3.3 Motor re-acceleration

When required in the datasheet, single speed motors shall be able to re-accelerate after a 30% - 0.5 s voltage dip.
When required in the datasheet, the motor shall be able to re-accelerate after a voltage loss of 0.5 s. Therefore, it shall be able to withstand supply reconnection onto full motor residual voltage at total phase opposition.

6.3.4 Quality control

For permanent magnet motors, quality control shall be well defined and mutually agreed in selection of magnets between the motor manufacturer and the magnet supplier(s). Parameters to consider are the magnet type, qualified supplier(s), maximum temperature and flux density ratings. Magnets shall be capable of withstanding worst-case operation/transient condition without loss of magnetisation.

Note 1. Typical magnetic materials suitable for subsea applications are samarium cobalt and neodymium iron boron (NdFeB or NIB). NIB magnets typically offer the largest energy product (BH) of any magnetic material available below 200C.

6.4 Design life

Unless specified otherwise in the data sheet, the subsea motor shall be designed for a life of 30 years. Planned maintenance intervals shall not be less than 5 years.

6.5 General electrical design requirements

6.5.1 Rated voltage

The motor rated voltage Un should be selected from the preferred ratings listed in IEC60038.

6.5.2 Rated Insulation Level

Unless specified otherwise by the purchaser in the data sheet, the rated insulation level shall be selected to provide adequate margins to be able to operate the motor continuously with a single phase to ground fault without reducing the life expectancy of the electrical insulation to below the design life of the machine (Clause 6.4).

For form wound machines, the manufacturer shall provide the following information for the stator insulation design including coil cross section dimensions:
i. Strand insulation material.
ii. Turn insulation material.
iii. Ground wall insulation.
iv. Slot stress grading.

Where specified, the Manufacturer shall submit for Purchaser approval a stator insulation design that will withstand the impulse test given in clause 11.7.16 without the use of external surge protective devices.

6.5.3 Thermal design requirements

Motor thermal class designation shall be as defined in Table 1 of IEC 60085 or NEMA MG1 (with reference to IEEE 1) and given in the data sheet. The motor cooling system shall be designed to ensure sufficient cooling of all motor parts in order to avoid temperature hot spots at rated operating conditions according to the requirements given in Section 4.1 and Section 5 of this document and to the electrical requirements given in Section 6.2.1 (Induction motors) and 6.3.1 (PM motors).

For variable speed motors, the motor manufacturer shall liaise with the ASD manufacturer to consider the effects of the ASD voltages, current waveform and symmetry on the motor thermal design. Unless otherwise specified in the datasheet, the thermal class for the motor electrical insulation shall be one class above the operational maximum temperature.

6.6 Mechanical design requirements

6.6.1 Motor housing

The design of driven equipment and motor pressure casings (wall thickness, flanges and bolts) shall be according to BS PD 5500 or ASME BPVC Section VIII Div 1/ASME BPVC Section VIII Div 2 at the rating defined in the data sheet. All critical areas shall be verified by analysis.
Stress analysis of all pressure boundaries shall be verified by a third party.

6.6.2 External cooler

To maintain cooling effect, cooling coils should not be painted. However, anti-fouling coatings may be used. Cooling coils are exposed to sea water, and thus protected by the CP system. Anode shall be located such that it does not generate any deposits on the cooling coils. Ring gasket materials for metal sealing between product and environment shall be corrosion resistant alloys.

6.6.3 Fluid filled motors

After filling, the filling fluid shall be filtered until NAS 1638 class 6 or equivalent has been achieved.

6.7 Stator

6.7.1 General

The complete stator winding system shall be designed and manufactured to tolerate the total temperature and pressure range specified for the motor.

Compatibility between all materials used, including any barrier fluid, shall be documented in the data sheet or test report.

6.7.2 Stator Core Pack

The Stator Core Pack shall be made with magnetic sheet steel that fulfils the requirements for motors when operated with the specified voltage, frequency range and harmonic distortion.

Adequate mechanical support shall be provided to ensure life time operation with the specified operational, loading and external electrical fault conditions as defined in the data sheet.

6.7.3 Stator Windings: General requirements

The stator windings shall be made of electrical grade copper alloy with a minimum electrical conductivity of 75% of the IACS standard. The winding connection configuration shall be “star” unless otherwise stated in the data sheet.

All coil and cable connections shall be made to last the design life of the motor without requiring any servicing or maintenance.

Windings shall be adequately supported, braced, and blocked to withstand, without damage, the dynamic stresses occurring during start (DOL) and short-circuit directly on motor terminals and to limit winding vibration throughout the motor speed and load operating range in order to avoid subsequent damage to the winding insulation. For machines operated from an ASD, reference shall be made to IEC 60034-25 to ensure that main insulation and the inter-turn insulation can withstand the peak electrical stress that is anticipated. Consideration shall be given to the requirement for electrical field grading of the insulation system to prevent localised electrical stress concentrations.

Note 1: For machines employing impregnation techniques, consideration should be given to the point during assembly at which impregnation is performed so as to provide the maximum benefit to components that require resin impregnation in order to insulate them, such as temperature sensors or end terminations.

6.7.4 Form-wound stator windings

The stator winding should have provisions for partial discharge and voltage stress suppression according to the voltage class for the insulation system making reference to clause 6.3.4.6 of API541.

6.7.5 Cable-wound stator windings

The use of proprietary cables for the formation of stator windings is permitted. Cables shall comply with the performance requirements as indicated by the type and routine test defined in IEC 60502-2 or ICEA S-97-682 as indicated by the datasheet.

Cable insulation ratings shall be selected such that the cable is able to operate continuously with the maximum peak electrical stress to which it will be subjected during testing and in service.

Particular consideration shall be given to the choice of insulating material so that it is chemically compatible with the fluids to which it will be exposed and without significant deterioration of the mechanical and electrical properties of the insulation. The cable shall be capable of being formed around the stator at the minimum specified bend radius without damage to the conductor or insulation. The cable shall also be capable of withstanding the hydrostatic pressure to which the machine will be subjected, including over-pressure for testing purposes, without damage or significant reduction in insulating properties. The ability of the cable to withstand rapid changes in pressure shall also be evaluated.

Joints and splices used to join motor winding cables shall be capable of meeting the specified performance requirements for the cable. Joints and splices are potential weak points and consideration shall be given to their electrical rating, discontinuity and stress concentrations in the insulation, air entrapment, vibration and mechanical fatigue.

The cable shall be rated for the thermal duty for which the machine is intended. Mechanical support of the cable shall be provided as necessary to prevent abrasion of the insulation due to vibration.

6.8 Rotor

6.8.1 Rotor Type

6.8.1.1 General

The rotor may be of induction or permanent magnet type as stated in the data sheet.

6.8.1.2 Induction type Rotor

When magnetic laminations are used, they shall be of the same grade and type as the stator magnetic material. Winding bars and short circuit rings shall be made of electrical grade copper alloy with a minimum electrical conductivity of 75% of the IACS standard.

The winding bars and short-circuit ring design should be optimized for the intended duty, which may require optimisation with the selected ASD. In DOL type motors the rotor design should be optimized to provide high starting torque and low starting current without compromising the design life or performance envelope required by this document and the data sheet.

6.8.1.3 Permanent magnet type rotor

The permanent magnet configuration may be of surface or embedded type. If surface mount type is used, as a minimum, mechanical provisions shall be provided to secure the magnets to the surface for all loading conditions, including required over speed and test conditions.

The rotor shaft shall be made in one piece of weld-less shaft type material.

6.8.2 Rotor Run-out

For all motors when assembled, the mechanical and electrical run-out in the proximity probe tracks shall not exceed the values defined in API 541 and API 546. For machines operating compressors or with AMB's, reference shall be made to API 617.

6.9 Bearings

Where specified in the datasheet, radial shaft displacement sensors shall be fitted to both liquid-filled and gas filled motors. The use of magnetic bearings shall be specified in the data sheet.

6.9.1 Bearings for liquid filled motors

Axial and radial bearings shall be bi-directional bearings. Reduced capacity in opposite from design rotational direction is acceptable, meaning that offset pivot bearings can be used. Thrust bearings (thrust runner) should be hydraulic fit.

Note 1: Hydraulic fit thrust bearings are preferred over thermal fit as they have been shown to offer greater reliability.

Note 2: Tilted pad bearings are one example of bi directional thrust bearing

The motor manufacturer shall indicate in the data sheet the derating considered from the maximum load given by the bearing manufacturer due to different viscosity of the barrier oil circuit.

6.9.2 **Active magnetic bearings**

For motors using active magnetic bearings, the active magnetic bearing system shall conform to the requirements of Annex E of API 617.

6.9.3 **Backup landing bearing**

Replaceable auxiliary bearings (also named backup/touchdown/landing bearings). When roller bearings are used, they shall be of the preloaded type. The manufacturer shall detail the auxiliary bearing technology, including damping system (if any). These bearings shall be capable to survive at least three rotor de-levitations from maximum continuous speed to zero speed when coupled to driven load

6.9.4 **Gas filled motors.**

The Manufacturer shall be provided with the expected gas composition by the client. The Manufacturer shall demonstrate with documentary evidence that the process gas composition (and associated contaminants, if any, such as mercury, TEG, MEG…) are compatible with all bearing components (such as laminations, run out sensors, coils, temperature sensors, wiring, etc.) and will not impair the equipment lifetime. Any limitations in the operating envelop resulting from the gas environment shall be understood and communicated to the purchaser.

6.10 Mechanical Seal

6.10.1 **Liquid filled motor seal**

Some motors may include dynamic mechanical seals, which separate the barrier fluid (motor side) from the process fluid side. The pressure on the barrier fluid side should be kept higher than the process pressure by at least 10 bar and the value specified in the data sheet.

The mechanical seals shall be designed for the same static absolute pressure as the motor housing plus a margin of 1.5 times the static absolute pressure. The seals shall also be designed to withstand a static differential pressure of 1.5 times the maximum differential pressure in service both from barrier fluid to process as well as the other way around. For machines having an integrated motor and load, the sealing requirements for the housing apply to the complete unit.

Manufacturer shall indicate in the datasheet the mechanical seal leakage flow at rated condition. For static sealing requirements, elastomeric O seals may be used provided sufficient measures are taken to prevent extrusion under differential pressure. All mechanical seals shall be tested at operating conditions of the application prior to assembly.

6.10.2 **Gas filled motor seals**

Static motor - compressor casing seals shall be metallic. Any static seal between barrier fluid and ambient seawater shall have two metallic barriers. Traditional O-rings are not accepted as primary seals.

Note 1. Typical seals may be Single BX – metallic seals or Double C-seal type helicoflex

6.10.3 **Gas filled motors - draining**

Motor stator and magnetic bearings shall be arranged such that all cavities and voids can be completely drained by gravity. There shall be no need for MEG injection during operation and standstill.

Note 1: The fact that the machine shall not require MEG injection does not mean that it should not be tolerant to MEG.

6.11 Cooling Requirements

For barrier fluid liquid cooled motors requiring forced-feed circulation and lubrication, the fluid shall be supplied directly from a main shaft-driven pump or impeller.

The motor coolant inlet temperature shall be such that the thermal design requirements of Clause 6.5.3 are not exceeded. This principle remains unchanged regardless of the ambient water temperature.

In designs where the ambient seawater temperature has a significant effect on the thermal performance of the motor, then if the ambient temperature exceeds the Normal Service Conditions defined in Section 4, special design measures should be performed to ensure that the motor coolant temperature is maintained within the required limits. This may result in the use of coolers supplied by the system integrator to ensure that the motor is fed with coolant at the required temperature.

6.12 Rotor dynamics

In the case of a flexibly coupled motor shaft being used a rotodynamic analysis a rotor dynamic analysis of the electric motor shall be performed by the manufacturer in order to:

- Determine the lateral natural frequencies of the rotor and associated mode shapes
- Build the rotor critical speed map (undamped analysis)
- Build the rotor Campbell diagram (damped analysis)
- Evaluate the unbalance responses and associated amplification factors.

The motor manufacturer shall liaise with the electrical system responsible party (normally ASD manufacturer) to consider as part of the shaft analysis the axial, radial and torsional stresses produced as a result of ASD voltage and current power supply. As the rotor dynamics of a machine vary considerably depending on manufacturer and application, the precise

methodology to be used in the analysis shall be agreed between the manufacturer and purchaser.

Additionally, for active magnetic bearings, the evaluation of stability margin according to ISO 14839-3 shall be performed. Evaluation criteria shall be at zone limit A/B. The lateral analysis shall be conducted considering all active control filters.

In case of rigidly coupled motor shaft a combined rotodynamic analysis shall be performed for the entire shaft system with motor and driven equipment.

6.13 Penetrators

Penetrators and connectors shall comply with IEC/IEEE 61886-1. The penetrator/motor cable interface shall be part of the penetrator type tests. Penetrators and connectors for instrumentation and control purposes shall comply with API 17F.

For gas-filled motors, the location of penetrators shall be such that liquid cannot accumulate around them during operation and standstill.

7 MATERIAL REQUIREMENTS

7.1 General material requirements

Casing materials shall be selected according to ISO 21457. All sea water exposed surfaces shall have a provision for a cathodic protection system according to DNV-RP-B401: Cathodic Protection Design. The responsibility for providing CP shall be agreed between the manufacturer and purchaser as this may be within the system integration scope of supply. The electrical continuity of the CP system shall be measured and documented.

Corrosion resistant surface coatings shall be applied to the housing and structure of the machine in order to preserve the life of the CP system. Reference shall be made to NACE SP0108, Norsok M501 and their associated standards.

Generally cathodic protection should form part of the anti-corrosion regime for the entire structure in order to prevent incompatibilities between the motor CP system and the structure to which it is mounted. If this is not the case, seawater exposed materials, not protected by Cathodic Protection, shall possess at minimum a Pitting Resistance Equivalent number (PREN>40).

Materials for sealing faces for non-pressure compensated enclosures shall be a seawater resistant alloy with a PREN>40.

Materials for sealing faces for pressure compensated enclosures may be made of 316 SS or a more corrosion resistant alloy. In such cases the sealing faces shall be cathodically protected. Sealing surfaces may be inlayed to provide the required corrosion resistance.

Sealing faces in alloys with PREN < 40 and other surfaces that rely on cathodic protection shall be properly preserved to avoid pitting corrosion during fabrication, transportation and storage.

All forged materials for pressure retaining applications shall possess adequate ductility and fulfil the minimum impact requirements as given by BS PD 5500 or ASME BPVC.

Non-metallic materials, such as elastomers, thermoplastics, epoxy resin and polyester resin shall be compatible with each other as well as with the barrier fluid, process fluid, cleaning fluid or gas with which they may be in contact. The programme of material evaluation shall be agreed between manufacturer and purchaser.

Some elements may be tested as a component directly following the reference standards whilst other assembled components may be tested similarly in the same type of media but criteria for pass/non-pass may be different. An example of an assembled component is a complete motor coil as fitted in the motor with associated cables, crimps and insulated terminations. A minimum of 5 items of each component shall be tested for statistical purposes.

7.1.1 Liquid cooled motors

All barrier fluid wetted components shall be compatible with the selected fluid. The barrier fluid system shall provide the following, non-exhaustive, list of main functionalities where applicable:

- Lubrication of bearings and mechanical seals
- Overpressure protection of motor and bearings
- Cooling media for the motor rotor/stator gap, windings, mechanical seals and all pump and motor bearings
- Dielectric media for motor (additional to the motor insulation), if applicable
- Corrosion protection of motor and pump internals.

7.1.2 Gas cooled motors

The stator and rotor shall be protected against corrosion by an appropriate treatment or by an appropriate material selection. The selected material or treatment shall be indicated in the data sheet.

The manufacturer shall demonstrate with documentary evidence that the gas composition (and associated contaminants as specified in the data sheet) is compatible with the selected windings insulation material and will not impair the equipment lifetime nor limit its operating envelope and/or availability. The motor shall be capable of remaining pressurized for the duration of the maintenance interval.

Unless specified in the data sheet, the motor internal parts (both materials and assemblies) shall be able to withstand Rapid Gas Decompression (RGD) from maximum working pressure to atmospheric at a rate as defined in ISO 23936-2.

8 INSTRUMENTATION AND MONITORING

8.1 General requirements

If instrumentation and monitoring is required by the purchaser then this should be raised at an early stage of procurement and specified in the data sheet.

Any penetrations into the motor pressure casing increase the risk of leakages, thus a minimum number of penetrations is recommended. All assembled equipment shall be qualified and proven for the specified operational conditions.

Failure of any part in the instrumentation/monitoring system shall not lead to a reduction in motor functionality or availability.

Some possible monitoring functions are discussed in the following sections.

8.2 Winding Temperature Monitoring

The stator winding temperature may be monitored either directly or indirectly. The method to be used shall be specified in the data sheet. Direct monitoring shall be performed with Embedded Temperature Detectors (ETD's) in the stator winding. Indirect monitoring may be achieved by measurement of barrier fluid temperature in correlation with acquired stator temperature measurements from performance or type test.

8.2.1 Direct Stator Windings Temperature Monitoring

The type and number of temperature detectors for use in service shall be specified in the datasheet, as agreed between the Manufacturer and the purchaser. The performance of the temperature detector at the rated pressure shall be verified by the manufacturer. Temperature monitoring of active magnetic bearings is mandatory.

The temperature detectors should be located at the points where the highest temperatures are likely to occur, in such a manner that they are effectively protected against contact with the primary coolant. For motors filled with barrier fluid and having cable-wound stator winding, the detector shall be placed in such a manner that the contact with the primary coolant is minimized.

8.2.2 Indirect Stator Temperature Monitoring

If direct winding temperature monitoring is not specified in the datasheet, an indirect method may be used with the approval of the purchaser. Real time measurement of the cooling fluid temperature and correlation of this with acquired winding temperature data from Temperature Rise test, is acceptable for trending of the thermal condition of the motor in operation.

Barrier fluid temperature and pressure shall be monitored at an accessible location where the fluid temperature is a maximum and used to determine temperature of the windings.

For barrier fluid liquid cooled motors requiring forced-feed lubrication, lubricant shall be supplied from the motor's shaft-driven pump.

8.3 Vibration

Unless otherwise agreed between manufacturer and purchaser as specified in the datasheet, vibration performance shall be according to Section 6.3.1.5 of API 541: 2014 for Induction machines or Section 4.3.1.18 of API 546: 2008 for permanent magnet machines. For machines utilising active magnetic bearings, reference shall be made to Annex E of API 617.

Note 1: Requirements for vibration monitoring shall be specified in the datasheet. The vibration requirements for active magnetic bearings shall be specified in the datasheet.

Note 2: API 17X is currently under development and when released will contain additional information relating to the rotational dynamics of subsea rotating equipment that may subsequently be adopted by SEPS.

9 RATING PLATE

Rating plate shall be as defined in IEC 60034-1 or API541/API546 with the following additional data:

- Rated water depth
- Rated Absolute Pressure
- Rated Differential Pressure
- Minimum ambient water temperature
- Maximum ambient water temperature
- Total mass in wet and dry conditions
- Maximum operating speed
- Trip speed limit

Furthermore, for ASD motors according to IEC 61800-2, IEC 61800-4, IEC 61800-8 or API 541/API546, the following additional data shall be indicated:

- Torque at rated speed;
- Torque at minimum operating speed;
- Minimum operating speed;

10 INSPECTION AND TEST REQUIREMENTS

10.1 General

The inspection and testing of motors according to this standard is divided in to five categories, Inspection during assembly, Type tests, Routine tests, Extended routine tests and Special tests. An explanation of each of these types of test is given in the definitions section of this standard.

During testing there shall be a determination of the performance, capacity and efficiency at selected operating conditions of the equipment and components of the systems to enable a comparison of the results with the values and conditions that have been guaranteed by the manufacturer. Testing should also verify the thermal and cooling characteristics at the most critical operating points of the motor.

Components assembled in the motor that are not part of the motor type test regime shall be type tested separately before being assembled in the motor assembly (e.g. penetrators, including motor/penetrator interface).

The tests specified in this chapter shall be performed on the motor assembly, before it is integrated into the machine assembly (pump/compressor) where applicable. For machines having an integrated pump or compressor, testing shall be performed with the load included but allowance should be made for the effects that this has on the results. In circumstances where it is impractical to perform a test on a machine with an integrated load the manufacturer shall propose an alternative arrangement that allows the performance of the system to be derived.

Each sequence of Assembly inspection, Type, Routine, Extended Routine and Special tests are listed in Tables 10-1, 10-2, 10-3, 10-4 and 10-5 respectively. The order in which the tests are listed in these tables indicates a preferred sequence of tests in order to optimise the test program but it is not mandatory to follow the sequence. The reference sections for each of the tests are given in the tables along with the applicability for the different motor types.

For liquid filled motors, where the liquid constitutes an integral part of the insulation system, electrical tests shall be performed with the actual liquid in the motor assembly, unless specified otherwise in the specific test procedure. Where the liquid used to fill the motor is inherently conductive, dielectric tests on the fluid that are referenced in this document are not applicable.

Partial Discharge testing is included as a Special Test and is to be conducted by agreement between the manufacturer and the purchaser.

It is important to recognise that testing and inspection is not simply an assessment of the machine design. Testing and inspection also directly and indirectly evaluate every aspect of the machine's supply chain, manufacturing, assembly and quality control. Careful consideration should be given to subsequent changes in any aspect of the machine's supply chain and fabrication that could alter inspection and test criteria, or invalidate previous Type Test results. Repeated Type Testing shall be undertaken for any change in the machine's design or fabrication that reduces the TRL to below 4 as defined by API 17N. For example, deviations to

rating or other characteristics may require new type tests. For instance, increased water depth may imply that some type tests must be repeated. The extent of type tests on previously type tested designs is subject to agreement between manufacturer and purchaser.

Unless specified otherwise, the acceptance criteria for the tests contained in this standard shall be those given in the reference standards.

10.2 Routine Tests During Assembly

In addition to the manufacturer's own inspection requirements, the following minimum routine test requirements shall be documented during assembly and reported to the purchaser.

Table 10-1 Routine tests during assembly

Step	Inspection Requirement	Application	Test procedure reference
1	Stator cable testing	Cable wound stators only	10.6
2	Stator Core and direction of field test	All machine types	11.3.1
3	Sealed winding conformance test	All machine types	11.3.2
4	Rotor balance assessment	All machine types	11.3.3
5	Mechanical and electrical runout of rotor	All machine types	11.3.4
6	Measurement of gap between rotor and stator	All machine types	11.3.5
7	Stator winding impulse voltage test of inter turn insulation	All machines types	11.3.6
8	Stator Winding and Bearing Temperature Detector – Functional test Functional test (all ETD types) IR test, Cold (electrical types)	Machines fitted with ETD's	11.3.7
9	Barrier Fluid – Dielectric Strength test	All machines filled with dielectric fluid	11.3.8
10	Inspection of equipment and piping for cleanliness prior to assembly	All machines types	11.3.9
11	Measurement of axial float	All machines types	11.3.10
12	Magnetic Flux Mapping for PM Motors	PM machines	11.4
NOTE The performance of magnetic bearings may be inferred from the vibration monitoring that is performed in the routine tests			

10.3 Type Tests

Type tests must be performed on at least one unit from a series of motors if the design is new. It is not permitted to perform the type test sequence on machines that will subsequently enter service as the type tests may weaken the machine. However, individual type tests that also appear as routine tests in Table 10-3 may be performed on a machine that is intended for service.

The Type test sequence includes all the routine tests to validate the performance of the machine alongside the tests necessary to qualify the system for service. The tests are listed in the recommended sequence.

For the purpose of improving the speed and efficiency of the test programme, Type tests may be performed with test penetrators and jumper cables rather than the connections that will be used in service. The penetrator interface to the motor internals shall however be representative for the actual delivery penetrators. This is particularly important for material and component testing and all electrical tests. If the delivery penetrators (interface) deviate from the penetrators used during the type tests, some of the type tests may have to be repeated with the delivery penetrators. These are listed under Extended Routine tests.

Table 10-2 Type test sequence

Step	Test	Application	Test procedure reference
1	Material and Component Type testing	All machine types	11.2
2	Stator Winding and Bearing Temperature Detector – Functional test Functional test (all ETD types) IR test, Cold (electrical types)	Machines fitted with ETD's	11.3.7
3	Stator winding line resistance test, cold	All machine types	11.6.1
4	Stator Winding IR & PI test, cold	All machine types	11.6.2
5	Withstand Voltage test ETDs	All machines fitted with electrical ETD's	11.6.5
6	Stator Winding Withstand Voltage test (Note 1)	All machine types	11.6.7
7	Stator winding surge test	All machine types	11.5.10
8	Vibration measurement	All machine types	11.5.1
9	Temperature rise test	All machine types	11.5.2
10	Stator Winding IR & PI test, hot	All machine types	11.5.3
11	Mechanical loss test	All machine types	11.5.4
12	Survey of torque curves and current	All machine types	11.5.5
13	Motor Load test at variable speed	All machine types	11.5.6
14	Locked rotor test	All machine types	11.5.7
15	Over-speed test	All machine types	11.5.8
16	Sudden short circuit test for PM motors	PM machines DOL started	11.5.9
17	Inspection of bearings and lubricant supply	All machine types	11.5.11
NOTE 1 When the temperature rise test is performed, the withstand voltage test to Section 11.6.8 may be carried out immediately afterwards. Additional tests when required, should follow the requirements of IEC 60034-1.			

10.4 Routine tests after assembly

All machines from a production run shall be routine tested. Unless specified in the test procedure, all Routine tests as outlined in Table 10-3 shall be performed after complete assembly of the motor where applicable. If it is not possible to install all of the connection systems for the routine tests, then extended routine testing shall be performed as described in Section 10.5. Liquid cooled motors shall be filled with the delivery fluid. Vibration monitoring shall be performed during tests as specified. Where electrical testing has previously been performed, the test voltage may be reduced to 80% of the original value so as to reduce repeated stressing of the electrical insulation.

Table 10-3 Routine test sequence

Step	Test	Application	Test procedure reference
1	Stator cable testing	Cable wound stators only	10.6
2	Sealed winding conformance test	All machine types if not conducted during assembly	11.3.2
3	Stator winding impulse voltage test of inter turn insulation	All machine types if not conducted during assembly	11.3.6
4	Stator Winding and Bearing Temperature Detector – Functional test Functional test (all ETD types) IR test, Cold (electrical types)	Machines fitted with ETD's	11.3.7
5	Stator winding line resistance test, cold	All machine types	11.6.1
6	Stator Winding IR & PI test, cold	All machine types	11.6.2
7	No-load test	All machine types except integrated load machines	11.6.3
8	Stator Winding and Bearing Temperature Detector – Functional test Functional test (all ETD types) IR test, Cold (electrical types)	Machines fitted with ETD's	11.6.4
9	Withstand Voltage test ETDs	All machines fitted with electrical ETD's	11.6.5
10	Direction of rotation test	All machine types	11.6.6
11	Stator Winding Withstand Voltage test	All machine types	11.6.7
12	Power factor tip-up test / Tan Delta test	Machines with impregnated coils	11.6.8
13	Vibration measurement	All machine types	11.5.1
14	Over-speed test	All machine types	11.5.8
15	Stator winding line resistance test, hot	All machine types	11.6.9
16	Stator Winding IR & PI test, hot	All machine types	11.6.10
17	Routine tests for cable wound stators	Cable wound machines	11.6.11
18	No load open circuit voltage test	PM machines	11.6.12
19	Inspection of bearings and lubricant supply	All machines with hydrodynamic bearings	11.5.11

10.5 Extended Routine Tests

The extended routine test is intended to demonstrate that the completed installation is fit for service and shall be performed with all connector assemblies (that form an integral part of the subsea motor) installed. The test may be performed as part of the pump/compressor submerged test. If the connection system (penetrators, jumper harnesses etc.) for the motor assembly was not part of the original routine tests and have been integrated subsequently, the extended routine tests given in Table 10-4 shall be performed. Where electrical testing has previously been performed, the test voltage may be reduced to 80% of the original value so as to reduce repeated stressing of the electrical insulation.

Table 10-4 Extended Routine test sequence

Step	Test	Application	Test procedure reference
1	Stator Winding and Bearing Temperature Detector – Functional test Functional test (all ETD types) IR test, Cold (electrical types)	Machines fitted with ETD's	11.3.7
2	Stator winding line resistance test, cold	All machine types	11.6.1
3	Stator Winding IR & PI test, cold	All machine types	11.6.2
4	Direction of rotation test	Direction of rotation test	11.6.6
5	Stator Winding Withstand Voltage test	All machine types	11.6.7
6	Power factor tip-up test / Tan Delta test	Machines with impregnated coils	11.6.8
7	Stator winding line resistance test, hot	All machine types	11.6.9
8	Stator Winding IR & PI test, hot	All machine types	11.6.10
NOTE: Although out of the scope of this document it is recommended that a system integration test is performed with the machine submerged in water			

10.6 Qualification and inspection requirements for cables used in cable wound stators

Cables and their associated components (e.g. joints and splices) that are to be used for cable wound stators shall be subjected to the sequence of tests shown in Tables 10-5 to 10-10. Routine testing in Table 10-6 shall be performed before and after type testing to verify the condition of the cable sample.

Table 10-5 Physical tests

Step	Test or inspection	Application	Test procedure reference
1	Visual Inspection	Sample test	IEC 60502-2
2	Electrical resistance of conductor	Sample test	IEC 60502-2, section 16.2
3	Insulation Thickness Measurement	Sample test	IEC 60502-2 or ICEA S-97-682 table 4-7
4	Internal Semi-conductive Layer Thickness Measurement	Sample test	IEC 60502-2 section 7.1
5	Internal Semi-conductive Layer Resistivity Measurement	Sample test	IEC60502-2 or ICEA S-97-682 section 3.6.1
6	Physical Measurements	Sample test	IEC60502-2 or ICEA S-97-682 Part 10.1.8
7	Sample Weight and Weight Change	Sample test	11.2.2

Table 10-6 Electrical routine tests

Step	Test or inspection	Application	Test procedure reference
1	Electrical Conductor Resistance	Routine test	IEC 60228
2	Insulation Resistance	Routine test	ISO 13628-5:2002
3	Partial Discharge Test	Routine test	IEC 60502-2 or ICEA S-97-682 section 4.3.2.1 table 4.7
4	Voltage Test	Routine test	IEC 60502-2 or ICEA S-97-682 table 4.7
5	Partial Discharge Test	Routine test	IEC 60502-2, section 18.2.5
6	Tan Delta Measurement	Routine test	IEC 60502-2, section 18.2.6
7	Resistivity of inner and outer semiconducting screen test if present	Routine test	IEC 60502-2, section 18.2.10
NOTE: If the cable is to be fitted with a protective layer, the PD test in Step 3 shall be performed before the protective layer is fitted. If the cable does not have semi-conductive screens, Step 7 shall be ignored.			

Table 10-7 Electrical Type tests

Step	Test or inspection	Application	Test procedure reference
1	Physical tests	Sample test	Table 10-5
2	Electrical routine tests	Sample test	Table 10-6
3	High Voltage Time tests (HVTT)	Type test	ICEA S-97-682 Part 10.1.3
4	Hot Impulse Tests	Type test	ICEA S-97-682 Part 10.1.4
5	Accelerated water treeing test (AWTT) at ambient pressure	Type test	ICEA S-97-682 Part 10.1.6
6	Electrical Measurements	Type test	ICEA S-97-682 Part 10.1.7
7	Impulse Voltage Test	Type test	IEC 60502-2, section 18.2.8
8	Bending and PD test	Type test	11.2.9
9	Voltage Test for 4h	Type test	IEC 60502-2, section 18.2.9
10	HV breakdown test	Type test	IEC 60243-1
11	Physical tests	Sample test	Table 10-5
12	Electrical routine tests	Sample test	Table 10-6
NOTE: If the electrical insulation of the cable is a material other than XLPE, alternative test references may be used by agreement between the manufacturer and purchaser			

Table 10-8 Mechanical and Thermal Type tests

Step	Test or inspection	Application	Test procedure reference
1	Physical tests	Sample test	Table 10-5
2	Electrical routine tests	Sample test	Table 10-6
3	Cyclic ageing Tests	Type test	ICEA S-97-682 Part 10.1.5
4	Bending test	Type test	IEC 60502-2, section 18.2.4
5	Thermal cycle test	Type test	IEC 60502-2, section 18.2.7
6	Thermal shock test	Type test	11.2.10
7	Vibration test	Type test	11.2.11
8	Physical tests	Sample test	Table 10-5
9	Electrical routine tests	Sample test	Table 10-6
NOTE: If the electrical insulation of the cable is a material other than XLPE, alternative test references may be used by agreement between the manufacturer and purchaser			

Table 10-9 Hydrostatic Type tests

Step	Test or inspection	Application	Test procedure reference
1	Physical tests	Sample test	Table 10-5
2	Electrical routine tests	Sample test	Table 10-6
3	Hydrostatic test	Type test	11.2.12
4	Hydrostatic “shut in” simulation test	Type test	11.2.13
5	Pressure cycling test	Type test	11.2.14
6	Rapid gas decompression test[1]	Type test	11.2.15
7	Physical tests	Sample test	Table 10-5
8	Electrical routine tests	Sample test	Table 10-6
NOTE 1: For cables exposed to gas			

Table 10-10 Material Type tests

Step	Test or inspection	Application	Test procedure reference
1	Material compatibility tests	Material test	11.2
2	Water absorption test	Material test	11.2.7
3	Shrinkage, tensile and elongation test	Material test	11.2.8

10.7 Special tests

Special tests shall be performed by agreement between the manufacturer and purchaser. Table 10-11 lists Inspection requirements, Type tests and Routine tests from which a selection of Special tests can be made and inserted in to the test programme at the appropriate stage agreed between manufacturer and purchaser.

Table 10-11 Special tests

Step	Test	Application	Test procedure reference
1	Bearing dimensional and alignment checks before tests	All machines types	11.7.1
2	Measurement of the shaft voltage and current for motors with insulated bearings	Machines with insulating bearings	11.7.2
3	Insulated bearing IR test	Machines with insulating bearings	11.7.3
4	Bearing Temperature Rise	All machine types except those with magnetic bearings	11.7.4
5	Thermal Stress on Magnet	PM motors	11.7.5
6	Partial discharge testing of stator	All machine types	11.7.6
7	Momentary excess torque test	DOL Motors	11.7.7
8	Survey of current values and locked rotor torque	All machines	11.7.8
9	Pull-out torque of synchronous motor	Synchronous motors	11.7.9
10	Sudden short circuit test	PM motors	11.7.10
11	Special surge test of coils	Pre-assembly inspection requirement	11.7.11
12	Rotor residual unbalance verification test	Post assembly inspection requirement	11.7.12
13	Vibration recording	Type and routine test	11.7.13
14	Complete test (efficiency and heat run)	Type test	11.7.14
15	DC high potential test	Type and routine test	11.7.15
16	Impulse voltage withstand test	Type test	11.7.16
17	Unbalanced response test	Type test	11.7.17
18	Cold temperature rotor vibration test.	Type test	11.7.18
19	Rated rotor temperature vibration test	Type test	11.7.19
20	Bearing dimensional, alignment and lubrication checks after tests	Post testing inspection requirement	11.7.20
21	Final assembly running clearances	Post testing inspection requirement	11.7.21

11 TEST PROCEDURES

11.1 General

This section describes the procedures for tests that are listed in Section 10.

Unless otherwise specified in the datasheet, the motor performance and testing shall comply with the tests and test criteria set forth in API 541, 5th Edition for induction motors and API 546, 3rd Edition for synchronous motors. Tests and associated activities shall include, but not be limited to, those listed in Section 10.

11.2 Material and Component Type Testing

11.2.1 General requirements

Type testing of new materials, new combinations of materials or bonding between materials shall be performed. New is regarded as a new material grade or materials not previously used in similar equipment, application and environment as defined by a TRL below 4 according to API 17N. The type test programme and acceptance criteria shall be agreed between manufacturer and purchaser. This testing also covers polymeric materials. A change in polymer material or in seal design shall require a new type test.

NORSOK M-001 should be used as a reference standard for materials selection and testing.

For cable-wound motors, the cable insulation shall be type tested according to the applicable standard for the cable.

11.2.2 Polymeric materials test requirements

The following requirements are applicable to polymeric materials:

- Chemical compatibility shall be documented according to those requirements and the test methodology given in NORSOK M-710, Qualification of non-metallic sealing materials and manufacturers.

Note 1: It is recognised that Norsok M710 relates specifically to sealing materials but the methodology contained therein should be adapted to suit testing of other non-metallic components.

- Testing of polymeric materials shall also include seal ability testing in relevant fluids or gas. Testing of this kind should be done in the actual seal/gland geometry and size, to ensure that sealing is adequate for the required functionality.
- For insulation materials, electrical properties shall be verified also after ageing tests. Examples of electrical properties that are relevant are dielectric strength, volume resistivity, dielectric permittivity and tan δ.

- New non-metallic sealing and barrier materials, new combinations of materials or bonding between materials shall be tested and qualified to prove the ability to withstand the thermal, electrical and mechanical stresses it may be exposed to.
- Changes in weight shall be measured to assist in determining if a material has absorbed or leached chemicals during compatibility testing. A balance shall be used relative to the size of sample that has sufficient resolution to determine weight change of 0.1%.
- Materials that may be subjected to rapid gas decompression shall be tested according to ISO 23936-2 Clause 7.

Assembled components shall be validated by the following:

- Visual appearance.
- Weight change (*).
- Stiffening / engineering judgement
- Surface adhesion. “Dolly test” ref ASTM4541-02 (*)
- Electrical characteristics test. Benchmarked against non- exposed sample (*).
    - Insulation resistance
    - Partial discharge
    - Tan delta
    - Dielectric breakdown

(*) For liquid filled motor test, secure wiping off and minimum 1 hour dripping off/drying time before these tests.

Note 1: ISO 23936 (part 1 and part 2) and NORSOK M710 relate to elastomers and thermoplastic tests specifically and it is recommended to use criteria as the basis for the evaluation of such materials.

11.2.3 **Compatibility tests**

Compatibility testing shall be undertaken to ensure that the functional properties of materials do not degrade when exposed to substances into which they will come into contact during service to the extent that the component will fail during the lifetime of the machine. Functional properties are those that are critical to the correct performance of the component. For example, a change in colour may be acceptable for an elastomeric component provided that other important properties remain within design limits.

Compatibility testing shall be mutual, i.e. investigating the effect that each material has on the other. For example, the degradation of an elastomeric compound in a dielectric fluid has an effect not only on the function of the elastomeric component but also on the properties of the dielectric fluid.

The manufacturer shall be responsible for proposing a comprehensive compatibility testing programme that investigates how the functional properties of material changes with contact with other materials (including gases and fluids). This requires an understanding of the function of the component, what material properties are important to this function and the

degree to which these properties can change without affecting the ability of the component to achieve its function within its expected lifetime. Some degradation of properties may be tolerated provided the properties remain within the safe working limits required for the component design.

Testing of the material properties shall be to an appropriate international standard.

Consideration should be given to ensuring that the compatibility test is representative of service. For example, differing results can be obtained depending upon whether a material is stressed (mechanically, electrically and thermally) compared with an unstressed sample. The stress imposed during compatibility testing should be representative of service conditions. Care should be taken if increasing the stress to provide acceleration of the test to ensure that the test conditions are not unrepresentative.

Acceleration of compatibility testing may be required to achieve a life prediction. A common method of achieving this is through thermal acceleration of the rate of reaction. An appropriate international standard shall be chosen for the material under test, for example ISO 188: 2011 for accelerated ageing of elastomers and thermoplastics. Other methods include stress cycling to accelerate the number of stressing events in a given time period, for example rapid gas decompression.

11.2.4 **Sealing test**

Testing of non-metallic O-ring seals shall be according to Norsok M 710. For other non-metallic components that perform a sealing function the tests will comprise of:

- Long term diffusion characteristics, to demonstrate acceptable diffusion rates (e.g. compensator bladder materials)
- Disc bursting tests (for insert moulding materials, e.g. epoxy)
- Mandrel test for boot seals. The mandrel test shall be performed at the same test conditions as the general ageing test (temperature, fluid, duration etc.)

11.2.5 **Adhesive Bonding tests**

- For non-metallic materials, the compatibility test programme should, in general, be based on NORSOK M-710 (Annex A and C) and supplemented by adhesive bonding tests to an appropriate standard for the type of bond being evaluated. All acceptance criteria shall be defined prior to the commencement of testing, be based on operational knowledge of the equipment, and shall be agreed between all parties prior to testing taking place.

Testing performed to an alternative standard than mentioned above may be acceptable, based on comparative qualification between the applicable standards. Due to material selection it may be appropriate to perform testing to other standards.

11.2.6 **Component hyperbaric testing**

The objective of the tests is to ensure that the internal components of the subsea motor assembly and its internal accessories (e.g. oil, windings and insulation materials, support

materials, ETDs etc.) that are vulnerable to absolute crush pressure are able to withstand the internal pressure. The test also validates that the accessories can withstand the required number of installation/retrieval cycles without degradation or damage and that acceptable performance characteristics are maintained throughout the pressure envelop. This test is applicable to the development stage of the machine in order to prove the choice of materials, design of components and the manufacturing/assembly processes. Actual components or scaled test structures may be used in the test provided they are representative of the final component. Unless otherwise specified, the test medium shall be tap water.

The outline test specification and sequence are as follows:

f) Establish the performance characteristics of the component (for example dielectric properties, magnetic properties, dimensions, IR etc.) before pressure cycling

g) Pressure cycling x 300 (from atmospheric pressure to 1.1 x RAP-2).

h) Establish the performance characteristics at pressure, 1.1 x RAP-2.

i) Remeasure the performance characteristics after pressure cycling, including visual inspection, dissection etc.

Pressurization and depressurization rate should be 20 bar/min. Hold time after each pressurization or depressurization shall be minimum 30 minutes. Other testing parameters may also be used, if agreed between the manufacturer and purchaser.

The properties to be measured before, at and after pressure cycling depend on the function of the component and material characteristics. The detail of the test procedure shall be agreed between the manufacturer and purchaser.

Acceptance criteria: The properties of the components shall remain within specification and the functionality maintained. Any degradation or damage shall be noted, and explanation given as to why performance and life time is not affected. The detailed acceptance criteria shall be agreed between the manufacturer and purchaser.

11.2.7 **Water absorption testing for motor cables and accessories**

The purpose of this test is to determine the effect of water absorption on the electrical and mechanical properties of materials to be used in motor cable insulation and their accessories. The material properties shall be tested according to Section 11.2.2 both prior to and after water absorption testing. The test specimens shall then be immersed in tap water and heated to a temperature equal to the highest expected service temperature. This may require the specimens to be placed in a sealed or pressurized vessel if evaporation or boiling is expected. The sample shall be held at a constant temperature for 7 days and then allowed to cool. The specimens shall be removed from the water, allowed to dry naturally at room temperature and then the relevant material properties remeasured. Changes in the properties shall be such that they do not affect the ability of the component to fulfill its intended function.

11.2.8 Shrinkage, tensile strength and elongation at break testing for motor cables and accessories

Samples of cable shall be cut and their length measured at room temperature such that the length is determined to within an accuracy of 2%. Sufficient samples shall be used to allow destructive testing both before and after the test. If used a joint or splice shall be included. Tensile strength and elongation at break testing shall be performed according to IEC60502-2

The samples shall be heated in air at atmospheric pressure to the maximum service temperature of the motor and held at this temperature for 168h. The cables shall then be allowed to cool naturally to the same room temperature and the lengths remeasured. The samples shall not have experienced shrinkage sufficient to impart a strain on the insulation that would damage it in service. On completion an elongation at break test shall be repeated in accordance with section IEC60502-2 and the results compared with those taken prior.

11.2.9 Bending and PD test for motor cables and accessories

Cables and accessories that are to be used for cable wound stators shall be subjected to a bending and PD test. PD testing shall be performed on cables and accessories rated at 3kV and above. Lengths of cable shall be formed so that the mid-section is bent to the minimum radius of the machine coil. If used a joint or splice shall be included. Electrical stress grading shall be applied to the cable ends if required. The mid-section shall be immersed in a conductive fluid at room temperature and pressure with the ends of the cable clear of the fluid level so that high voltage can be applied. Care shall be taken to avoid electrical stress concentrations at the fluid level. It may be necessary to degas the fluid to removed trapped gas bubbles that may interfere with the test. The sample shall then be subjected to a partial discharge test at 1.73Uo according to IEC60502-2. The partial discharge magnitude shall be less than 10pC. For cables manufactured to ICEA standards, reference shall be made to section 4.3.2.1 of ICEA 97-682.

11.2.10 Thermal shock test for motor cables and accessories

Cable samples and their accessories shall be heated in air at atmospheric pressure to the maximum temperature of the motor and held for 1h. Then shall then be immersed in tap water at room temperature and held for 1h. The cycle shall be repeated a further two times. On completion the insulation shall be visually inspected. There shall be no cracks.

11.2.11 Vibration test for motor cables and accessories

Cables and their accessories shall be subjected to vibration testing to ensure that they can withstand the vibration conditions of service. The cable samples shall be formed on a mandrel that is representative of the service arrangement. Unless otherwise specified, the vibration limits specified by section 8.3 shall be used to devise a vibration test according to IEC 60068-2-6 in one axis along the major axis of the mandrel for 24h. There shall be no mechanical damage.

11.2.12 Hydrostatic test for motor cables and accessories

Cables and their accessories shall be subjected to hydrostatic testing. The samples shall be pressurized in tap water at room temperature to a pressure of 1.5 x RAP and held for 72h. There shall be no mechanical damage

11.2.13 Hydrostatic shut-in simulation test for motor cables and accessories

Cables and their accessories shall be subjected to hydrostatic testing to simulate a shut-in. The samples shall be pressurized in tap water at room temperature to a pressure of 15000 PSI and held for 4h. There shall be no mechanical damage

11.2.14 Pressure cycling test for motor cables and accessories

Cables and their accessories shall be subjected to hydrostatic pressure cycling tests. The samples shall be heated to maximum working temperature and pressure cycled using tap water. Samples shall be subjected to 300 pressure cycles between atmospheric pressure and a pressure of 1.0 x RAP with 5 minutes hold durations at each pressure extreme. There shall be no mechanical damage

11.2.15 Rapid gas decompression test for motor cables and accessories

Cables and their accessories that are to be exposed to gas shall be subjected to a rapid gas decompression test. Unless otherwise specified an inert gas such as helium or nitrogen may be used. The requirements of ISO 23936-2 shall be followed, and this allows the use of either a standard procedure or a customised procedure by agreement. When using the standard procedure, the lower limit of pressure shall be 10 bar, the upper limit on pressure shall be 1.0 x RAP. The average rate of depressurisation shall be 20 bar/min and the test temperature shall be defined by the maximum operating temperature. The number of pressure cycles and the hold periods shall be as defined by ISO 23936-2

There shall be no cracking or blistering of the insulation.

11.3 Inspection during assembly

11.3.1 Stator Core and Direction of Field Test

After completing the stator core mechanically, prior to insertion of windings, the integrity of the insulation of the stator core laminations shall be tested with nominal flux in the back core. Testing shall be according to Ch 6.3.4.1 of API 541 Edition 5: 2014 or Section 4.3.4.1 of API 546 Edition 3: 2008 for PM machines.

The stator windings shall be inspected and tested during assembly to verify that the direction of rotation of the field is in accordance with the manufacturer’s requirements.

11.3.2 Sealed winding conformance test

Machines having encapsulated windings shall be subjected to a sealed winding conformance test according to Section 12.62 of ANSI/NEMA MG1: 2016. The test may be performed on a

sample winding or on the winding to be used in service by agreement between the manufacturer and the purchaser.

11.3.3 **Rotor balance assessment**

The rotor shall be mechanically balanced according to Section 4.4.6.3 of API 541 Edition 5: 2014 with reference to ISO 21940-11: 2016. Unless otherwise specified, the balance assessment shall yield a vibration performance within the requirements of the standards referenced in Section 8.3.

Note 1 : Sensitivity testing of the rotor balance machine shall be performed by agreement between the purchaser and manufacturer.

11.3.4 **Electrical and mechanical runout of rotor**

The runout of the rotor shall be determined in accordance with Sections 6.3.3.1 and 6.3.3.3 of API 541 Edition 5: 2014 for induction motors or Sections 4.3.3.1 and 4.3.3.3 of API 546 Edition 3: 2008 for PM machines. For machines that are to be vertically oriented the measurement shall be taken with the rotor mounted horizontally. For machines having AMBs, runout performance shall be determined in accordance with Annex E of API 617.

11.3.5 **Measurement of gap between rotor and stator**

The clearance between the rotor and internal components of the machine shall be determined during assembly according to Sections 6.3.2.1(m) and 4.4.7.2.4 of API 541 Edition 5: 2014 or Section 4.2.1.1(e) of API 546 Edition 3: 2008 for PM machines. Where this is impractical due to, for example, the machine being hermetically sealed, the manufacturer shall propose an alternative analysis (for example a tolerance stack-up analysis or multiple measurements of rotor outside diameter against stator inside diameter at defined positions).

11.3.6 **Stator Winding Impulse Voltage test of Inter Turn insulation**

For motors with form wound stator coils, with rated voltage greater than 6,0kV, surge tests should be carried out in accordance with procedures in Section 6.3.4.2 of API 541 Edition 5: 2014 and IEC 60034-15. In relation the total quantity of coils manufactured for the motor, two coils must be manufactured (Sample coils or “sacrificial coils"). They shall be additional to and identical to the production items and randomly selected from the batch for the implementation of Test impulse withstand voltage ("impulse-test") in accordance with the requirements indicated in IEC 60034-15. The two coils must be impregnated and processed under the same conditions of the other coils. If a coil fails, the failure shall be investigated. Only if there are acceptable explanation for the failure shall the test proceed using the same batch of coils. The test should be repeated on an additional set of two coils. If the two coils fail, the whole set of coils must be rejected.

11.3.7 **Stator Winding and Bearing Temperature Detector – Functional test**

The ETD’s, when fitted, shall be functionally tested by measurement of their output relative to the frame temperature according to IEC60034-1 Ch 8.6.3. The output measurements shall

be compared against a calibrated temperature monitoring device on the frame and the readings shall be within the stated accuracy of the ETD devices.

An Insulation Resistance test shall be performed on the ETD if it is of an electrical type. Testing shall be according to IEC 60034-1, Sect. 9.2, Table 17, Item 9

11.3.8 **Barrier fluid – Dielectric Strength test**

If the Barrier Fluid is defined as a dielectric fluid then a Dielectric Strength test of the liquid shall be performed according to IEC60156. The specific fluid dielectric strength pass requirement shall be defined by the manufacturer in line with the design requirements.

11.3.9 **Inspection of equipment and piping for cleanliness prior to assembly**

Prior to completion of the machine and filling with fluid (if applicable) an inspection shall be performed on all equipment and piping for cleanliness prior to final assembly This is in accordance with Clause 6.2.3 of API 541 Edition 5: 2014.

11.3.10 **Measurement of axial float**

The axial float of the rotor supported by its bearings shall be determined and shall be within the manufacturer's specified limits.

11.4 Magnetic Flux mapping for PM motors

For PM motors a magnetic sensing probe shall be used to determine that the expected magnetic flux levels are being achieved

Note: This is a useful quality check to determine that the magnets are installed correctly and that they are delivering the specified magnetic flux.

11.5 Type Tests

11.5.1 **Vibration measurement**

A. Observation of bearings and mechanical operation of the motor shall be performed during the full load heat run on Type test and the overspeed test during Routine testing when practical to do so. Where accessible, measurements of motor vibration shall be made on each bearing housing throughout the entire period of the heat run. For motors having provisions for vibration monitoring systems, vibration measurements shall also be made on the motor shaft at each bearing. Unless otherwise specified the vibration on bearing housings and shaft shall not exceed limits required by the reference standards in Section 8.3.

B. Where accessible for measurement, heat run test log data shall include amplitude and unfiltered frequency of vibration at the rotor, each bearing and, for motors having forced feed lubrication, oil pressures, and inlet and outlet oil temperatures at each bearing.

C. If a conventional heat run cannot be made, the motor manufacturer shall submit to the Purchaser or their Representative for approval the complete details of an alternative test that will permit measurements of motor vibration throughout the test for a minimum period of four hours with motor operating at rated speed and with its rotor at full load temperature.

11.5.2 **Temperature Rise Test**

The motor shall be subject to a temperature rise test. The purpose with the test is to run the motor at rated load (or simulate the heating effects at rated load) and speed to achieve stable temperatures to prove that no parts of the motor overheat. The temperature may be monitored by ETD's, thermocouples, winding resistance or by monitoring the temperature of the barrier fluid if applicable, or any combination of these techniques. The test shall be performed according to and acceptance criteria in accordance with IEC 60034-1:2017 Ch 8, IEC 60034-29 or IEEE 112. Where applicable the test shall be performed with the representative cooling media present and with observance of the duty cycle that has been defined by Clauses 6.2.1 and 6.3.1 of this standard.

If it is not practical to perform the temperature rise test on a completed motor, then by agreement between the manufacturer and the purchaser the test may be performed on a representative test sample or motorette.

11.5.3 **Stator winding insulation resistance and PI test, hot**

On completion of the Temperature Rise test and as quickly as possible after shut down, the stator winding insulation resistance and polarisation index (PI) shall be measured. The test shall be performed according to CH. 6.3.2.1 d. of API 541 Edition 5: 2014 or Section 4.3.2.1(d) of API 546 Edition 3: 2008 for PM machines. For liquid filled and gas pressurised motors it may not be practical to access the individual winding terminals in sufficient time to allow a hot insulation resistance measurement to be taken on each of the windings directly. In such instances it is permissible to perform the test through the penetrators of the motor provided that a baseline insulation tests has been performed on the system prior to commencing the test. The temperature at which the readings were taken shall be recorded. There are no acceptance criteria and there is no requirement to normalise the insulation resistance readings for temperature but the data shall be reported for use in future diagnostic testing.

11.5.4 **Mechanical Loss test**

In subsea motors and in particular liquid filled and gas pressurised motors, the losses related to friction and windage or rather viscous losses, may be significant. In a subsea motor the fan may be replaced by a shaft driven impeller. The losses related to the impeller shall be included in the mechanical losses.

The mechanical losses shall be determined by either calibrated machine, retardation or calorimetric method according to either IEEE112 or IEC 60034-2. If it is not possible to perform this test due to the machine having an integrated load, an alternative method shall be agreed between manufacturer and purchaser.

11.5.5 **Survey of torque and current**

A torque curve survey shall be performed in accordance with Section 7.3 of IEEE 112. Where this is impractical to perform, the manufacturer shall propose an alternative method to the purchaser.

11.5.6 **Motor load test at variable speed**

The load test at variable speed shall be performed according to IEC 60034-2-1:2014 CH. 8.1.3.2.1.

The test should be performed at 100%, 75%, 50% and 25% of rated speed unless otherwise agreed between purchaser and manufacturer.

11.5.7 **Locked rotor test**

A locked rotor torque test shall be performed to evaluate the impact that a locked rotor has on the electrical supply network. Testing shall be according to Section 6.3.5.1.1 b of API 541 Edition 5: 2014 with reference to IEEE 112 Ch 5.10.3.1 or Section 4.3.5.1.1 b of API 546 Edition 3: 2008 for PM motors. Where impractical due to the machine being hermetically sealed with an integrated load, the manufacturer shall propose an alternative method to the purchaser.

11.5.8 **Overspeed test**

Unless otherwise specified in the datasheet, the motor shall be run with overspeed test as defined in Section 6.3.5.6 of API 541 Edition 5: 2014 but with the speed defined by the requirements of Section 6 of standard SEPS SP-1003.

11.5.9 **Sudden Short Circuit test for PM motors**

1. The test must be performed on the hot machine after a heat run test.
2. Prior to this test, an open-circuit measurement must be performed in accordance with section 4 of IEEE 1812-2014 to determine the open-circuit voltage and the no-load losses.
3. Accelerate the PM machine to the desired speed, then disconnect the motor from the power supply. After the motor is disconnected, a sudden three phase short-circuit must be applied to the machine terminals.
4. All phase currents must be recorded as a function of time at a high sampling rate immediately following the sudden short circuit.
5. The open-circuit test is again performed to determine if the sudden short-circuit test affected the open-circuit voltage due to any demagnetization of the magnets.
6. Any damage to other components such as bearings etc must be investigated and reported to Purchaser.
7. Acceptance criteria must be mutually agreed between manufacturer and Purchaser. The fault current could be limited to a pre-determined mutually acceptable level which must resemble worst case actual field conditions due to faults in penetrators, wet-mate connectors, electrical flying leads or the output of ASD.

11.5.10 Stator winding surge test

Surge testing of the main stator insulation shall be conducted in accordance with IEC 60034-15 by applying a rated power-frequency withstand voltage (2 Un + 1 kV) for 1 minute between coil terminals and earth. The applied voltage shall be increased at a rate of 1 kV/s up to 2 (2 Un + 1 kV) and then immediately be reduced at a rate of at least 1 kV/s to zero.

11.5.11 Inspection of bearings and lubricant supply

For hydrodynamic bearings, a bearing and lubricant supply verification shall be performed according to Ch 6.3.2.1 j of API 541 Edition 5: 2014 on completion of the test sequence. Any damage or performance out of specification shall be recorded and reported. Where this is impractical to perform because it involves disassembly of a production unit, the manufacturer and purchaser shall agree an alternative inspection method.

11.6 Routine tests

11.6.1 Stator Winding Line Resistance – cold

The stator Winding Resistance shall be measured between all phases in cold condition. The motor frame temperature shall be measured at the same time. Testing shall be according to Ch 6.3.2.1 e of API 541 Edition 5: 2014. The winding resistance value once corrected to 20C shall be used as a benchmark and subsequent winding resistance tests shall not yield a difference of more than 5% from the benchmark value after being corrected for temperature.

11.6.2 Stator Winding Insulation Resistance & PI Test, cold

The stator winding insulation resistance and polarisation index (PI) shall be measured according to Ch 6.3.2.1 d of API 541 Edition 5: 2014, IEC 60034-27-4 or IEEE 43-2013. For fluid filled motors the test shall be performed with the stator filled. The Insulation resistance shall be at least 400MΩ after 1 minute of energisation once corrected to 20C and the value measured in the routine test shall be used as a benchmark for subsequent insulation resistance tests. The value of insulation resistance (corrected to 20C) measured in subsequent tests shall be compared with the benchmark value and deviations greater than 10% shall be reported and explained.

11.6.3 No load test

For machines not having an integrated load, the total no-load losses shall be determined by a no-load loss test. The motor shall be decoupled from the load shaft, but all devices required for circulation and cooling shall be in place. Testing shall be according to IEC 60034-2-1: 2014 CH. 6.2.6.2 and 60034-1:2017 CH. 9.1 Table 15

For machines having an integrated load, the manufacturer shall propose an alternative test with the load attached and allowances made in the results.

11.6.4 Stator Winding and Bearing Temperature Detector – Functional test

Prior to undertaking the withstand test in Section 11.6.5, the ETD's, when fitted, shall be functionally tested by measurement of their output relative to the frame temperature under

conditions of thermal stability. The output measurements shall be compared against a calibrated temperature monitoring device and the readings shall be within ±2 ºC of the stated accuracy of the ETD devices.

An Insulation Resistance test shall be performed on the ETD if it is of an electrical type. Testing shall be according to API 541 Section 6.3.2 (i).

11.6.5 **Temperature Detector – Withstand Voltage test**

The Withstand Voltage test shall be performed with all winding terminals and other devices not under test grounded. Prior to performing the withstand voltage test the frame temperature shall be measured and an Insulation Resistance test on both the ETD and winding shall be performed with all other windings and ETDs earthed. Testing shall be according to IEC 60034-1, Sect. 9.2, Table 17, Item 9 and the voltage applied for 60 seconds.

Note 1: If a signal penetrator and cables are employed in the test circuit, it may be necessary to reduce the test voltage to be within the limits of these components.

The functional test in Section 11.6.4 shall then be repeated.

11.6.6 **Direction of Rotation test**

The motor terminals U, V and W shall be connected to phase L1, L2 and L3 respectively. The magnetic field direction of rotation shall be according to the manufacturer's requirements. Reference shall be made to IEC 60034-1:2017 CH. 9.1 Table 16 No. 6a/6b. The direction of rotation may be observed or sensed if direct observation is not possible.

11.6.7 **Stator Winding Withstand Voltage test**

The Withstand Voltage test shall be performed according to the requirements given in the IEC60034-1:2017 Ch 9.2 Table 17. Alternatively, Ch 6.3.2.1 c of API 541 Edition 5: 2014 may be used. The test voltage shall be applied between each stator phase in sequence with the remaining phases and casing grounded provided both ends of each winding are accessible. If not then all three phases shall be tested simultaneously with the casing earthed. All electrical type ETD's shall be grounded and any windings not under test shall be also grounded. For liquid filled motors the test shall be performed with the stator filled. The windings shall withstand the test without breakdown, surface arcing or flashover.

11.6.8 **Power Factor Tip-up test**

For machines with encapsulated windings, the power factor tip-up (tan-delta) test shall be performed on the completely wound stator in accordance with IEEE 286 or IEC 60034-27-3 with the machine at ambient temperature. The temperature at which the test has been performed shall be recorded. The acceptance criteria shall be mutually agreed upon between the manufacturer and purchaser according to the type of insulation used.

11.6.9 **Stator winding line resistance test hot**

The stator Winding Resistance shall be measured between all phases with the machine at operating temperature. The machine shall be operated at full load to bring the motor up to working temperature. Testing shall be according to Ch 6.3.2.1 e of API 541 Edition 5: 2014. The resistance of penetrators and cables shall be taken into account. There are no acceptance criteria but the data shall be reported for use in future diagnostic testing.

If there are practical difficulties in performing this test due to the time taken to access the winding terminals, the manufacturer shall propose an alternative method.

11.6.10 **Stator winding insulation resistance and PI test hot**

The machine shall be operated at full load to bring the motor up to working temperature. As quickly as possible after shut down, the stator winding insulation resistance and polarisation index (PI) shall be measured. The test shall be performed according to CH. 6.3.2.1 d. of API 541 Edition 5: 2014.

For liquid filled and gas pressurised motors it may not be practical to access the windings in sufficient time to allow a hot insulation resistance measurement to be taken on the windings directly. In such instances it is permissible to perform the test through the penetrators of the motor provided that a baseline insulation tests has been performed on the electrical system prior to commencing the test. There are no acceptance criteria but the data shall be reported for use in future diagnostic testing.

If there are practical difficulties in performing this test due to the time taken to access the winding terminals, the manufacturer shall propose an alternative method (for example total electrical system IR and PI trending with temperature).

Note 1: Electrical system refers to the motor windings, terminals, cables and penetrators that are employed in the test circuit.

11.6.11 **Routine tests for cable wound stators**

For cable wound machines, the routine test programme in Section 10.6 may be supplemented by the cable manufacturer's own routine tests with the approval of the purchaser. Any such additions shall be detailed and reported to the purchaser and the data sheet.

Table 11-2 Stator cable sample and routine test procedures

Conductor Check	Sample test	IEC 60502-2, section 16.2
Electrical Conductor Resistance	Sample test	IEC 60228
Hot Set Test	Sample test	IEC 60502-2 table 19
Insulation Thickness Measurement	Sample test	ICEA S-97-682 table 4-7
Insulation Resistance	Sample test	ISO 13628-5:2002
Internal Semi-conductive Layer Thickness Measurement	Sample test	IEC 60502-2 section 7.1

Internal Semi-conductive Layer Resistivity Measurement	Sample test	ICEA S-97-682 section 3.6.1
Electrical resistance of conductors	Routine test	IEC 60502-2, section 16.2
Partial Discharge Test	Routine test	ICEA S-97-682 section 4.3.2.1 table 4.7
Voltage Test	Routine test	ICEA S-97-682 table 4.7

11.6.12 No load open circuit voltage test for PM machines

This test determines the back-EMF from a permanent magnet machine with open-circuit voltage and speed measurements.

The EMF can be obtained:

- by driving the machine being tested open-circuited and by recording its terminal voltage and speed.

- or by the retardation method (coast-down test) where the machine is fed by a ASD until rated speed followed by switching the machine terminal to open circuit and by recording its terminal voltage and speed during coast down.

11.7 Special tests

Special tests are tests that are agreed between manufacturer and purchaser on a project basis. They may be performed at any point in the test programme and may form the basis of type or routine tests as agreed. In instances where the special test is not applicable to the specific design of motor, the manufacturer may recommend an alternative proposal.

11.7.1 Bearing dimensional and alignment checks before tests

When specified, an inspection shall be performed on bearing dimensions and alignment before testing commences in accordance with Section 6.3.2.1 k of API 541 Edition 5: 2014. The readings shall remain within the manufacturer's acceptable limits.

11.7.2 Measurement of Shaft Voltage and Current for motors with insulated bearings

When specified and practically possible the voltage between the two ends of the motor shaft shall be measured according to Ch 6.3.2.1 n of API 541 Edition 5: 2014 with reference to Section 8 of IEC TS 60034-25. The voltage shall be within the rating of the bearing insulation. If practical a measurement of the resulting current shall be made and the current should be such that it does not cause arcing or otherwise interfere with the correct functioning of the machine

11.7.3 **Insulated bearing IR test**

When specified and practically possible a test of the bearing insulation shall be performed. This test shall be considered together with 11.7.1 above. Testing shall be according to Ch 6.3.2.1 g of API 541 Edition 5: 2014 and IEEE 112: 2017 Ch. 8.4.

11.7.4 **Bearing temperature rise**

When specified and practical a bearing temperature rise test shall be performed according to IEC60034-1:2017 Ch 8.9 Table 7 or Ch 6.3.2.1 h of API 541 Edition 5: 2014.

11.7.5 **Thermal stress on magnet for PM motors**

A thermal analysis shall be performed to identify maximum temperature rise in magnet and to ensure that the magnet remains outside of the demagnetization region. A back EMF measurement or open-circuit voltage test shall then be conducted at nominal speed, maximum load and ambient temperature to detect any change in the machine's magnetic flux.
A temperature cycling test shall follow in accordance with API 6A and API 17D.
The acceptance criteria must be mutually agreed between manufacturer and Purchaser

11.7.6 **Partial Discharge testing of the stator**

When specified PD test shall be performed on the stator of the motor. This is particularly relevant to machines fed by an ASD where repetitive voltage spikes may be present. Reference shall be made to API 541 or API 546 as appropriate in addition to an agreed normative reference standard such as IEEE 454, IEEE1434, IEC TS 60034-18-42, IEC 60034-27 - 1 & 2 and IEC 60270. The test voltages and acceptance criteria shall be agreed between the manufacturer and the purchaser.

If the motor is cable wound, the PD test described in Step 3 of Table 10-6 and Step 8 of Table 10-7 shall be used.

11.7.7 **Momentary Excess Torque test (DOL motors)**

When specified and practically possible the maximum excess torque shall be measured on the motor shaft according to Section 9.4 of IEC60034-1: 2017.

11.7.8 **Survey of current values and locked rotor torque**

When specified and practical to perform, a locked rotor test shall be performed on rotor shaft. (This test is considered a Drive System test.). Reference shall be made to IEC60034-1 and Ch 7.2.2 & 7.3.1.1 of IEEE 112-2017. Where it is impractical to perform this test due to the motor unit having an integrated load, the manufacturer shall propose an alternative method to the manufacturer.

11.7.9 **Survey of pull out torque**

When specified for synchronous machines and practical to perform, a pull-out rotor torque test shall be performed on rotor shaft. Reference shall be made to IEC 60034-4.

11.7.10 Sudden short circuit test

For machines that are direct on line supplied, a sudden short circuit test shall be performed according to Ch 4 of IEEE 1812: 2014

11.7.11 Special surge test of coils

When specified a voltage surge test of two additional stator coils shall be performed according to Section 6.3.4.2.1 of API 541 Edition 5: 2014.

11.7.12 Rotor residual unbalanced verification test

When specified the residual unbalance of the rotor shall be determined in accordance with clause 4.4.6.3.4 of API 541 Edition 5: 2014 or Section 4.3.5.3 of API 546 Edition 3: 2008 for PM machines.

11.7.13 Vibration recording

When specified in addition to the Type test in Section 11.5.1, a more extensive vibration test may be requested in accordance with Section 6.3.3 of API 541 Edition 5: 2014 or Section 4.3.5.2 of API 546 Edition 3: 2008 for PM machines but using the vibration limits given in the reference standards in Section 8.3 of this document.

11.7.14 Complete test (efficiency and heat run)

When specified a Complete Test (efficiency and heat run) shall be performed according to Section 6.3.5.1 of API 541 Edition 5: 2014.

11.7.15 DC High Potential test

Where it is not practical to perform high potential tests with the correct a.c. voltage, a DC high potential test may be substituted with the approval of the purchaser. This test shall be in accordance with Section 6.3.5.1.2 of API 541 Edition 5: 2014 or 4.3.5.1.2 of API 546 Edition 3: 2008.

11.7.16 Impulse voltage withstand test

When specified an Impulse Voltage Withstand test shall be undertaken on each coil with the other coils and the frame earthed according to IEC 60034-15:2009 Ch. 4.2 Table 1.

11.7.17 Unbalanced response test

When specified an Unbalanced response test shall be performed according to Section 6.3.5.3 of API 541 Edition 5: 2014.

11.7.18 Cold temperature rotor vibration test

When specified, cold temperature rotor vibration tests shall be performed according to Section 6.3.1.5 of API 541 Edition 5: 2014. The temperature shall be equivalent to the coldest temperature that the machine is expected to operate at start up.

11.7.19 Rated temperature rotor vibration test

If specified a rated temperature rotor vibration test shall be performed according to Section 6.3.5.2.1 of API 541 Edition 5: 2014. The temperature shall be equivalent to the maximum temperature that the machine will experience under normal operation.

11.7.20 Bearing dimensional, alignment and lubrication checks after tests

If specified, bearing dimensional and alignment checks shall be performed after the test programme in accordance with Section 6.3.2.1 L of API 541 Edition 5: 2014. For machines having lubricated bearings, the lubrication system shall be checked according to Section 6.3.2.1 J of API 541 Edition 5: 2014.

11.7.21 Final assembly running clearances

If specified the final assembly clearances of rotating parts shall be determined according to Section 6.2.1.1 e of API 541 Edition 5: 2014.

12 QUALITY CONTROL

Manufacturers shall operate and maintain a quality system to a recognised and audited quality management standard such as ISO 9001. Careful consideration shall be given to all aspects of quality management in the qualification of prototype machines as this qualifies not only the design but the method of supply, inspection, manufacture and assembly. Any subsequent changes to any aspect could invalidate qualification. Qualification must be representative of the system and arrangements and not introduce artificial situations that cannot be achieved in reality e.g. access for intervention when that is not possible subsea.

Particular attention should be paid to the sourcing and control of magnetic materials in order to ensure that they meet the requirements of the design. Refer to clause 4.4.10.7 of API 541 Edition 5: 2014 and 4.2.2.4 of API546 2008.

13 APPENDICES

Appendix 1 Subsea motor data sheet

Requirement	Data		Comments
General			
Purchaser Name			
Manufacturer Name			
Product name/series			
Part No			
Project name			
Number of motor units required			
Motor type (Induction/PM etc)			
Choice of reference standards from Section 2	**Purchaser requirement [a]**	**Product capability [b]**	
API			
IEC			
IEEE			
Other			

Environmental data	Purchaser requirement [a]	Product capability [b]	Comments
Service design life time	_years	_years	
Maintenance interval	_years	_years	
Maximum operational water depth	_m	_m	
Ambient external operating temperatures (min./max.)	_ / _ °C	_ / _ °C	
Ambient Internal operating temperatures (min./max.)	_ / _ °C	_ / _ °C	
Storage temperatures (min./max.)	_ / _ °C	_ / _ °C	
Handling temperatures (min./max.)	_ / _ °C	_ / _ °C	
Maximum storage time topside	_ days	_days	
Maximum storage time subsea (Non-operating)	_ days	_ days	
External surrounding media and concentration	Gas ( ), Fluid ( )	Gas ( ), Fluid ( )	
Internal surrounding media and concentration	Gas ( ), Fluid ( )	Gas ( ), Fluid ( )	
Types of chemicals to which the unit could be exposed and duration			
Rapid gas decompression rate	_Bar/min	_Bar/min	
Maximum landing speed and shock	_m/s _g	_m/s _g	
Inclination to the horizontal at installation	_°	_°	
Marine growth % of weight and % reduction in cooling	_% / _%	_% / _%	
Seismic loading capability for each of the three major axes (acceleration and duration)	X-X _g / _ s Y-Y _g / _ s Z-Z _g / _ s	X-X _g / _ s Y-Y _g / _ s Z-Z _g / _ s	
Heat exchanger fitted (Yes/No)			
Cathodic Protection Arrangement			
Special storage, transport or handling requirements			

Electrical parameters	Purchaser requirement [a]	Product capability [b]	Comments
Rated Power	_kW / _hp	_kW / _hp	
Power factor	_%	_%	
Rated voltage, *Un/Um*	_ kV / _kV	_ kV / _kV	
Full Load Current (RMS, symmetrical)	_ A RMS	_ A RMS	
Starting current	_ A RMS	_ A RMS	
Rated frequency range	_Hz	_Hz	
Short circuit current rating (kA RMS symmetrical and duration)	_kA, _ms	_kA, _ms	
Power supply type (e.g. ASD / DOL)			
Duty Cycle Type (IEC 60034-1. e.g. S1)	S_	S_	
Efficiency	_%	_%	
Rated Insulation level	_ kV	_ kV	
Insulation Thermal class	_ °C	_ °C	
Total Harmonic Distortion	_ %	_ %	
Nominal Insulation Resistance of each stator winding to earth	_MΩ	_MΩ	
Stator Winding configuration (e.g. star/delta)			
Earth fault tolerance (Yes/No)			
Earthing method (Resistance/Reactance/Solid/Ungrounded)			
Re-acceleration capability after voltage loss (% for time s)	_ % / _ s	_ % / _ s	
Number of starts permitted per unit time	_/time	_/time	
Material compatibility	**Purchaser requirement [a]**	**Product capability [b]**	**Comments**

Mechanical parameters	Purchaser requirement [a]	Product capability [b]	Comments
Weight in air	_kg	_kg	
Weight in water	_kg	_kg	
Overall dimensions (l x w x h)	_mm	_mm	
Rated speed	_ RPM	_ RPM	
Minimum Operating Speed	_ RPM	_ RPM	
Maximum Operating Speed	_ RPM	_ RPM	
Overspeed limit	_ RPM	_ RPM	
Trip Speed	_ RPM	_ RPM	
Torque at rated speed	_kNm	_kNm	
Torque at minimum operating speed	_kNm	_kNm	
Locked rotor torque	_kNm	_kNm	
Pull up Torque	_kNm	_kNm	
Breakdown torque	_kNm	_kNm	
Rated absolute pressure	_Bar	_Bar	
Rated differential pressure (RAP 1 / RAP 2)	_Bar / _Bar	_Bar / _Bar	
Pressure retaining components design code			
Bearing type (e.g. Tilted pad, AMB)			
Bearing thrust (inboard / outboard)	_kN / _kN	_kN / _kN	
Internal barrier fluid/gas type			
Barrier fluid/gas pressure	_ Bar	_ Bar	
Vibration performance specification			
De-rating required from maximum power due to bearing performance	_%	_%	
Rotor material and corrosion treatment			
Rotor nominal run-out	_mm	_mm	
Seal type			
Seal leakage rate	_mbar/min (or other suitable units)	_mbar/min (or other suitable units)	
Normal direction of rotation viewed from in front of rotor shaft	Clockwise/ anticlockwise	Clockwise/ anticlockwise	
Total driven-equipment/load inertia reflected to motor	GD²_____kg-m² or Wk²_____lb-ft² at:_____RPM	GD²_____kg-m² or Wk²_____lb-ft² at:_____RPM	

Instrumentation Requirements	Purchaser requirement [a]	Product capability [b]	Comments
Temperature detector type			
Temperature detector locations			
Vibration detector type			
Vibration detector locations			
Pressure sensor type			
Pressure sensor locations			
Shaft displacement sensors			
Other instrumentation			
Cable Wound Motors	**Purchaser requirement [a]**	**Product capability [b]**	**Comments**
Governing cable standard			
Cable Rated voltage	_kV RMS	_kV RMS	
Cable rated current	_A RMS	_A RMS	
Conductor material and cross section area	_mm^2	_mm^2	
Conductor diameter	_mm	_mm	
Insulation material			
Diameter over insulation	_mm	_mm	
Cable screen (yes/no)			
Screen type (no screen, tape, wire)			
Screen material and cross section area	_ mm^2	_mm^2	
Outer sheath material			
Outer diameter	_mm	_mm	
Maximum allowable pull force on the cable termination	_N	_N	
Other performance or test data			

Special test requirements (Section 10.7)	Purchaser requirement [a]	Product capability [b]	Comments
Bearing dimensional and alignment checks before tests			
Measurement of the shaft voltage and current for motors with insulated bearings			
Insulated bearing IR test			
Bearing Temperature Rise			
Thermal Stress on Magnet			
Partial discharge testing of stator			
Momentary excess torque test			
Survey of current values and locked rotor torque			
Pull-out torque of synchronous motor			
Sudden short circuit test			
Special surge test of coils			
Rotor residual unbalance verification test			
Vibration recording			
Complete test (efficiency and heat run)			
DC high potential test			
Impulse voltage withstand test			
Unbalanced response test			
Cold temperature rotor vibration test.			
Rated rotor temperature vibration test			
Bearing dimensional, alignment and lubrication checks after tests			
Final assembly running clearances			
[a] This information shall be provided by the purchaser to the manufacturer. b This information shall be provided by the manufacturer to the purchaser.			