



# Supplementary Specification to IEC 60034-1 for High-voltage Three-phase Cage Induction Motors

**NOTE** This version (S-704J) of the specification document provides the justification statements for each technical requirement, but is otherwise identical in content to S-704.

## Revision history

VERSION	DATE	PURPOSE
1.1	October 2023	Issued for Public Review
1.0	January 2021	First Edition

## Acknowledgements

This IOGP Specification was prepared by a Joint Industry Programme 33 Standardization of Equipment Specifications for Procurement organized by IOGP with support by the World Economic Forum (WEF).

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## Foreword

This specification was prepared under Joint Industry Programme 33 (JIP33) "Standardization of Equipment Specifications for Procurement" organized by the International Oil & Gas Producers Association (IOGP) with the support from the World Economic Forum (WEF). Companies from the IOGP membership participated in developing this specification to leverage and improve industry level standardization globally in the oil and gas sector. The work has developed a minimized set of supplementary requirements for procurement, with life cycle cost in mind, resulting in a common and jointly agreed specification, building on recognized industry and international standards.

Recent trends in oil and gas projects have demonstrated substantial budget and schedule overruns. The Oil and Gas Community within the World Economic Forum (WEF) has implemented a Capital Project Complexity (CPC) initiative which seeks to drive a structural reduction in upstream project costs with a focus on industry-wide, non-competitive collaboration and standardization. The CPC vision is to standardize specifications for global procurement for equipment and packages. JIP33 provides the oil and gas sector with the opportunity to move from internally to externally focused standardization initiatives and provide step change benefits in the sector's capital projects performance.

This specification has been developed in consultation with a broad user and supplier base to realize benefits from standardization and achieve significant project and schedule cost reductions.

The JIP33 work groups performed their activities in accordance with IOGP's Competition Law Guidelines (November 2020).

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## Introduction

The purpose of the IOGP S-704 specification documents is to define a minimum common set of requirements for the procurement of high-voltage three-phase cage induction motors in accordance with IEC 60034-1, Edition 13.0, 2017, Rotating electrical machines – Part 1: Rating and performance for application in the petroleum and natural gas industries.

The IOGP S-704 specification documents follow a common structure (as shown below) comprising a specification, also known as a technical requirements specification (TRS), a procurement data sheet (PDS), an information requirements specification (IRS) and a quality requirements specification (QRS). These four specification documents, together with the purchase order, define the overall technical specification for procurement.



This specification is to be applied in conjunction with the supporting PDS, IRS and QRS as follows.

### **IOGP S-704: Supplementary Specification to IEC 60034-1 for High-voltage Three-phase Cage Induction Motors**

This specification defines technical requirements for the supply of the equipment and is written as an overlay to IEC 60034-1, following the IEC 60034-1 clause structure. Clauses from IEC 60034-1 not amended by this specification apply as written. Modifications to IEC 60034-1 defined in this specification are introduced by a description that includes the type of modification (i.e. Add, Replace or Delete) and the position of the modification within the clause.

**NOTE** Lists, notes, tables, figures, equations, examples and warnings are not counted as paragraphs.

### **IOGP S-704D: Procurement Data Sheet for High-voltage Three-phase Cage Induction Motors (IEC)**

The PDS defines application-specific requirements. The PDS is applied during the procurement cycle only and does not replace the equipment data sheet. The PDS may also include fields for supplier-provided information required as part of the purchaser's technical evaluation. Additional purchaser-supplied documents may also be incorporated or referenced in the PDS to define scope and technical requirements for enquiry and purchase of the equipment.

**IOGP S-704L: Information Requirements for High-voltage Three-phase Cage Induction Motors (IEC)**

The IRS defines information requirements for the scope of supply. The IRS includes information content, format, timing and purpose to be provided by the supplier, and may also define specific conditions that invoke the information requirements.

**IOGP S-704Q: Quality Requirements for High-voltage Three-phase Cage Induction Motors (IEC)**

The QRS defines quality management system requirements and the proposed extent of purchaser conformity assessment activities for the scope of supply. Purchaser conformity assessment activities are defined through the selection of one of four generic conformity assessment system (CAS) levels on the basis of evaluation of the associated service and supply chain risks. The applicable CAS level is specified by the purchaser in the PDS or in the purchase order.

The specification documents follow the editorial format of IEC 60034-1 and, where appropriate, the drafting principles and rules of ISO/IEC Directives Part 2.

The PDS and IRS are published as editable documents for the purchaser to specify application-specific requirements. The TRS and QRS are fixed documents.

The order of precedence of documents applicable to the supply of the equipment, with the highest authority listed first, shall be as follows:

- a) regulatory requirements;
- b) contract documentation (e.g. purchase order);
- c) purchaser-defined requirements (e.g. PDS, IRS and QRS);
- d) this specification;
- e) IEC 60034-1.

## 1 Scope

### Add new subclause

#### 1.1 Motors included in scope

The scope of this specification includes the following types of electric motors:

- with a form-wound stator coil AC squirrel cage induction type;
- with a rated power 100 kW or greater;
- with a rated voltage above 1 kV AC;
- with air or water cooling;
- with rolling element bearings, sleeve bearings or tilted pad thrust bearings;
- for single-speed use;
- suitable for hazardous and non-hazardous area environments;
- for converter duty and converter capable applications.

In this specification, the requirements for converter duty applications are also applicable to converter capable applications.

#### **Justification**

*This subclause indicates the change in scope in comparison with IEC 60034-1. It aligns with the scope of this specification as defined by the work group in the statement of intent. The value of 100 kW is taken from IEC 60034-1, Table 1.*

### Add new subclause

#### 1.2 Motors excluded from scope

The scope of this specification excludes the following types of electric motors:

- with a wire-wound stator coil type;
- submersible, subsea, canned or hermetically sealed motors;
- DC motors;
- synchronous motors.

#### **Justification**

*This subclause indicates the change in scope in comparison with IEC 60034-1. It aligns with the scope of this specification as defined by the work group in the statement of intent.*



Add new subclause**1.3 Extended use of this specification**

This specification may be used as a basis for the purchase of electric motors that are outside the immediate scope of this specification. The extended use of this specification based on similar construction and cooling methods may include the following types:

- induction generators;
- form-wound motors with a rated voltage below 1 kV;
- multi-speed motors;
- reverse-speed motors;
- motors with magnetic bearings.

Those parameters that are outside the scope of this specification are subject to agreement between the purchaser and the manufacturer.

**Justification**

*This subclause indicates the change in scope in comparison with the parent standard. It aligns with the scope of this specification as defined by the work group in the statement of intent.*

**2 Normative references**Add to first paragraph

The following publications are referred to in this document, the PDS (IOGP S-704D) or the IRS (IOGP S-704L) in such a way that some or all of their content constitutes requirements of this specification.

Add to section

ANSI/NEMA MG 1, *Motors and Generators*

API Standard 541:2014 (Reaffirmed 2021), *Form-wound Squirrel Cage Induction Motors—375 kW (500 Horsepower) and Larger*

API Standard 670, *Machinery Protection Systems*

IEC 60034-2-1:2014, *Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)*

IEC 60034-7, *Rotating electrical machines – Part 7: Classification of types of construction, mounting arrangements and terminal box position (IM Code)*

IEC 60034-8:2007+AMD1:2014 Edition 3.1 CSV, *Rotating electrical machines – Part 8: Terminal markings and direction of rotation*

IEC 60034-14, *Rotating electrical machines – Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher – Measurement, evaluation and limits of vibration severity*

IEC 60034-18-41:2014+AMD1:2019 Editions 1.1 CSV, *Rotating electrical machines - Part 18-41: Partial discharge free electrical insulation systems (Type I) used in rotating electrical machines fed from voltage converters - Qualification and quality control tests*

IEC 60034-18-42:2017+AMD1:2020 Edition 1.1 CSV, *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 TS 60034-25:2022, *Rotating electrical machines – Part 25: AC electrical machines used in power drive systems – Application guide*

IEC 60034-27-1, *Rotating electrical machines – Part 27-1: Off-line partial discharge measurements on the winding insulation*

IEC 60034-27-3, *Rotating electrical machines – Part 27-3: Dielectric dissipation factor measurement on stator winding insulation of rotating electrical machines*

IEC 60034-28:2012, *Rotating electrical machines – Part 28: Test methods for determining quantities of equivalent circuit diagrams for three-phase low-voltage cage induction motors*

IEC 60072-2, *Dimensions and output series for rotating electrical machines - Part 2: Frame numbers 355 to 1000 and flange numbers 1180 to 2360*

IEC 60079 (all parts), *Explosive atmospheres*

IEC 60092-101, *Electrical installations in ships – Part 101: Definitions and general requirements*

IEC 60423:2007, *Conduit systems for cable management – Outside diameters of conduits for electrical installations and threads for conduits and fittings*

IEC 60751, *Industrial platinum resistance thermometers and platinum temperature sensors*

IEC 61800-2:2021, *Adjustable speed electrical power drive systems – Part 2: General requirements – Rating specifications for adjustable speed AC power drive systems*

IEEE 112:2017, *IEEE Standard Test Procedure for Polyphase Induction Motors and Generators*

IEEE 522, *IEEE Guide for Testing Turn Insulation of Form-Wound Stator Coils for Alternating-Current Electric Machines*

ISO 281, *Rolling bearings — Dynamic load ratings and rating life*

ISO 1680, *Acoustics — Test code for the measurement of airborne noise emitted by rotating electrical machines*

ISO 5753-1:2009, *Rolling bearings — Internal clearance — Part 1: Radial internal clearance for radial bearings*

ISO 12944-1, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 1: General introduction*

ISO 12944-2, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 2: Classification of environments*

ISO 12944-6, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 6: Laboratory performance test methods*

ISO 21940-11, *Mechanical vibration — Rotor balancing — Part 11: Procedures and tolerances for rotors with rigid behaviour*

ISO 21940-11 AMD 1, *Mechanical vibration — Rotor balancing — Part 11: Procedures and tolerances for rotors with rigid behaviour AMENDMENT 1 — First Edition*

ISO 21940-12, *Mechanical vibration — Rotor balancing — Part 12: Procedures and tolerances for rotors with flexible behaviour*

ISO 21940-32, *Mechanical vibration — Rotor balancing — Part 32: Shaft and fitment key convention*

Delete from clause

IEC 60034-8:2007, *Rotating electrical machines – Part 8: Terminal markings and direction of rotation*

IEC 60034-8:2007/AMD1:2014, *Amendment 1 Rotating electrical machines – Part 8: Terminal markings and direction of rotation*

IEC 60034-18-41:2014, *Rotating electrical machines – Part 18-41: Partial discharge free electrical insulation systems (Type I) used in rotating electrical machines fed from voltage converters – Qualification and quality control tests*

IEC 60034-18-41:2014/AMD1:2019, *Amendment 1 Rotating electrical machines – Part 18-41: Partial discharge free electrical insulation systems (Type I) used in rotating electrical machines fed from voltage converters – Qualification and quality control tests*

IEC 60034-18-42:2017, *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 60034-18-42:2017/AMD1:2020, *Amendment 1 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 TS 60034-25:2014, *Rotating electrical machines – Part 25: AC electrical machines used in power drive systems – Application guide*

Replace Clause 3 title with

### **3 Terms, definitions and abbreviated terms**

Add new subclause 3.0 to start of clause

#### **3.0 Abbreviated terms**

Ex explosive atmosphere

GRP glass reinforced plastic

RTD resistance temperature device

Add new term 3.38

#### **3.38**

##### **critical speed**

shaft rotational speed at which a machine component (e.g. shaft, rotor) is in a state of resonance

Add new term 3.39

#### **3.39**

##### **maximum continuous operating speed**

highest rotational speed at which the motor, as-built and tested, is defined for continuous operation, expressed as revolutions per minute [min<sup>-1</sup>]

Add new term 3.40

**3.40**

**minimum continuous operating speed**

lowest rotational speed at which the motor, as-built and tested, is defined for continuous operation, expressed as revolutions per minute [min<sup>-1</sup>]

**4 Duty**

**4.2 Duty types**

**4.2.9 Duty type S9 – Duty with non-periodic load and speed variations**

Replace "IEC TS 60034-25:2014" with

IEC TS 60034-25:2022

**Justification**

*Edition 4.0 (2022) supersedes Edition 3.0 (2014).*

**4.2.10 Duty type S10 – Duty with discrete constant loads and speeds**

Replace "IEC TS 60034-25:2014" with

IEC TS 60034-25:2022

**Justification**

*Edition 4.0 (2022) supersedes Edition 3.0 (2014).*

**5 Rating**

**5.5 Rated output**

**5.5.2 AC generators**

Replace "volt-amperes (VA)" with

kilovolt-amperes (kVA)

**Justification**

*The high-voltage generator power rating is expressed in kVA, which is consistent with supplier catalogues, international standards and industry practices.*

**5.5.3 Motors**

Replace "watts (W)" with

kilowatts (kW)

**Justification**

*The high-voltage motor power rating is expressed in kW, which is consistent with supplier catalogues, international standards and industry practices.*

#### 5.5.4 Synchronous compensators

Replace "volt-amperes (VA)" with

kilovolt-amperes (kVA)

##### **Justification**

*The rating of the high-voltage machine used as synchronous compensator is expressed in kVA, which is consistent with supplier catalogues, international standards and industry practices.*

#### 5.6 Rated voltage

##### 5.6.2 AC generators

Replace "7.3" with

7.4

##### **Justification**

*This incorrect reference is a carryover from the previous edition where the reference was to subclause 7.3 which in the current edition is subclause 7.4. This is understood to be a typographical error.*

#### 5.8 Machines with more than one rating

In third paragraph, replace "7.3" with

7.4

##### **Justification**

*This incorrect reference is a carryover from the previous edition where the reference was to subclause 7.3 which in the current edition is subclause 7.4. This is understood to be a typographical error.*

Add new subclause

#### 5.9 Efficiency

For 2-pole and 4-pole motors, compliance with Table 23 shall be confirmed at the rated voltage and frequency in accordance with IEC 60034-2-1:2014, Table 2.

##### **Justification**

*Defining minimum efficiency requirements demonstrates JIP33's intent to reduce carbon emissions and capitalize on new technologies to ensure that environmental considerations have been addressed. IEC 60034-30-1 defines IE3 (international efficiency standard) as premium efficiency for low-voltage motors, however high-voltage does not have an equivalent definition for efficiency. New Table 23 has been developed from existing operator values. Testing requirements for single-speed machines are as per IEC 60034-2-1. For converter duty motors, testing is performed with sinusoidal sine wave as per single-speed motors to provide benchmark of efficiency. It is acknowledged that the converter supply has an adverse effect on efficiency, however this requirement ensures that testing can be standardized.*

NOTE 6-pole and 8-pole motor efficiency is declared by the manufacturer.

### Justification

Defining minimum efficiency requirements demonstrates JIP33's intent to reduce carbon emissions and capitalize on new technologies to ensure that environmental considerations have been addressed. IEC 60034-30-1 defines IE3 (international efficiency standard) as premium efficiency for low-voltage motors, however high voltage does not have an equivalent definition for efficiency. New Table 23 has been developed from existing operator values. Testing requirements for single-speed machines are as per IEC 60034-2-1. For converter duty motors, testing should be performed with sinusoidal sine wave as per single-speed motors to provide benchmark of efficiency. It is acknowledged that the converter supply has an adverse effect on efficiency, however this requirement ensures that testing can be standardized.

### Add new Table 23

**Table 23 – Minimum motor efficiency**

Power rating kW	2-pole motor efficiency value %	4-pole motor efficiency value %
185	94,2	94,6
200	94,5	94,7
220	94,7	95,1
250	95,1	95,2
280	95,3	95,4
300	95,4	95,5
315	95,5	95,5
335	95,6	95,6
355	95,7	95,7
375	95,8	95,8
400 - 500	96,0	96,0
530 - 570	96,2	96,2
800 - 950	96,4	96,4
≥1 000	96,5	96,5

### Justification

Table 23 supports the requirement in 5.9 which addresses minimum efficiency levels for high-voltage motors.

## 6 Site conditions

### Add new subclause

### 6.8 Degree of ingress protection

The minimum degree of ingress protection of the motor shall be as specified in Table 24 and in accordance with IEC 60034-5.

### Justification

The degree of ingress protection of motors is governed by the location of installation and the environmental conditions it is exposed to, such as “indoor”, “outdoor – onshore”, “outdoor – offshore (fixed/floating)”. IEC 60034-5 adequately covers the protections taken against respective environmental conditions.

Add new Table 24**Table 24 – Minimum degree of ingress protection based on the location of the installation**

Installation environment	Minimum degree of ingress protection	
	Motor	Terminal box
Indoor	IP55	IP55
Outdoor – coastal and onshore	IP55	IP55
Outdoor – offshore / open deck	IP56	IP56

**Justification**

*Table 24 lists the minimum degree of ingress protection used in the industry based on the location of installation of the motor. The individual parts on the motor such as the terminal box and bearing housing may have a higher degree of the ingress protection as required.*

**8 Thermal performance and tests****8.1 Thermal class**Replace first paragraph with

The motor insulation system shall be minimum thermal class 155 (F) without exceeding thermal class 130 (B) temperature rise for the motor rated output at the maximum ambient air temperature.

**Justification**

*Insulation system class F, class B temperature rise is an industry recognized cost-effective specification facilitating increased motor life by improved winding insulation quality. This specification is acknowledged by manufacturers as the most commonly requested for industrial motors. Therefore, it is compliant with the minimum specification philosophy of JIP33. The use of class F insulation with class B temperature rise gives products a 25 °C safety margin. This can be exploited to increase the loading of the machine for limited periods to operate at higher ambient temperatures or altitudes, or with greater voltage and frequency tolerances. It can also be exploited to extend insulation life. Manufacturers qualify insulation systems by means of functional tests as defined in IEC 60034-18-1:2022, 4.5.*

Add to subclause

For converter duty motors, the insulation system shall be minimum thermal class 155 (F) without exceeding thermal class 130 (B) temperature rise within the operating load envelope at the maximum ambient air temperature.

**Justification**

*This requirement defines the performance standard, for converter duty motors, which is commonly used throughout the industry, however IEC 60034-1 does not provide a performance requirement on temperature rise limits for converter duty motors. Manufacturers qualify insulation systems by means of functional tests as defined in IEC 60034-18-1:2022, 4.5.*

**NOTE** For motors with air-cooled and water-cooled heat exchangers, the “ambient” is the temperature of the internal air discharged from the heat exchanger and flows into the cooling air circuit.

**8.6 Determination of winding temperature****8.6.1 Choice of method**Delete third paragraph



### **Justification**

*This paragraph has been deleted to ensure that there is no conflict in requirements as this is now covered by an optional requirement in S-704D.*

## **9 Other performance and tests**

### **9.1 Routine tests**

#### Add to subclause

A "soft feet" check in accordance with API Standard 541:2014 6.3.1.16 shall be made prior to running tests.

#### **Justification**

*The "soft feet" check ensures that the motor mounting is of a defined pre-agreed standard and that the mounting arrangement does not have an adverse effect on the test results on motor vibration. This requirement aligns JIP33 with API Standard 541:2014:2014, 6.3.1.16.*

#### Add to subclause

For forced lubrication systems, factory tests shall be carried out using the specified lube oil viscosity with the oil temperature maintained within the range of operating values recommended by the manufacturer.

#### **Justification**

*This requirement ensures that testing parameters are as close to the operating conditions on site as possible. This excludes the possibility of using other parameters in the testing facility, either for convenience or to optimize testing results.*

#### Add to subclause

During vibration severity tests, the lube oil inlet temperature shall be adjusted to the maximum temperature permitted by the lubrication system design.

#### **Justification**

*This requirement ensures that vibration levels are tested at the maximum lube oil temperature and the recorded vibration values do not exceed maximum allowable levels. This requirement aligns in principle with API Standard 541:2014, 6.3.1.7.*

#### Add to subclause

When bearing modification or replacement is undertaken during testing, bearing related tests shall be repeated to reassess the bearing performance.

#### **Justification**

*Bearing modification or replacement can affect the performance of the motor, whether adversely or positively. This requirement ensures that relevant tests are repeated to reassess the bearing performance after bearing modification or replacement have taken place.*

#### Add new NOTE

**NOTE** Cosmetic repairs such as removal of scratches that do not otherwise affect motor performance are not a reason for retesting.



Replace Table 16 title with

**Table 16 – Tests for motors assembled and tested at the manufacturer's factory**

Replace Table 16 with

Test No.	Test description	Reference standard	Remarks
<b>Routine tests</b>			
1	Visual inspection	Approved drawing and documents	
2 <sup>f</sup>	Measurement of ohmic resistance of stator windings referred to 25 °C	IEC 60034-2-1:2014, 5.7.1	
3	Measurement of insulation resistance of stator windings	IEC 60034-27-4	Test also carried out post withstand voltage test
4 <sup>f</sup>	Check of phase sequence/direction of rotation and terminal markings	IEC 60034-8:2014, 6.7	
5 <sup>f</sup>	No-load losses and current test at rated frequency <sup>a</sup>	IEC 60034-2-1:2014, 6.1.3.2.4	
5A	No-load losses and current test at minimum continuous operating speed	IEC 60034-2-3	Test for converter duty motor
5B	No-load losses and current test at maximum continuous operating speed	IEC 60034-2-3	Test for converter duty motor
6	Verification of magnetic centre and end play (where sleeve bearings are provided)	API Standard 541:2014, 4.4.9.3	
7 <sup>f</sup>	Withstand voltage test	IEC 60034-1:2022, 9.2	
8	Measurement of insulation resistance of insulated bearings	IEEE 112:2017, 8.4	
9	Functional tests of auxiliary devices and controls	Manufacturer's standard	
10	Withstand voltage tests on resistance temperature device (RTDs), space heaters and insulated bearings where applicable	IEC 60034-1:2022, 9.2	
11	Insulation resistance tests on RTDs and space heaters where applicable	IEC 60204-1:2016, 18.3	
12	Vibration test at no load	IEC 60034-14:2018, Clause 8 and Clause 9	
<b>Performance tests<sup>g</sup></b>			
1	No-load characteristic (saturation curve) at rated frequency <sup>b</sup>	IEC 60034-2-1:2014, 6.1.3.2.4	Not applicable for motors with rated power less than 400 kW
2	Locked rotor current test	IEC 60034-28:2012, 6.6.3	Test for single-speed motor
3	Locked rotor torque test	IEEE 112, 7.2.2	Not applicable for motors with rated power less than 400 kW Test for single-speed motor
4	Temperature rise test	IEC 60034-1:2022, Clause 8 or IEC 60034-29 <sup>c</sup>	
5	Sleeve bearing inspection	API Standard 541:2014, 6.3.2	
6	Determination of efficiency at 100 %, 75 % and 50% load at rated power factor	IEC 60034-2-1:2014, Clause 6	Test for single-speed motor
6A	Determination of efficiency at 100 %, 75 % and 50% load at rated power factor	IEC 60034-2-3:2020, Clause 6	Not applicable for motors with rated power less than 400 kW Test for converter duty motor

**Table 16** (continued)

Test No.	Test description	Reference standard	Remarks
<b>Special tests<sup>h</sup></b>			
1	Rated rotor temperature vibration test (heat run test)	API Standard 541:2014, 6.3.5.2	Alternately testing (procedure, purpose, etc.) to be agreed between purchaser and manufacturer
2	Overspeed test	IEC 60034-1:2022, 9.7	Not applicable for motors with rated power less than 400 kW
3	Measurement of electrical and mechanical run out	IEC 60034-14:2018, Clause 9	
4	Measurements of shaft voltage at no-load	IEEE 112:2017, 8.3	
5	Bearing temperature rise at no-load	API Standard 541:2014, 6.3.2	
6	Noise level at no load	ISO 1680	
7	Measurement of moment of inertia	Manufacturer's standard	
8	Measurement of torque and current as function of speed during starting	IEEE 112:2017, 7.3.2	
9	Dielectric dissipation test ( $\tan \delta$ ) on stator windings	IEC 60034-27-3	In process test
10	Partial discharge test on complete stator	IEC 60034-27-1	In process test
11	Sealed winding conformance test	ANSI/NEMA MG 1	In process test
12	Unbalanced response test	API Standard 541:2014, 6.3.5.3	
13	Bearing housing natural frequency test	API Standard 541:2014, 6.3.5.4	
14	Stator core test	API Standard 541:2014, 6.3.4.1	In process test
15	Surge comparison test (complete stator assembly)	IEEE 522	In process test
16	Sample coil test	API Standard 541:2014, 6.3.4.2, IEC 60034-15, IEC 60034-27-1, IEC 60034-27-3	
17	Heat exchanger performance verification test	API Standard 541:2014, 6.3.5.5	
18	Hydrostatic pressure test of heat exchanger tubing devices <sup>d</sup>	Design code <sup>e</sup>	

<sup>a</sup> No stabilization of temperature required for measurement of no-load losses.

<sup>b</sup> The no-load characteristic shall be measured up to a minimum of 125 % of the rated voltage.

<sup>c</sup> IEC 60034-29 shall be used as the reference standard where testing to IEC 60034-1 is restricted due to the physical size of the machine.

<sup>d</sup> Water to air heat exchanger testing is performed at the heat exchanger manufacturer's premises.

<sup>e</sup> Heat exchanger design code to be confirmed by the supplier.

<sup>f</sup> Heat exchanger design code to be confirmed by the supplier.

<sup>g</sup> Where one or more than one identical motor is purchased, the listed performance tests are carried out on at least one motor. However, the need for the performance tests and the number of motors to be tested may be agreed between the purchaser and manufacturer.

<sup>h</sup> Specify the special tests required to be performed in IOGP S-704D.

### Justification

*The original Table 16 in IEC 60034-1 has minimal test requirements which cover all motors whereas the revised content of Table 16 has tests exclusively for high-voltage motors, including additional routine tests, as well as special tests specified by the purchaser.*

*For high-voltage motors in the oil and gas industry, special/additional tests are performed to verify that the required performance criteria is met prior to the machine leaving the manufacturer's premises due to the following reasons.*

- *High-voltage motors are typically regarded as high value items.*
- *High-voltage motors are used in systems where, if they do not perform as required, it could have a severe financial consequence to the end user.*
- *In most cases, high-voltage motors are engineered equipment to some extent and therefore, all test criteria are verified before acceptance by the purchaser.*
- *Logistically, any remedial work required once the high-voltage motors is on site can be complex.*
- *These routine tests provide a performance benchmark which can be compared to test results post installation at site and throughout the design life of the high-voltage motor.*

## 9.2 Withstand voltage test

*In eighth paragraph, replace "7.3" with*

7.4

### Justification

*This incorrect reference is a carryover from the previous edition where the reference was to subclause 7.3 which in the current edition is subclause 7.4. This is understood to be a typographical error.*

## 10 Information requirements

### 10.3 Rating plate

*Replace first sentence of first paragraph with*

Rating and marking plates shall be 316L stainless steel.

### Justification

*Stainless steel rating plates are a readily available standard offering and proven solution to issues experienced using other methods. For example, industry experience shows that illegibility due to other types of marking plates cause problems such as delayed troubleshooting.*

*Replace second sentence of first paragraph with*

The information included on rating and marking plates shall be stamped or engraved.

### Justification

*This is a common user requirement to prevent machine information from getting lost over time due to wear and tear. This is a tried, tested and proven industry practice which ensures that the information remains attached to the equipment during the operational life. Although this information is also made available in other associated documents of the equipment, the relevant information is available with the equipment. This requirement is included in most operator specifications but not stated in IEC 60034-1.*

In first sentence of second paragraph, replace "The rating plate(s) shall preferably be mounted on the frame of the machine" with

The rating and marking plates shall be attached to a non-removable part of the motor frame with stainless steel 316L fasteners

#### **Justification**

As per 10.3, first sentence of first paragraph, this requirement ensures that the fasteners are of the same durability as the rating plate. By ensuring that the rating and marking plates are attached to a non-removable part, there is no chance of the part being mistakenly reattached to a different unit or misplaced during maintenance or breakdown activities.

### **10.4 Information content**

#### **10.4.1 General**

In first sentence of first paragraph, replace "10.4.5" with

10.4.6

#### **Justification**

Subclause 10.4.6, named "Optional information" in IEC 60034-1, has been renamed "Additional information" in this specification and the list of items included in this subclause have now been added to the list of information to be provided as applicable (i.e. to the list of items subject to the requirement in 10.4.1). It is necessary to include information related to the cooling method, converter capability, torque capability, impulse voltage insulation class (IVIC) level and rated power factor on the rating plate specifically as these are more critical machines. Bearing and bearing lubrication information is required for bearing replacement on-site. This is beneficial on the nameplate when maintenance is being performed on site as there is no need to look for the documentation. The mixing of lubricants could damage a bearing.

In first sentence of second paragraph, replace "jj)" with

kk)

#### **Justification**

This requirement results from the addition of new list item kk) in 10.4.6.

#### **10.4.2 Minimum information requirements**

Replace list item j) with

j) Efficiency at full load.

#### **Justification**

The nameplate has to mention the efficiency value achieved at full load during the factory acceptance test. The original text in this subclause 10.4.2, item j) specifies efficiency class (IE codes) for motors within the scope of IEC 60034-30-1 and IEC 60034-30-2. However, for high-voltage motors, Table 23 specifies the minimum efficiency values. Subclause 10.4.2, item j) is replaced to specify the efficiency value achieved at full load during the factory acceptance test as part of the minimum information requirements on the nameplate for the machines.

Replace list item k) with

k) The total mass of the motor.

### Justification

*This replacement provides the total mass of the motor for lifting operations and the assessment of the equipment/effort for lifting.*

Replace subclause 10.4.6 title with

#### 10.4.6 Additional information

Replace item gg) with

- gg) On a separate rating plate, the types of the bearings, bearing sizes, clearance, bearing insulation, shaft and housing fit for drive end and non-drive end bearings, type of lubricant, lubrication interval, minimum and maximum allowable quantity of lubricant and oil pressure/flow rate for forced lubricated bearings.

### Justification

*This information on bearings is beneficial for maintenance staff during predictive/preventive maintenance activities and provides a means for instant and reliable verification while at site without the need for equipment documentation.*

Add new list item kk)

- kk) For motors used in a hazardous area, the equipment marking on a separate nameplate applied to Ex Equipment and/or Ex Components in accordance with IEC 60079.

### Justification

*By marking the equipment in accordance with IEC 60079, the manufacturer confirms that the equipment/components are manufactured, successfully tested and certified for use in accordance with the applicable requirements of the relevant standards.*

## 11 Miscellaneous requirements

### 11.1 Protective earthing of machines

Replace fourth paragraph with

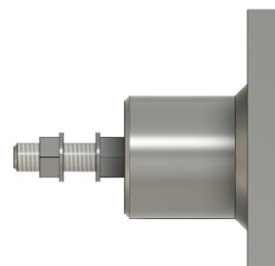
The machine shall have two diagonally opposite earthing bosses with M12 internal threads, fitted externally on the machine frame.

### Justification

*This requirement drives industry standardization on earthing externally. These earthing bosses are rounded metal parts with internal threads (typically M12) welded on the machine surface for external earth connections as per Justification Figure a and Justification Figure b.*



Justification Figure a



Justification Figure b


Add to subclause

The motor shall have a means for connecting a conducting cable sheath inside each terminal box.

**Justification**

*This requirement drives industry standardization on earthing externally and internally. It also provides full optionality for instances where the machine is used in a different application.*

Add to subclause

The earthing boss shall be permanently marked with the symbol  (IEC 60417-5019) to indicate protective earth.

**Justification**

*This requirement is in line with the identification of components on the equipment in accordance with IEC 60417. The marking highlights the purpose of the component and prompts to leave clear access for termination/connection at site.*

Add to subclause

The motor shall have bonding straps across joints within or between the motor frame components.

**Justification**

*Bonding straps ensure that earth continuity is provided across the complete motor assembly. This is especially critical across joints where gaskets are installed. Bonding straps prevent stray current sparking in the enclosure during start up.*

Add new subclause**11.3 Performance criteria****11.3.1 Single-speed motor starting, re-starting and re-acceleration****11.3.1.1**

For motors without specific starting requirements, the locked rotor current shall be between 4,5 and 6,5 times the rated current.

**Justification**

*Maximum starting currents are defined to ensure that electrical power systems are not adversely affected. This requirement ensures consistency in electrical supply design. It is acknowledged that the values may be higher for high-efficiency machines and this has been considered when developing the requirement. Establishing the locked rotor current of the motor enables the motor cable sizing and ensures that the upstream/downstream bus-bars do not experience excessive under voltage during motor starting. 4,5 to 6,5 times the rated current has been defined as this value can be generally complied with by manufacturers as their standard offering, and this value also corresponds to API Standard 541:2014, 4.2.4.4.*

**11.3.1.2**

The motor shall be designed for direct-on-line starting across full line voltage in accordance with Table 25.

### Justification

*When a motor is subjected to frequent starting, it cannot be loaded at its rated output because of thermal starting losses in the windings. Table 25 establishes the minimum requirements to ensure consistency for these parameters across the industry. These parameters are the current industry standard and compliance to these are already the norm.*

### Add new Table 25

**Table 25 – Number of re-starts of motors**

Starting condition	Status	Minimum number of consecutive starts <sup>a</sup> per hour
With the initial temperature at or below maximum ambient temperature	Cold	3
With the initial temperature above maximum ambient temperature but not exceeding the maximum rated operating temperature	Hot	2
<sup>a</sup> Coasting to rest between consecutive starts.		

### Justification

*When a motor is subjected to frequent starting, it cannot be loaded at its rated output because of thermal starting losses in the windings. Minimum requirements should be specified to ensure consistency for these parameters across industry. These parameters are well established and compliance to these are already the norm. Given this, no significant cost adders are anticipated. The values in the table are the current industry standard.*

#### 11.3.1.3

Motors shall be designed and constructed for a minimum of 5 000 full-voltage starts.

### Justification

*Though 1 000 starts per year is the industry standard and provides assurance on the design life of the motor, such a requirement does not qualify to be an essential minimum requirement. Such large motors are not started/stopped so frequently and do not need these severe design requirements. Instead, a more practical approach in line with API Standard 541:2021, 4.2.4.1 is considered as a better essential minimum requirement for motor design.*

#### 11.3.1.4

The motor shall start direct-on-line and accelerate with the rated load at 80 % of the rated voltage applied at the motor terminals.

### Justification

*The 80 % value allows for upstream system deviations and voltage drop in conductors from the point of supply to the motor location typically incurred in the oil and gas industry. The 80 % value is particularly prevalent in island networks and also aligns with API Standard 541:2014), 4.2.3.1.*

#### 11.3.1.5

The locked rotor withstand time under hot condition shall be greater than 5 s.



### **Justification**

*This requirement ensures that there is a sufficient amount of time between the acceleration time of the specified load and the locked withstand time under hot condition. This margin adequately ensures that the motor protection devices operate and isolate the motor prior to damage occurring due to over-heating of motor windings.*

#### **11.3.1.6**

Inclusive of the negative tolerance, the accelerating torque of the motor at the rated frequency with 80 % of the rated voltage applied at the motor terminals shall be at least 10 % of the full load torque at any point.

### **Justification**

*The purpose of this requirement is to provide assurance that there is a defined margin between the load requirements and the capability of the motor to ensure that the torque at the driven load is sufficient.*

#### **11.3.1.7**

When re-acceleration is required following a power interruption to the motor not exceeding 0,2 s, the motor shall re-accelerate with full residual voltage in total phase opposition to the supply voltage.

### **Justification**

*A power interruption to the motor will initiate a decay of the motor flux as per the time constant. The frequency of the residual voltage is proportional to the speed of the motor. Since the duration of 0,2 s is brief, the flux decay is minimal and the residual voltage will also be full. A power supply restoration with a phase difference of 180 degree (total phase opposition) is always a probability which results in a severe mechanical stress (electrodynamic shock) to the winding and damage to the shaft, mounting base and foundation. When re-acceleration is required by the purchaser, this requirement ensures that the manufacturer is aware that the motor is subjected to this situation during operation. Accordingly, the manufacturer ensures that the motor frame, shaft and active iron core systems withstand the mechanical stresses developed on power restoration without damage.*

#### **11.3.1.8**

Running-up times shall be calculated using inertia values and torque-speed characteristics of the driven equipment.

### **Justification**

*Running-up time can typically be calculated using either approximation methods or actual values for load inertia and driven equipment torque-speed characteristics. For high-voltage motors which are typically high value equipment installed in critical systems, the actual values are to be used to ensure accuracy.*

### **11.3.2 Transient air-gap torques**

The rotor shaft and active iron core systems shall withstand a two-phase short-circuit current at the motor terminals for 0,1 s.

### **Justification**

*This requirement addresses the capability of the rotor shaft and active iron systems to withstand a two-phase short-circuit current which is considered to be the most adverse fault type. This is a fundamental requirement that is not addressed by IEC 60034-1.*



### 11.3.3 Pulsating torques

The inertia of the motor driving equipment requiring variable torque during every revolution shall restrict the stator current variation to 40 % of the motor rated current.

#### *Justification*

*This requirement ensures that there is sufficient inertia present in the rotor and the shaft to maintain rotation where there is variable torque such that the stator current does not exceed a 40 % of full load current. It ensures that unnecessary overheating of the motor does not occur. This ultimately reduces the design life of the motor and can cause reliability issues where this overheating causes harm to the winding insulation. This requirement aligns with API Standard 618.*

### 11.3.4 Critical speed

#### 11.3.4.1

For single-speed motors, the lateral natural frequencies that result in resonance amplification of vibration amplitudes shall fall outside the band of operating speed  $\pm$  minimum 15 %.

#### *Justification*

*Rotating shafts deflect during rotation. The mass of the rotating object causes deflection which creates resonant vibration at certain speeds known as the critical speeds. If the speed, as a result of the forced surge frequency, is the same as the lateral natural frequency of the system, resonance can occur. The magnitude of deflection depends upon the following:*

- stiffness of the shaft and its support;*
- total mass of shaft and attached parts;*
- balance of the mass with respect to the axis of rotation;*
- amount of damping in the system;*
- foundation design of motor mounting area.*

*In view of these influencing parameters, this requirement ensures that the lateral natural frequencies fall outside the safe band enveloping the operational speed and that the measurable margin is defined as 15 %, which is adequately distant to not cause resonance.*

#### 11.3.4.2

For converter duty motors, the lateral natural frequencies that result in resonance amplification of vibration amplitudes shall fall outside the band of operating speed range  $\pm$  minimum 15 %.

#### *Justification*

*Converter duty motors stabilizing at many speeds throughout the operating envelope are more likely to encounter critical speeds than a single-speed motor. To prevent resonance and thereby vibrations, this requirement ensures that the lateral natural frequencies or the critical speeds fall outside the entire operational speed range and the safe margin practically is 15 % as per industry practice.*

### 11.3.5 Noise

#### 11.3.5.1

The sound pressure level of the machine operating at rated speed and no load when fed with sinusoidal supply voltage, measured in any direction at a distance of 1 m, shall be less than 85 dB(A).

### **Justification**

Noise regulations are part of health and safety at the workplace in industry and are legally binding, especially by countries as part of the national law. Limiting the noise level to which operating personnel is exposed reduces the harmful effects of noise on hearing. The permissible maximum noise level value along with the use of hearing protection corresponding to a daily or weekly average noise exposure is typically restricted to 85 dB(A). Considering the rating and size of the machines, if an upper limit is not specified, the noise from the equipment can cause detrimental effect to operating personnel. ISO 1680, Clause 4 indicates that rotating electrical machines can be fed by network supply (sinusoidal) or a converter. Though the scope of this specification also covers converter duty motors, the testing conducted with "sinusoidal supply" is the normal practice.

#### **11.3.5.2**

Motors shall meet the noise limits by design without implementing corrective measures.

### **Justification**

Noise abatement measures can camouflage machine deficiencies and seem to have fulfilled the stated noise limit requirement. The exclusion is explicitly stated as these noise abatement measures can have an undesirable effect on the performance of the motor and impede access during maintenance activities.

#### **11.3.5.3**

Noise measurements shall be in accordance with ISO 1680.

### **Justification**

ISO 1680 is the recognized reference for noise measurement by most manufacturers and for noise requirements in the oil and gas industry. This requirement ensures consistency going forward, especially with new manufacturers.

#### Add new subclause

## **11.4 Design criteria**

### **11.4.1 General**

#### **11.4.1.1**

The motor shall be designed and constructed for a minimum service life of 25 years excluding parts subjected to wear and tear.

### **Justification**

The motor is expected to provide a minimum useful service life of 25 years in the specified environmental conditions. However, the expectation of minimum useful service life considers that the manufacturer's recommended maintenance activities are performed as per the maintenance plan. High value assets such as the motor include an expected service life as part of the asset integrity plan.

#### **11.4.1.2**

The motor shall be designed for continuous operation of at least six years, excluding oil change of self-lubricated sleeve bearings.

### **Justification**

*Operating companies may have a turnaround period ranging from four to six years and motors are expected to operate without interruption for this duration. A major scheduled maintenance is an activity that is performed during the turnaround time that further extends the period of operation and provides an expected service life of 25 years. However, oil change of self-lubricated sleeve bearings is an activity that needs to be performed as per the supplier's recommendations to ensure the expected service life of the bearings.*

#### **11.4.1.3**

The motor shall be constructed with components, materials and design features with proven service in the industry for at least two years.

### **Justification**

*This requirement ensures that if the product proposed by the manufacturer is not of a proven design, the purchaser is made aware of this such that they can evaluate the need for any additional steps, measures or activities to be undertaken. Typically, this is not an issue, but without this requirement, there is nowhere else in this specification that causes the manufacturer to make the purchaser aware of this.*

## **11.4.2 Enclosure design**

### **11.4.2.1 General**

#### **11.4.2.1.1**

The motor enclosure shall have a low point drain hole with removable plug.

### **Justification**

*Typically, drain holes are provided in the enclosure of motors for egress of moisture/condensation from within the housing. These drain holes have removable plugs and following the manufacturer's guidelines, they ensure that the degree of ingress protection is maintained.*

#### **11.4.2.1.2**

Drain plugs shall be accessible with the motor installed in service position.

### **Justification**

*This requirement facilitates maintenance activities associated with draining the motor without dismantling any of the parts or components. In some cases, this can require the removal of the coupling guard for ease of access.*

### **11.4.2.2 Mounting**

#### **11.4.2.2.1**

The motor mounting arrangement shall be in accordance with IEC 60034-7.

### **Justification**

*The reference to IEC 60034-7 is for most commonly used mounting methods across suppliers and in industry-wide applications. This requirement standardizes the definition of mounting and provision for installation on the baseplate for driven equipment. It also ensures that motors can be replaced and upgraded. The choice of mounting is as per application / driven equipment specifications and manufacturers' design needs.*

#### 11.4.2.2.2

Frame supports shall be provided with two vertical pilot holes for the installation of alignment dowels.

##### *Justification*

*This requirement provides an efficient method for future motor alignment following initial alignment. Once the initial alignment has been successfully completed, the dowels can be installed to facilitate a fast method of locating the motor. This is as per API Standard 541:2014, 4.4.2.11.*

#### 11.4.2.2.3

Vertically mounted motors with a downward facing drive end shaft shall be provided with a canopy shielding the upward facing air inlets.

##### *Justification*

*This requirement ensures that the possibility of water/fluid ingress from around the motor shaft area is fully addressed when motors are vertically mounted and air inlets are upward facing. The canopy (rain cap) fitted over the fan cowl / air inlets of motors mounted with the shaft vertically down prevents rain water or any sprayed water/fluid from reaching near the motor shaft area, thereby preventing the water/fluid from following the minor clearance around the motor shaft into the motor. A seepage of water/fluid causes failure of the part (bearing, winding, etc.) that gets exposed to water/fluid.*

#### 11.4.2.2.4

Vertically mounted motors with an upward facing drive end shaft shall be provided with a seal in addition to the bearing seal and/or shaft mounted water flinger to prevent water/fluid ingress through the drive end bearing.

##### *Justification*

*This requirement ensures that the possibility of water/fluid ingress from around the motor shaft area is fully addressed when motors are vertically mounted and the shaft is facing upwards. The seal / water flinger (water deflector) fitted over the drive end shaft of motors mounted with the shaft vertically up prevents rain water or any sprayed water/fluid from reaching near the motor shaft area, thereby preventing the water/fluid from following the minor clearance around the motor shaft into the motor. A seepage of water/fluid causes failure of the part (bearing, winding, etc.) that gets exposed to water/fluid. This requirement addresses operating company experiences where water has accumulated on the face of the upward facing bearing and has over time prematurely deteriorated the bearing seal, causing failure and subsequent interruption of service.*

#### 11.4.2.3 Frame

##### 11.4.2.3.1

Frame numbers and fixing dimensions shall be in accordance with IEC 60072-2.

##### *Justification*

*This requirement reduces variants and ensures that any motor outside of the scope of IEC 60072-2 is assessed by the purchaser to ensure that it is acceptable prior to order placement. Any design outside of the scope of IEC 60072-2 is likely to be unproven and/or can have characteristics or features for which the purchaser requires more information before order placement.*

##### 11.4.2.3.2

The motor frame and add-on assemblies inclusive of terminal box covers heavier than 25 kg shall be provided with lifting lugs or lifting eyebolts.

### Justification

*This requirement facilitates the safe lifting for installation, removal and refitting of the equipment and heavier frame mounted add-on assemblies including terminal boxes and terminal box covers. Without this requirement, non-compliance with HSE norms followed in the industry can happen.*

#### 11.4.2.3.3

Foot-mounted motors shall be provided with vertical jacking provisions and, when a soleplate is included in scope of supply, with horizontal jacking provisions.

### Justification

*This requirement enables a safe and standard means of alignment of the motor with the coupled equipment during installation.*

#### 11.4.2.3.4

Where a corrosivity category of C4 or greater is specified, the selection of hardware used on the frame shall be in accordance with Table 26.

### Justification

*ISO has defined six corrosivity categories (i.e. C1 - very low, C2 - low, C3 - medium, C4 - high, C5 - very high, CX - extreme) based on a one-year corrosion mass loss or penetration of steel, zinc, copper and aluminium coupons. Environmental conditions contribute directly to the occurrence of corrosion and are therefore accounted for in this specification. The effects of corrosion and the rate at which they occur are consequences of the choice of material, exposure to environment (both severity and duration) and operational conditions. Where a category greater than C3 is specified, the selection of hardware is done in accordance with these environment conditions to meet the life cycle requirements. This requirement ensures that the equipment can withstand the environmental conditions and meet the life cycle requirements. Table 26 compiles a preferred selection of material from most manufacturers for corrosivity category of C4 or greater.*

**Table 26 – Selection criteria for hardware used on frame**

Hardware type	Hardware material
External screws, bolts, nuts and washers of a thread diameter less than or equal to 10 mm	316L stainless steel
External screws, bolts, nuts and washers with a thread diameter greater than 10 mm	Hot-dip galvanized
Cooling air inlet protection mesh	316L stainless steel
Grease nipples	316L stainless steel

### Justification

*ISO has defined six corrosivity categories (i.e. C1 - very low, C2 - low, C3 - medium, C4 - high, C5 - very high, CX - extreme) based on one-year corrosion mass loss or penetration of steel, zinc, copper and aluminium coupons. Environmental conditions contribute directly to the occurrence of corrosion. The effects of corrosion and the rate at which they occur are consequences of the choice of material, exposure to environment (both severity and duration), and operational conditions.*

*This table considers environmental factors in the selection of hardware in order to meet the life cycle requirements. It also compiles a preferred option of material from most manufacturers for corrosivity category of C4 or greater.*

#### 11.4.2.3.5

Motors with a frame size 630 and above shall have removable inspection covers for the following:

- where applicable, inspection of coil end turns;
- inspection of air gap in at least three positions located 90° apart.

#### **Justification**

*This requirement substantially reduces the time taken to perform the routine inspection by providing designated borescope inspection facilities for the inspection of the air gap and coil end turns as applicable. It also ensures that inspection can be performed throughout the lifetime of the motor, which facilitates the early detection of abnormalities and corresponding proactive corrective actions to reduce downtime. This requirement also provides alignment with API Standard 541:2014, 4.1.10.*

NOTE The provision of inspection covers is not possible in all situations and deviations, if any, are brought to the attention of the purchaser.

#### 11.4.2.4 Surface finish

##### 11.4.2.4.1

For onshore applications, the protective paint system corrosivity category shall be at least C3 in accordance with ISO 12944-2.

#### **Justification**

*This requirement specifies the surface finish in relation to the environmental conditions in which the motor is located and drives standardization among operating companies. Therefore, it allows the purchaser to specify environmental conditions from the listed categories in accordance with ISO 12944-2 in the PDS for the selection of the appropriate protective paint system. ISO 12944-2 defines corrosivity categories and these definitions align with a number of manufacturer's options. C3 as the default choice for onshore applications in the PDS sets the essential minimum requirement for the equipment across suppliers.*

##### 11.4.2.4.2

For offshore exterior applications, the protective paint system corrosivity category shall be CX in accordance with ISO 12944-2.

#### **Justification**

*This requirement specifies the surface finish in relation to the environmental conditions in which the motor is located and drives standardization among operating companies. Therefore, it allows the purchaser to specify environmental conditions from the listed categories in accordance with ISO 12944-2 in the PDS for the selection of the appropriate protective paint system. ISO 12944-2 defines corrosivity categories and these definitions align with a number of manufacturer's options. C3 as the default choice for onshore applications and CX as default choice for offshore exterior applications in the PDS sets the essential minimum requirement for the equipment across suppliers. A higher option is selectable dependent on environmental conditions. CX for offshore is aligned with IOGP S-715.*

##### 11.4.2.4.3

The protective paint system durability category shall be at least "medium" in accordance with ISO 12944-1 for all locations.



### Justification

*This requirement specifies the surface finish in relation to the environmental conditions in which the motor is located and drives standardization among operating companies. Therefore, it allows the purchaser to specify environmental conditions from the listed categories in accordance with ISO 12944-2 in the PDS for the selection of the appropriate protective paint system. For durability, “medium” is the default option as this is considered the lowest reasonable selection for the oil and gas industry (both onshore and offshore) and aligns with the default offering from most manufacturers. More onerous options are available in the PDS, if required.*

## 11.4.3 Cooling

### 11.4.3.1 General

#### 11.4.3.1.1

Motor cooling shall be selected from the cooling methods listed in Table 27, in accordance with IEC 60034-6 and the specified degree of ingress protection.

### Justification

*Limiting the method of cooling to Table 27 ensures consistency, provides alignment with IEC 60034 (all parts) and drives standardization among motor manufacturers.*

**Table 27 – Motor cooling method**

Cooling method	Code
Frame surface cooled motors using surrounding medium with self-circulation of secondary coolant	IC4A1A1
Motors with an integral heat exchanger using surrounding medium with self-circulation of secondary coolant	IC5A1A1
Motors with a machine mounted heat exchanger using surrounding medium with self-circulation of secondary coolant	IC6A1A1
Motors with a machine mounted heat exchanger using remote medium with self-circulation of primary coolant	IC7A1W7
Motors with a machine mounted heat exchanger using surrounding medium with self-circulation of primary coolant	IC8A1W7

### Justification

*Limiting the method of cooling to Table 27 ensures consistency, provides alignment with IEC 60034 series and drives standardization among motor manufacturers.*

#### 11.4.3.1.2

The operating frequency, or frequencies for converter duty motors, and operating frequency multiples of the motor shall not trigger the natural frequency of vibration of any cooling system components.

### Justification

*The cooling components could be add-on components (e.g. heat exchanger, externally mounted fans). This requirement ensures that the natural frequency of any add-on components is not triggered by the operating frequency or its multiples, resulting in unwarranted vibration and damages (e.g. cracks and/or breakages to the motor).*

#### 11.4.3.2 Air cooled heat exchangers

##### 11.4.3.2.1

Cooling air tubes shall be accessible for cleaning without removal of the exchanger assembly.

##### *Justification*

*Regular cleaning of cooling tubes is important to maintain the heat removing capability. Restriction to access or any cumbersome means to access the exchanger tube ends prevents regular cleaning, thereby posing inadequate cooling and possibility of failure.*

##### 11.4.3.2.2

A three-wire Pt-100 temperature sensor shall be provided to monitor the heat exchanger outlet air temperature.

##### *Justification*

*This requirement provides a temperature monitoring facility which alerts the user when the performance of the heat exchanger is outside its normal operating values. By identifying deficiencies in a timely manner, prolonged equipment outages can be avoided and machine damage can be prevented or minimized.*

##### 11.4.3.2.3

Air-cooled heat exchangers shall be in accordance with API Standard 541:2014, 4.4.10.8.

##### *Justification*

*API Standard 541:2014, 4.4.10.8 adequately covers the selection of tube material for the exchanger design.*

#### 11.4.3.3 Water-cooled heat exchangers

##### 11.4.3.3.1

Water-cooled heat exchangers shall be provided with low point drains and air release vents.

##### *Justification*

*This requirement ensures that maintenance can be performed with minimal disruption/outage time and coolant sampling can be done, if required. The low point drains also ensure that the entire cooling medium is drained out of the system, which helps to flush the system. This air release facility is imperative for releasing the trapped air from the cooling system when topping up with the cooling medium.*

##### 11.4.3.3.2

Water-cooled heat exchangers shall have provision for leakage or condensation collection and drainage of coolant.

##### *Justification*

*While it is acknowledged that water leakage should not occur, it is accepted that from time to time that water leakage can be possible. This requirement addresses the need for a secondary defence to prevent the water from coming into contact with vulnerable motor components, and for the water to be contained within a designated area. This facilitates the identification of any leakages and provides a facility for removing the leaked coolant in a controlled manner. This requirement helps prevent aggravated failure and ultimately prolonged equipment outages.*



#### 11.4.3.3.3

Water-cooled heat exchangers shall be provided with 20 % spare tubes.

##### *Justification*

*This requirement provides additional capacity to allow for failure of tubes over the design lifetime of the machine. Replacing damaged tubes can in some cases be a complex process which requires a complete outage of the heat exchanger and therefore of the machine. By providing spare capacity (tubes) to allow for plugging of damaged tubes, the machine can continue to operate with minimal disruption for extended periods of time with the same cooling capability. This requirement uses 20 % spare tubes instead of 10 % since the repair/replacement of tubes is cumbersome, costlier and impractical (at times) when compared to providing an additional 10 % spare tubes by default. The probability of the need for undertaking a repair/replacement of tubes of the exchanger becomes remote when 20 % spare tubes are provided since the failed tubes can be plugged and forgotten as there are adequate spares. This spare quantity would generally last for the life cycle of the exchanger. Providing 20 % spare tubes does not impact the exchanger size and is a preferred alternative for reducing exchanger repair/maintenance over the life cycle.*

#### 11.4.3.3.4

Water-cooled heat exchanger tube bundles shall have provision for plugging and isolating the leaking tubes.

##### *Justification*

*This requirement ensures faster resolution of leakage problems since replacing damaged tubes can in some cases be a complex process which requires a complete outage of the heat exchanger and therefore of the machine. By plugging and isolating the damaged tubes, the machine can continue to operate with minimal disruption for extended periods of time.*

#### 11.4.3.3.5

Water-cooled heat exchangers shall be in accordance with API Standard 541:2014, 4.4.10.8.

##### *Justification*

*API Standard 541:2014, 4.4.10.8 adequately covers the selection of tube material for the exchanger design.*

#### 11.4.3.3.6

When the required parameters on the water side are not available from the purchaser, cooling water system design criteria shall be in accordance with API Standard 541:2014, 4.4.1.2.4.

##### *Justification*

*There could be a situation when the required parameters for the exchanger design are not available and the fall back is parameters from of API Standard 541:2014, 4.4.1.2.4. This requirement sets common default criteria instead of an arbitrary chosen value for manufacturers in the absence of a required value.*

### 11.4.4 Stator windings

#### 11.4.4.1

Winding coils shall be of a form-wound, fully vacuum-pressure impregnated (VPI) construction.

### Justification

*Form wound designs are desirable for medium-voltage and high-voltage applications wherein the ability to provide better turn-to-turn insulation and greater mechanical strength results in a more reliable motor, with relatively minor sacrifices in performance and cost. Applications that use continuous, repeated surge loads to the motor are usually best served with a form wound design. The surge loads result in magnetic reactions in the windings, particularly in the end turns of the stator, that tend to deform the windings or even break them over time. With a rigid, heavily braced design in case of form winding, the impact of these mechanical stresses can be more easily mitigated. The VPI process provides an insulation system with high dielectric strength, mechanical resilience, chemical and moisture resistance, and good thermal capabilities. Also, the solvent free resins used in the VPI process are the non-reactive components of the formulation that have a very high initial boiling point and non-inflammable properties making it safer.*

NOTE If accepted by the purchaser, resin-rich windings can be provided.

#### 11.4.4.2

For motors with a rated voltage greater than or equal to 6 kV, the winding insulation system shall use partial discharge suppressant materials.

### Justification

*Partial discharge provides an evidence of a deteriorating insulation system which could lead to a breakdown/failure of high voltage equipment and would result in very costly repairs. Partial discharge occurs in areas of the insulation system or on the surface of insulation materials that is subjected to very high local electric field stresses. They typically occur in the surface anomalies like in a minor cavity of a solid dielectric or a minor sharp protrusion on the surface. The partial discharges within an insulating material are usually initiated within gas-filled cracks/voids within the insulations. Partial discharges dissipate energy in the form of heat, sound and light, causing thermal degradation of the insulation. Partial discharge can usually be prevented through careful design and material selection. Materials like hydrophobic cycloaliphatic epoxy (HCEP) resins demonstrate excellent creep resistance, thermal stability, weathering and erosion resistance and are a perfect choice of partial discharge suppressant material.*

#### 11.4.4.3

Winding coils shall have uniform insulation levels rated for line-to-line voltage.

### Justification

*This requirement ensures that the insulation thickness is consistent throughout the stator windings all along its length, otherwise it may be argued that the insulation level is met just by demonstrating its thickness at a single location and may not be consistent at another location.*

#### 11.4.4.4

Winding connections, except those completed in the main terminal box, shall be brazed using a silver-based brazing material.

### Justification

*Historical data confirms that wherever these connections have been crimped, only those connections fail. Brazing or soldering is also deployed as it is proven to provide a connection that is stronger over time. While the results of brazing are superior, the practicalities of brazing that can cause damage to the insulation can be challenging due to the high temperature involved, therefore manufacturers were consulted on how this is addressed (manufacturers were consulted during the development of IOGP S-745). Based on the manufacturers' responses, the requirement is considered feasible and acceptable for standardization.*

#### 11.4.4.5

The windings of the motor shall be star connected.

##### *Justification*

*The six ends of the stator windings are brought out into the terminal boxes (three ends each to main and neutral terminal box). For differential protection, when required, either full differential or self-balancing scheme is arranged with the six ends of the stator windings as applicable. This requirement, along with the data sheet element for neutral connection, ensures that the terminal boxes are adequately sized for all six ends of the stator windings.*

#### 11.4.5 Rotor

##### 11.4.5.1

The rotor shaft material shall comply with API Standard 541:2014, 4.4.5.1.3.

##### *Justification*

*This requirement ensures that the torsional strength of the rotor shaft is not compromised and is uniform throughout the shaft length. Shafts made of hot-rolled round steel are most common in small and medium-sized motors. Hot rolling is a mill process which involves rolling the carbon structural steel at a high temperature (typically at a temperature over 1 700 °F) which is above the recrystallization temperature of the steel. When the steel material is above the recrystallization temperature, it can be shaped and formed easily, and be made in much larger sizes. The block diameter is selected in accordance with the maximum diameter of the shaft anywhere along its length plus the machining allowance. Therefore, the amount of cutting is relatively large. Hot rolling improves the following:*

- toughness and strength;*
- ductility;*
- resistance to vibration and shock;*
- formability;*
- weldability.*

*Forged shafts are preferred for larger shaft diameters. The forged steel has high mechanical strength and the general shape of the stepped shaft can save raw materials and cutting time, but forged shafts are more expensive than hot-rolled shafts. The advantages of forging include the following.*

- It is generally tougher than alternative manufacturing techniques.*
- The nature of forging excludes the occurrence of porosity, shrinkage, cavities and cold pour issues.*
- The tight grain structure of forgings makes it mechanically strong. There is less need for expensive alloys to attain high-strength components.*
- The tight grain structure offers great wear resistance without the need to make products “super hard”.*

##### 11.4.5.2

Where shaft keys are provided, rotors shall be balanced with a half-key fitted in the shaft keyway in accordance with IEC 60034-14 and ISO 21940-32.

##### *Justification*

*Rotor shaft construction and balancing requirements ensure consistency across operators and manufacturers with a minimum specification. The rotor shaft is balanced in accordance with IEC 60034-14:2018, Clause 7 with the key-way in accordance with ISO 21940-32. This requirement is generally the default for manufacturers but is currently not covered in IEC 60034-1.*

##### 11.4.5.3

Rotors shall be balanced to restrict the residual unbalance below the permissible limit determined by the specified balance quality grade.

### **Justification**

*As part of the rotor balancing, ensuring minimum residual unbalance is a good start to achieve low vibration values in a completely assembled machine. Setting the limits for residual unbalance based on balance grade G 2,5 is the typical industry practice for large motor unbalance. This requirement allows the purchaser to procure machines with lower residual unbalance magnitudes by pointing to a PDS element that specifies the required balancing grade to determine the permissible limits for residual unbalance.*

#### **11.4.5.4**

Rotors with rigid shaft characteristics shall be balanced in accordance with ISO 21940-11.

### **Justification**

*The balance grade is defined to ensure consistency. ISO 21940-11:2016, Table 1 defines the actual requirement and level of accuracy required. The applicable category is "Electric motors and generators (of at least 80 mm shaft height), of maximum rated speeds above 950 r/min". ISO 21940-11 also describes the balancing process. The maximum shaft vibration and run out limits are specified in the PDS.*

#### **11.4.5.5**

For converter duty motors with rigid shaft characteristics, the maximum vibration magnitude limits shall be applicable throughout the defined speed range.

### **Justification**

*The balance grade is defined to ensure consistency. ISO 21940-11:2016, Table 1 defines the balancing quality grades for typical machinery categories. The applicable category is "Electric motors and generators (of at least 80 mm shaft height), of maximum rated speeds above 950 r/min". ISO 21940-11 also describes the balancing process. This requirement supplements 11.4.5.4 by stating that the maximum vibration magnitude is applicable not only for the maximum rated speed but for the entire defined speed range for a converter duty motor. The maximum shaft vibration and run out limits are specified in the PDS.*

#### **11.4.5.6**

Rotors with flexible shaft characteristics shall be balanced at rated speed in accordance with ISO 21940-12.

### **Justification**

*Balancing rigid shafts is performed at a speed that is not considered critical, however this is not the case for a flexible shaft machine. This type of rotor is balanced at a low speed where the rotor does not flex. Correction for unbalance is made, then the speed is gradually increased and the unbalance is corrected in stages until the rated/operating speed of the rotor is reached. This requirement ensures that the rotor does not flex in the entire range up to the rated speed. The maximum shaft vibration and run out limits are specified in the PDS.*

#### **11.4.5.7**

For converter duty motors with flexible shaft characteristics, the maximum vibration magnitude limits shall be applicable throughout the defined speed range.

### **Justification**

*When balancing rigid shafts, it is a given that balancing is performed at a speed that is not considered critical, however, this is not the case for a flexible shaft machine. This type of rotor is balanced at a low speed where the rotor does not flex. Correction for unbalance is made, then the speed is gradually increased and the unbalance is corrected in stages until the rated/operating speed of the rotor is reached. This requirement ensures that the rotor does not flex in the entire range up to the rated speed. This requirement supplements 11.4.5.6 by stating that the maximum vibration magnitude is applicable not only for the maximum rated speed but for the entire defined speed range for a converter duty motor. The maximum shaft vibration and run out limits are specified in the PDS.*

#### **11.4.5.8**

Rotor shaft ends shall be provided with an ISO metric threaded hole to facilitate coupling and rolling element bearing removal.

### **Justification**

*This requirement for a threaded hole ensures that maintenance/breakdown activities are facilitated in a timely manner with minimal down-time.*

#### **11.4.5.9**

For motors with sleeve bearings, the rotor shall be permanently marked to be visible in operation and standstill position with the magnetic centre and limits of permissible shaft axial movement.

### **Justification**

*This requirement facilitates the monitoring of bearing performance and condition when the motor is in use. It provides the user with the ability to identify a bearing malfunction in the early stages and reduces the chances of bearing failure becoming catastrophic.*

#### **11.4.5.10**

Shaft extensions shall be in accordance with IEC 60072-2.

### **Justification**

*IEC 60072-2 ensures that dimensions are uniform across manufacturers. This requirement ensures that the motor is replaceable and interchangeable.*

### **11.4.6 Terminals**

Terminal bushings and post insulators shall be made of cycloaliphatic epoxy resin material.

### **Justification**

*Cycloaliphatic epoxy resin is a low viscosity, low molecular weight epoxy resin designed for use in high-voltage outdoor electrical applications because it achieves crack-free components with excellent mechanical and electrical properties with high uniformity. Cycloaliphatic epoxy resins are alternatives to standard bisphenol epoxies because they have superior resistance to moisture and ultraviolet, better colour and gloss stability, excellent electrical properties, high heat deflection temperature and high compression strength. High compression strength and other qualities of cycloaliphatic epoxy resin make the insulators from these epoxy resins reliable for many years of service. This requirement aligns with API Standard 541:2014, 5.1.1.*

#### 11.4.7 Terminal boxes

##### 11.4.7.1

The main terminal box shall be made of fabricated steel with a thickness greater than or equal to 3 mm.

##### *Justification*

*This requirement is not covered in IEC 60034-1 and ensures that terminal boxes are made of a material and of a thickness that aligns with the operating life of the machine body. The specified thickness is consistent with manufacturer's standard offerings and aligns with API Standard 541:2014, 4.4.1.1.*

##### 11.4.7.2

Main and neutral terminal boxes shall have terminal markings and the direction of rotation in accordance with IEC 60034-8.

##### *Justification*

*IEC 60034-8 provides a letter designation to the terminals for the connection diagram of the motor windings. This requirement provides a standard method for terminal markings and the direction of rotation that is commonly understood by suppliers and users.*

##### 11.4.7.3

Threaded cable gland entries shall have a metric thread in accordance with IEC 60423:2007, Table 1.

##### *Justification*

*This requirement ensures that terminal box gland entries are consistent with no variation in thread size/pitch across manufacturers.*

##### 11.4.7.4

Cable entries shall be fitted with blanking devices to retain the ingress protection rating of the motor during transportation and storage.

##### *Justification*

*This requirement ensures that the intended ingress protection rating is maintained during transportation and storage and until the installation of cables is completed.*

##### 11.4.7.5

Where single core power cables are specified, the gland plate and multi-cable transit frame shall be made of a non-magnetic material.

##### *Justification*

*Where single core cables are used for each phase, the magnetic flux does not cancel out as it does in case of a three-core cable. This causes the individual cable magnetic flux to produce eddy current circulation in the metallic plate, causing overheating of the gland plate. Hence, the gland plate or multi-cable transit frame is made of a non-magnetic material to avoid eddy current and heating. Though this phenomenon is widely recognized, it is not specified in IEC 60034-1, hence this requirement.*

##### 11.4.7.6

Where provided, the neutral terminal box shall be located on the opposite side of the main terminal box.



### **Justification**

*Mounting the neutral terminal box (which would typically be required for current transformers with full differential protection scheme) opposite the line conductor terminal is standard practice among manufacturers. Moreover, it is not practical to locate both large terminal boxes on one side and locating one on either side achieves the best balance in order to provide convenient access for installation, testing and maintenance.*

#### **11.4.7.7**

For non-Ex db main terminal boxes, a corrosion-resistant pressure-relief diaphragm shall be incorporated in the terminal box.

### **Justification**

*Safety and integrity of high-voltage terminal boxes during internal faults are ensured by deliberately incorporating a weak spot within the terminal box. In normal operation, the cable box is adequately sealed and maintains the integrity and enclosure protection level. In the event of an internal fault, a relatively modest rise in pressure within the box ruptures the pressure-relief diaphragm and relieves the energy, preventing damage to the terminal box. The location of the pressure-relief diaphragm is also important as during the rupture of diaphragm, the pressure is released away from where any personnel could be present. Also, the corrosion resistant property ensures that environmental effects do not affect the integrity of the diaphragm.*

#### **11.4.7.8**

The discharge of the pressure-relief diaphragm shall be located on the back panel of the terminal box and directed towards the motor frame.

### **Justification**

*Safety and integrity of high-voltage terminal boxes during internal faults are ensured by deliberately incorporating a weak spot within the terminal box. In normal operation, the cable box is adequately sealed and maintains the integrity and enclosure protection level. In the event of an internal fault, a relatively modest rise in pressure within the box ruptures the pressure-relief diaphragm and relieves the energy preventing damage to the terminal box. The location of the pressure-relief diaphragm is also important as during the rupture of diaphragm, the pressure is released away from where any personnel could be present.*

#### **11.4.7.9**

The bottom of the terminal box shall be higher than the mounting surface of the motor.

### **Justification**

*This requirement ensures that the motor mounting base is the lowest point and that terminal boxes can remain installed on the motor housing even during transport and storage. This requirement ensures that the motor can be installed on the base frame without any additional structural assembly required to elevate the lowest point of the motor up to or above the base frame level. When stated upfront, this requirement helps the manufacturer to choose the tilt and orientation of the terminal box at the initial stage.*

#### **11.4.7.10**

Motor auxiliaries and instruments shall be wired to separate auxiliary terminal boxes mounted on the side of the motor.

### **Justification**

*This requirement ensures that the number of auxiliary terminal boxes are in accordance with the segregation of signals and that the location of these boxes on the motor housing and routing of wiring are determined uniformly by all manufacturers. This requirement rules out the possibility of manufacturers combining auxiliary terminal boxes.*

## **11.4.8 Fans**

### **11.4.8.1**

Fan impellers external to the stator end shields shall be keyed or screwed to the rotor shaft.

### **Justification**

*Rotors need to be removed for many maintenance operations. If fan impellers are mounted external to the rotor end shields, the fans are removed as part of the rotor removal process. It is important to maintain the same relative position between the rotor and the fan when the fan is reinstalled such that rotor balance is maintained. Keying or screwing to the rotor shaft is a simple and accurate method of ensuring this alignment.*

### **11.4.8.2**

Motors with unidirectional fans shall have a permanently affixed label with an arrow indicating the direction of rotation.

### **Justification**

*Where a unidirectional fan is provided, the engraved arrow helps the installer of the fan to confirm the orientation for which the fan should be installed, ensuring it operates as per the design. The arrow is also a check for the direction of rotation of the driver to ensure the phase sequence of the power cables.*

### **11.4.8.3**

Where a corrosivity category greater than C3 has been specified, fan impellers external to the stator end shields shall not be aluminium.

### **Justification**

*With the exception of some internal fans, this requirement prohibits an aluminium fan impeller in environments with a corrosivity factor greater than C3 due to the increased corrosion that aluminium typically incurs compared to steel or GRP. However, some internal fans made of aluminium are not prohibited due to protection from the external environmental factors.*

### **11.4.8.4**

Fan covers shall be constructed from ferrous metal.

### **Justification**

*In general, manufacturer documentation shows that for high-voltage motors of smaller frame sizes, cast iron frames are standard with a metal fan cover. For Ex motors, cast-iron framed motors can have either a steel or a hot-dip galvanized steel fan cover. This requirement rationalizes the variants available and excludes the use of aluminium and GRP which both have implications with corrosion and withstanding impacts which are predominant issues in the industry.*



## 11.4.9 Bearing and Lubrication

### 11.4.9.1 Bearing insulation

#### 11.4.9.1.1

The non-drive end bearing shall be electrically insulated from the rotor shaft.

#### *Justification*

*Bearing currents occur when there is an induced voltage, on the motor shaft, that is high enough to overcome the breakdown voltage on the bearing lubricant. Shaft voltages cause either of the following:*

- current to flow directly from the shaft, through a bearing, then through the motor or load frame and then into ground;*
- current to circulate from one side of the shaft, through a bearing, through the motor frame, back into the opposite bearing, and then back into the shaft.*

*Insulating the non-drive end bearing will help in preventing premature bearing failures.*

#### 11.4.9.1.2

The bearing housing shall bear a prominent label to indicate the use of insulated bearing.

#### *Justification*

*The caution label on the bearing housing states that no action causes the bearing insulation to be bridged by any conductive connection. This requirement also cautions for appropriate replacement spares and compliance to procedures as recommended by the manufacturer to maintain the integrity of bearing insulation.*

### 11.4.9.2 Sleeve bearings

#### 11.4.9.2.1

Sleeve bearings shall be spherical seated and self-aligning.

#### *Justification*

*On spherical seated self-aligning sleeve bearings, the outer rings get press fit into housings. This requirement allows the fracture to remain closed and prevents the rotation of the outer ring under heavy rotational or oscillating loads. Inner rings may have interference or clearance fits on shafts depending on the application. To facilitate the mounting of bearings of this design, the ends of pins or shafts and the edges of housing bores have a lead chamfer of 10° to 20°. These bearings can be more easily pressed into position and there is little risk of damage to mating surfaces caused by skewing of the bearing. This ultimately facilitates a more efficient bearing replacement, with less opportunity to damage the bearing housing faces, which minimizes additional motor downtime.*

#### 11.4.9.2.2

Replacement of sleeve bearing liners, pads or shells shall be possible without disassembly of the lower half of the end bells, plates and ductwork or without disassembly of the coupling on the motor.

#### *Justification*

*This requirement enables rectification work to be performed on sleeve bearings with minimal disruption and outage time.*

#### 11.4.9.2.3

The motor shall start and run without the need for jacking oil to the sleeve bearings.

### **Justification**

*When the motor shaft is rotating very slowly or during start-up phase and shut-down phase, the normal lubricating oil supply cannot ensure an adequate hydrodynamic oil wedge to prevent bearing damage/breakdown. Additional pumps provide the necessary high pressure “jacking oil” to lift the motor shaft within the sleeve bearings prior to starting the rotation of the shaft and prevent bearing damage. Sleeve bearings can be designed such that they do not require jacking oil, but again it does also depend on the weight (mass) of the shaft and the space available for journals and bearings. Without this requirement, the manufacturer can decide to add a jacking oil pump to the motor lubrication system.*

#### **11.4.9.2.4**

Self-lubricated sleeve bearings shall be provided with an oil level indicator.

### **Justification**

*This requirement provides lubrication level monitoring to ensure that maintenance activities can identify a low oil level without performing intrusive maintenance. This allows trends to be easily monitored if increased oil usage or any leakage occurs.*

#### **11.4.9.2.5**

Sleeve bearings with a ring lubricating system shall permit the visual inspection of oil ring operation while the motor is running.

### **Justification**

*Visual inspection while the motor is running provides the user with a non-intrusive means of ensuring that the lubrication system is operating properly on a regular basis. Some manufacturers recommend to check oil ring operation daily.*

#### **11.4.9.2.6**

For a flood lubrication system with a lube oil re-circulation circuit, a flow indicator shall be provided in the lube oil return lines.

### **Justification**

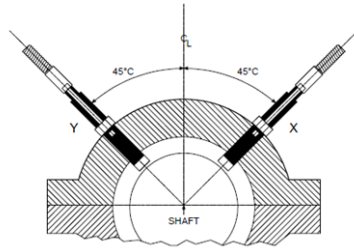
*This requirement provides lubrication oil flow monitoring to ensure that maintenance activities can identify low oil flow without performing intrusive maintenance.*

#### **11.4.9.2.7**

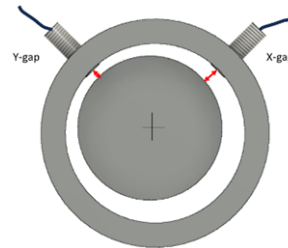
Machines shall have provision for two non-contacting vibration measurement proximity probes per sleeve bearing in accordance with API Standard 670.

### **Justification**

*This requirement ensures that the machine is provided with a means for vibration measurement. API Standard 670 provides further definition on proximity sensor specification. The proximity probes are sensors that detect objects without coming into physical contact, thereby measuring the shaft displacement relative to the sleeve bearing housing. Typically, two proximity probes identified as X and Y are mounted per sleeve bearing at 45-degree angle from vertical, thus being 90-degree angle apart from one another. The relative motion between the shaft and probes generates varying eddy current flow that gives a proportional corresponding change in both amplitude and phase of the signal. This signal is then interpreted as shaft displacement and runout.*



Justification Figure c



Justification Figure d

**11.4.9.2.8**

The oil and bearing temperatures shall be in accordance with API Standard 541:2014, 4.4.7.1.14.

**Justification**

*The bearing over-temperature is the most common cause of premature bearing failure and stating a maximum temperature provides alignment for industry requirements.*

**11.4.9.2.9**

The flood lubrication system shall have redundant oil pumps.

**Justification**

*For large capacity machines, lubrication is an important requirement for reliable operation. Hence, the lubrication system has a redundant oil pump to keep the oil flow into the bearings. The topology (flood lubrication or pressure/force lubrication) is dependent on the manufacturer's model/design, capacity of the machine, etc. Redundancy in oil pumps ensures improved reliability and availability.*

**11.4.9.2.10**

The flood lubrication system shall have provision for topping up the oil level while the motor is in operation.

**Justification**

*This requirement ensures that a proper arrangement for topping up the oil level is provided in the event of a leakage in the lubrication system. This requirement also ensures that the provision for air venting is part of the design and the top up location is easily approachable and safe for the activity. This requirement also ensures that the supplier can demonstrate the activity of topping up the oil level and that the purchaser can validate the ease of access to perform the topping up activity.*

**11.4.9.2.11**

If the forced lubrication system fails or is switched off, the motor shall rundown safely.

**Justification**

*Oil reservoirs or rundown tanks are simple vessels used for the storage of oil above a certain height from the shaft centre line of the rotary equipment (e.g. motor, generator, pump, compressor). Bearings are critical parts of the rotating machine with a high level of sensitivity and even a small damage can ruin the bearing rapidly. The most probable cause of bearing damage is reduced lubrication or loss of lubrication. This situation is likely to happen in case of a power interruption when the method of flood lubrication or pressure lubrication is used. Another cause could be someone switching off the pump by mistake. To counter this situation, the oil reservoir or rundown tank supplies the lubrication oil to the bearings at the required flow rate, pressures until the equipment coasts down (runs down) and comes to a standstill. This arrangement keeps the bearing adequately lubricated and protects it from damage. Typically, the status of oil level in the reservoir is used as a start permissive interlock in the equipment starting logic.*

**11.4.9.2.12**

The flood lubrication system of the hydrocarbon gas compressor motor shall be separate from the hydrocarbon gas compressor seal or lube oil system unless a dry gas seal system that prevents the following is provided:

- seal gas from entering the lube oil system;
- lube oil from penetrating the dry gas seals.

**Justification**

*This requirement ensures that the lubrication oil system of the driver and driven machine is separate (i.e. if the driven machine is a gas compressor, the motor as a driver cannot share the lubrication oil system with the compressor lubrication system or seal oil system). An alternative method is to provide a dry seal gas system which prevents seal gas from entering the lube oil system and prevent the lube oil from entering the dry gas seals. These are mitigation measures to prevent cross contamination. This is because the lubrication system can get contaminated by gas and cause an explosion when circulated into the motor lubrication system. Hence, in such cases, this requirement ensures that both systems are free of cross-contamination.*

**11.4.9.2.13**

When low-speed barring is required, the motor bearing, excluding rolling element type, shall be lubricated irrespective of the specified lubrication system.

**Justification**

*Low-speed barring requirement typically arises due to the motor driven equipment influenced by equipment inertia. Hence, when in coupled state, the motor also continues to run for a prolonged time till coast-down with starved lubrication which is detrimental for the bearings. This requirement ensures that necessary provisions are implemented to provide adequate lubrication to bearings other than rolling element bearings when low-speed barring is required to safeguard the bearings.*

**11.4.9.3 Rolling element bearings****11.4.9.3.1**

The minimum lubrication interval of grease lubricated rolling element bearings shall be in accordance with Table 28.

**Justification**

*This requirement ensures that excessive maintenance is not incurred as a result of specifying rolling element bearings. This gives the purchaser consistency for planned maintenance frequency for high-voltage motors. The values stated in Table 28 are aligned with manufacturers' standard offerings.*

Add new Table 28

**Table 28 – Lubrication intervals of grease lubricated rolling element bearings**

Motor mounting type	Lubrication interval h
Horizontal	≥ 4 000
Vertical	≥ 2 000

### Justification

*This table ensures that excessive maintenance is not incurred as a result of specifying rolling element bearings. This gives the purchaser consistency for planned maintenance frequency for high-voltage motors. The values stated in this table are aligned with manufacturers' standard offerings.*

#### 11.4.9.3.2

Rolling element bearings shall be C3 type in accordance with ISO 5753-1:2009, Table 1, Group 3.

### Justification

*C3 refers to normal clearance as commonly used to prevent too little internal bearing clearance in operation. This reduces variations and is considered the default choice for high-voltage motors in oil and gas up to circa frame size 450. Most manufacturers offer this as standard or as an existing option.*

#### 11.4.9.3.3

The minimum L10h bearing design lifetime in accordance with ISO 281 shall be in accordance with Table 29.

### Justification

*This requirement ensures operators have stipulated a minimum requirement for the performance of bearings on vertically mounted motors as well as horizontally mounted. Bearing life extended from average of 40 000 h (existing IEC industry standard) to 50 000 h for horizontally mounted motors where this requirement was reviewed with various manufacturers and confirmation obtained that they can achieve this requirement without additional cost. The value of 40 000 h for vertically mounted motors has been confirmed as a standard offering from manufacturers, however it is recognized this requires the installation of an angular contact bearing and this requires the purchaser to confirm the magnitude of axial force of the load to the manufacturer in the PDS.*

Add new Table 29

**Table 29 – Minimum L10h bearing design lifetime**

Motor mounting type	Minimum L10h bearing design lifetime h
Horizontal	50 000
Vertical	40 000

### Justification

*This requirement ensures that operators have stipulated a minimum requirement for the performance of bearings on vertically mounted as well as horizontally mounted motors. Bearing life extended from an average of 40 000 h (existing IEC industry standard) to 50 000 h for horizontally mounted motors where this requirement was reviewed with various manufacturers and it was confirmed that they can achieve this requirement without additional cost. The value of 40 000 h for vertically mounted motors has been confirmed as a standard offering from manufacturers, however it is recognized that this requires the installation of an angular contact bearing and it also requires the purchaser to confirm the magnitude of axial force of the load to the manufacturer in the PDS.*

#### 11.4.9.3.4

Motors with rolling element bearings shall have provision for specified vibration measurement sensors per bearing.

### **Justification**

*This requirement ensures that the provision is available for the specified sensor type.*

#### **11.4.9.3.5**

For motors with no vibration sensor provision, the bearing housings of the motor shall have a flat surface with two positions X and Y clearly marked for measurement using a portable vibration sensor.

### **Justification**

*A portable vibration sensor is used to measure casing vibration on the motor as a complete unit. In many cases these sensors are specified in the PDS to be provided and where this is not the case, it is highly likely that throughout the design life of the motor, vibration measurement is done by means of a portable vibration sensor, hence this requirement.*

#### **11.4.9.3.6**

Lubrication ports of rolling element bearings shall be accessible while the motor is running.

### **Justification**

*This requirement ensures that it is possible to re-lubricate motor bearings while the motor is running, thereby improving the motor availability while maintaining reliability.*

#### **11.4.9.3.7**

Rolling element bearings shall use grease that contains mineral based oil and lithium complex thickener.

### **Justification**

*This requirement provides consistency for grease specification for rolling element bearings. Lithium based grease exhibits good stability and provides better performance for high temperature and moisture resistance. The use of such grease prevents premature wear of the rolling element bearings, especially in typical harsh environments of oil and gas industry.*

#### **11.4.9.3.8**

Grease lubricated rolling element bearings assembly shall be provided with a labyrinth seal and a grease-relief valve.

### **Justification**

*While the re-lubrication is performed, the grease follows a guided path through the bearing gaps and pushes out the old, used grease through the grease-relief valve or drain plug. The labyrinth seal helps prevent the pressurized grease to find its way between the shaft and the inner bearing cap into the inside of the motor. It also prevents loss of grease and ingress of dust or moisture.*

#### **11.4.9.3.9**

Selection of rolling element bearings for horizontal motors shall be in accordance with API Standard 541:2014, 4.4.7.1.3.

### **Justification**

*API Standard 541 determines the selection of rolling element bearing based on the dN factor method. The dN factor is the product of bearing size in millimetres and speed in revolutions per minute. The other parameter influencing the selection is L10 rating life of bearings based on loading at the rated speed.*



#### 11.4.9.3.10

Selection of rolling element bearings for vertical motors shall be in accordance with API Standard 541:2014, 4.4.7.1.4 and 4.4.7.1.5.

##### *Justification*

*API Standard 541 determines the selection of rolling element bearing based on the dN factor method. The dN factor is the product of bearing size in millimetres and speed in revolutions per minute. The other parameter influencing the selection is L10 rating life of bearings based on maximum up and down thrust during starting, stopping or operation at the rated load.*

#### 11.4.10 Lateral analysis

When specified, lateral analysis shall be carried out for test floor and final site conditions in accordance with API Standard 541:2014, 4.4.6.2.1.

##### *Justification*

*Lateral vibration of a shaft rotor is caused by instability, rotor mass, unbalance or other forces acting on the rotor. Lateral analysis simulates the rotating system, calculates the critical speeds, predicts vibration amplitudes and provides data that may result in additional measure applied by the manufacturer to reduce vibration risks. The foundation stiffness and damping also impacts the analysis. When the foundation data is significantly different between the test floor and final site conditions, additional analysis is done. The foundation data for the factory acceptance test is the manufacturer's test floor conditions and the foundation data for the site acceptance test is the final site conditions. This requirement specifies that lateral vibration and critical speed analysis is performed as this is not specified in IEC 60034-1. This requirement also aligns with API Standard 541:2014, 4.4.6.2.1.*

#### 11.4.11 Torsional analysis

When specified, torsional analysis shall be performed in accordance with API Standard 541:2014, 4.4.6.2.2.

##### *Justification*

*This requirement defines how torsional vibration and critical speed analysis is performed as this is not specified in IEC 60034-1. This requirement also aligns with API Standard 541:2014, 4.4.6.2.2.*

#### 11.4.12 Monitoring and protection devices

##### 11.4.12.1 General

##### 11.4.12.1.1

External connections between motor mounted devices and respective terminal boxes shall be routed in steel conduits clamped on the motor frame.

##### *Justification*

*These mounted devices are small instrumentation devices (such as sensors, probes and transducers) which have flexible and thin connecting cable leads. This requirement ensures that these devices are grouped in accordance with signal category and wired to the respective auxiliary terminal boxes located on the motor frame. Since these devices are located all over the motor surface depending on its application, the connecting cable leads need to be routed on the motor surface up to the auxiliary terminal boxes safely. The safest way to protect the cables is to route them in a steel conduit that is fixed on to the motor frame. Without this requirement, the manufacturer could adopt different means of routing that can be inconsistent and sometimes less safe than desired.*



#### 11.4.12.1.2

Each wire of the mounted device shall be connected to an individual terminal in the respective terminal box.

##### *Justification*

*These mounted devices are small instrumentation devices (such as sensors, probes, transducers) that have flexible and thin connecting cable leads. As required, these devices are to be grouped in accordance with signal category and need to be wired to respective auxiliary terminal boxes located on the machine housing. The grouping of the signals is based on the signal types such as digital input/output, analog input/output, volt free contact, voltage levels, interface systems (electrical, control and instrumentation, etc.). This requirement mandates that each wire of the device needs to be terminated in the terminal box, which ensures that the terminal boxes are adequately sized and provided with the required number of terminations. This ensures that all spare signal inputs are also wired up and connected to the respective systems.*

#### 11.4.12.1.3

Three-wire Pt-100 platinum resistance temperature sensors in accordance with IEC 60751 shall be used for temperature detection.

##### *Justification*

*This requirement standardizes the use of three-wire Pt-100 sensors for temperature measurement. Though two-wire can also work, three-wire is better as the addition of a third wire, connected to one side of the measuring element, helps to compensate for lead resistance. To compensate for lead wire resistance, three-wire RTDs have a third wire that provides a measurement of the resistance of the lead wire and subtracts this resistance from the value read.*

#### 11.4.12.2 Winding temperature sensors

Two winding temperature sensors per phase shall be installed to detect the highest temperatures of the stator winding.

##### *Justification*

*The intent of providing the temperature sensors is to capture the value of the highest temperature attained in any part of the motor. The prospective location is underneath the conductors at the bottom portion of the slot or on the conductors in the end winding portion. The other locations could be the core pack laminations or the pressure plates but the conductors at the bottom portion of the slot or on the conductors in the end winding portion are the most commonly identified as the hottest part and preferred installed locations for temperature sensors. Thus, each phase winding has two sensors that are placed 120° apart. This provides a fairly uniform temperature measurement value during normal operation.*

#### 11.4.12.3 Bearing temperature sensors

Where bearing insulation is provided, the integrity of bearing insulation shall remain uncompromised on the installation of the temperature sensor.

##### *Justification*

*For the installation of temperature measurement, the temperature sensors are installed in a mounting hole, drilled in the bearing housing which reaches the bearing outer race surface. The sensors are fitted very close to the bearing surface to get the most accurate reading. In this effort, this requirement mandates the manufacturer to exercise caution not to breach the integrity of the bearing insulation which is generally placed over the outer race of the bearing which is then closest to the temperature sensor tip. The manufacturer should locate the mounting provision such that under no circumstances, the installation of the sensor interferes with the bearing insulation but still measures the most accurate temperature present on the bearing surface.*

#### 11.4.12.4 Heat exchangers

##### 11.4.12.4.1 Air-cooled heat exchangers

For air-cooled heat exchangers, a three-wire Pt-100 temperature sensor shall be provided to measure the temperature of the cooling air leaving the heat exchanger.

##### *Justification*

*A temperature monitoring facility alerts the user when the performance of the heat exchanger is outside its normal operating values. By identifying deficiencies in a timely manner, prolonged equipment outages can be prevented and extreme motor damage can be prevented or minimized.*

##### 11.4.12.4.2 Water-cooled heat exchangers

###### 11.4.12.4.2.1

For water-cooled heat exchangers, three-wire Pt-100 temperature sensors shall be provided to monitor the inlet and outlet air temperatures.

##### *Justification*

*A temperature monitoring facility alerts the user when the performance of the heat exchanger is outside its normal operating values. By identifying deficiencies in a timely manner, prolonged equipment outages can be prevented and extreme motor damage can be prevented or minimized.*

###### 11.4.12.4.2.2

Water-cooled heat exchangers shall be provided with leakage detection.

##### *Justification*

*A leakage detection facility can ultimately save time and cost by identifying deficiencies in a timely manner and may ultimately prevent prolonged equipment outage.*

#### 11.4.12.5 Partial discharge monitoring

##### 11.4.12.5.1

Where stator winding partial discharge sensors are provided, the lead wires shall be connected to the terminals in a dedicated terminal box mounted on the motor frame.

##### *Justification*

*This requirement ensures that personnel need not access the main high-voltage terminal box and be exposed to high-voltages to get access to the partial discharge sensor lead wire terminals. This is a safety consideration which is normal practice in the oil and gas industry.*

##### 11.4.12.5.2

Where stator winding partial discharge sensors are provided, the line conductor terminal box shall be sized to adhere with the installation requirements of the sensors' supplier.

### **Justification**

*This requirement ensures that the size of the line conductor terminal box is adequate to accommodate the partial discharge sensing device as per the spacing and orientation recommendations of the sensor supplier. This requirement mandates that the sensor information is obtained before sizing the terminal box, which is not normal practice in general and later causes non-compliance to installation recommendations of the sensors' supplier.*

#### **11.4.12.5.3**

Where stator winding partial discharge sensors are provided for motors used in a hazardous area, the sensors shall have an independent hazardous area certification.

### **Justification**

*Generally, partial discharge measurement uses coupling capacitors or wide band current transformers to acquire the partial discharge signals from the motor windings. These are normally used for safe area applications. Where partial discharge monitoring is required for motors installed in hazardous areas, these sensors are special, using Rogowski coils, and certified for use in both safe and hazardous areas. This requirement ensures that sensors are certified independently so that the entire installation is compliant with the area classification requirement.*

#### **11.4.13 Anti-condensation heaters**

##### **11.4.13.1**

Anti-condensation heaters provided around stator windings or within power terminal boxes shall keep the inside temperature 5 K above the ambient air temperature while the motor is not in operation.

### **Justification**

*This requirement measures the performance of the anti-condensation heaters. Without a value for temperature rise, there is no assurance that the heater is adequately specified to perform its duty.*

##### **11.4.13.2**

Anti-condensation heaters shall be wired to terminals in a separate terminal box mounted on the motor frame.

### **Justification**

*A separate terminal box ensures that low-voltage and high-voltage terminations are in separate enclosures. It also ensures that personnel are not exposed to low-voltage live terminals when performing work on the main terminal box.*

##### **11.4.13.3**

A warning label stating "External voltage source" shall be affixed on the cover of the anti-condensation heater terminal box.

### **Justification**

*The warning label warns personnel to isolate the low-voltage supply that is from a different source and/or location from the main power source to the machine.*

#### 11.4.14 Additional requirements for converter duty motors

##### 11.4.14.1

Converter duty motors shall be in accordance with IEC TS 60034-25.

##### *Justification*

*The scope of this specification includes motors used in power drive systems. This requirement details additional considerations and requirements necessary to operate this arrangement. These additional requirements include temperature monitoring, bearing insulation, certification and testing.*

##### 11.4.14.2

The stated continuous motor output ratings for converter duty motors shall be in accordance with IEC 61800-2:2021, 5.3.3.

##### *Justification*

*The continuous output rating as defined in IEC 61800-2:2021, 5.3.3 is defined in terms of motor shaft parameters, i.e. the following:*

- *rated torque (MN) [N·m];*
- *rated speed (NN) [r/min];*
- *maximum rated speed (NNMax) [r/min];*
- *minimum rated speed (NNMin) [r/min];*
- *minimum speed (NMin) [r/min];*
- *maximum rated safe speed (NSNMax) [r/min];*
- *rated output power (PsN) [kW].*

##### 11.4.14.3

When specified, torsional analysis of converter duty motors shall be in accordance with IEC 61800-2:2021, 5.13.2 and API Standard 541:2014, 4.4.6.2.2.

##### *Justification*

*This requirement defines how torsional vibration and critical speed analysis is as this is not specified in IEC 60034-1. This requirement also aligns with API Standard 541:2014, 4.4.6.2.2 and for converter duty motor, it aligns with IEC 61800-2:2021, 5.13.2.*

#### 11.4.15 Motors intended for use in hazardous areas

##### 11.4.15.1 Certification

##### 11.4.15.1.1

Motors and their mounted components shall be certified for the specified protection type in accordance with IEC 60079.

##### *Justification*

*IEC 60079 specifies the general requirements for construction, testing and marking of Ex equipment and Ex components for the specified protection type and hazardous area. IEC 60079 provides guidelines for equipment grouping and equipment protection level based on the gas group and temperature classification.*

#### 11.4.15.1.2

Motors for use in a hazardous area shall be provided with a certificate issued by a notified body or a certification body.

##### *Justification*

*This requirement ensures that where it may be possible in accordance with IEC 60079 to self-certify the equipment, the certification is issued by a notified or certifying body as per oil and gas industry requirements and standard practice.*

NOTE A manufacturer's declaration of conformity alone does not satisfy the requirement of 11.4.15.1.2.

#### 11.4.15.2 Flameproof (type Ex db)

Motors with protection level Ex db shall have terminal boxes with protection level Ex eb.

##### *Justification*

*This requirement aligns with the manufacturers' standard offering and minimal requirement philosophy. This addresses the ambiguity of Ex db machine terminal box classification which without this could be construed as Ex db in its entirety. Ex eb terminal boxes have the advantage to still comply with Zone 1 requirements and provide a very cost-effective solution that facilitates easy maintenance, and allows cables with lugs to be easily handled and cable terminals to be easily accessed. A terminal box one size larger is possible with easy access and plenty of space to route and handle cables.*

#### 11.4.15.3 Pressurized (type Ex pxb and Ex pzc)

The pressurization unit shall provide the following status information:

- purge cycle in progress;
- purge cycle complete;
- pressurized;
- pressure low / pressure fail.

##### *Justification*

*This requirement ensures that the essential minimum status information for the control system is provided irrespective of the make and model of the pressurization unit.*

## 12 Tolerances

### 12.1 General

In NOTE 2, replace "IEC Guide 115:2021" with

IEC Guide 115:2023

##### *Justification*

*Edition 3.0 (2023) supersedes Edition 2.0 (2021).*

## 13 Electromagnetic compatibility (EMC)

### 13.1 General

Replace first paragraph with

The EMC requirements specified in Clause 13 shall apply to all electrical machines included in the scope of this specification.

#### **Justification**

*The original paragraph restricts the applicability of Clause 13 to high-voltage machines (i.e. rotating electrical machines with rated voltages exceeding AC 1 000 V intended for operation and use in industrial environments). The replacement of this paragraph ensures the expansion of the applicability of these EMC requirements to all electrical machines covered by this specification.*

## Bibliography

### Add to start of Bibliography

The following documents are informatively cited in the text of this document, IEC 600034-1, the PDS (IOGP S-704D) or the IRS (IOGP S-704L).

### Add to Bibliography

API Specification Q2, *Specification for Quality Management System Requirements for Service Supply Organizations for the Petroleum and Natural Gas Industries*

API Standard 618, *Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services*

IEC GUIDE 115:2023, *Application of measurement uncertainty to conformity assessment activities in the electrotechnical sector*

IEC 60034-18-1:2022, *Rotating electrical machines – Part 18-1: Functional evaluation of insulation systems – General guidelines*

IEC 60375, *Conventions concerning electric circuits*

IEC 61082-1, *Preparation of documents used in electrotechnology — Part 1: Rules*

IEC 61355-1, *Classification and designation of documents for plants, systems and equipment – Part 1: Rules and classification tables*

IEC 61892-5, *Mobile and fixed offshore units – Electrical Installations – Part 5: Mobile units*

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ISO 9001, *Quality management systems — Requirements*

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ISO 10209, *Technical product documentation — Vocabulary — Terms relating to technical drawings, product definition and related documentation*

ISO 13880:1999, *Petroleum and natural gas industries — Content and drafting of a technical specification*

ISO 19901-5, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 5: Weight control during engineering and construction*

IEC GUIDE 115:2021, *Application of uncertainty of measurement to conformity assessment activities in the electrotechnical sector*

IEC 60079 (all parts), *Explosive atmospheres*



**Registered Office**

City Tower  
Level 14  
40 Basinghall Street  
London EC2V 5DE  
United Kingdom  
T +44 (0)20 3763 9700  
reception@iogp.org

**Brussels Office**

Avenue de Tervuren 188A  
B-1150 Brussels  
Belgium  
T +32 (0)2 790 7762  
reception-europe@iogp.org

**Houston Office**

15377 Memorial Drive  
Suite 250  
Houston, TX 77079  
USA  
T +1 (713) 261 0411  
reception-americas@iogp.org

[www.iogp.org](http://www.iogp.org)

www Draft