International Association of Oil & Gas Producers

SPECIFICATION
IOGP S-704

November 2024
Version 2.0

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

JIP33
JOINT INDUSTRY PROGRAMME

Revision history

VERSION	DATE	PURPOSE
2.0	November 2024	Second Edition
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).

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).

This second edition cancels and replaces the first edition published in January 2021. Due to technical writing requirements leading to extensive changes, this second edition should be treated as a new document.

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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 14.0, 2022, 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.

JIP33 Specification for Procurement Documents
Supplementary Technical Requirements Specification (TRS)

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;

– suitable for hazardous and non-hazardous area environments;

– for single-speed, converter duty or converter capable applications.

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

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;

– DC;

– synchronous.

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:

– induction generators;

– form-wound motors with a rated voltage below 1 kV;

– multi-speed motors;

– motors with rated speed above 3600 rpm;

– 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.

2 Normative references

Add to first paragraph

The following documents are referred to in this specification, 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 these specification documents.

Add to clause

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 60034-2-1:2024, *Rotating electrical machines – Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)*

IEC 60034-2-3, *Rotating electrical machines - Part 2-3: Specific test methods for determining losses and efficiency of converter-fed AC motors*

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

IEC 60034-14:2018, *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 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 60034-27-2, *Rotating electrical machines – Part 27-2: On-line partial discharge measurements on the stator 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 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 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 61000-2-4:2002, *Electromagnetic compatibility (EMC) – Part 2-4: Environment – Compatibility levels in industrial plants for low-frequency conducted disturbances*

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 519:2014, *IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems*

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

IEEE 1799, *IEEE Recommended Practice for Quality Control Testing of External Discharges on Stator Coils, Bars, and Windings*

ISO 15, *Rolling bearings — Radial bearings — Boundary dimensions, general plan*

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

ISO 492, *Rolling bearings — Radial bearings — Geometrical product specifications (GPS) and tolerance values*

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 21940-11 including AMD1:2022, *Mechanical vibration — Rotor balancing — Part 11: Procedures and tolerances for rotors with rigid behaviour*

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 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

CAS conformity assessment system

Ex explosive atmosphere

FAT * factory acceptance test

FEA * finite element analysis

GRP * glass reinforced plastic

IRS information requirements specification

MRB * manufacturer's record book

PDS procurement data sheet

QRS quality requirements specification

RTD resistance temperature device

TRS technical requirements specification

VPI vacuum pressure impregnated

* Cited in IOGP S-704J only.

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^{-1}]

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^{-1}]

4 Duty

4.2 Duty types

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

In second sentence of fourth paragraph, replace "IEC TS 60034-25:2014" with

IEC TS 60034-25:2022

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

In second sentence of last paragraph, replace "IEC TS 60034-25:2014" with

IEC TS 60034-25:2022

5 Rating

5.5 Rated output

5.5.2 AC generators

In first paragraph, replace "volt-amperes (VA)" with

kilovolt-amperes (kVA)

5.5.3 Motors

Replace "watts (W)" with

kilowatts (kW)

5.6 Rated voltage

5.6.2 AC generators

Replace "7.3" with

7.4

5.8 Machines with more than one rating

In second sentence of last paragraph, replace "7.3" with

7.4

Add new subclause

5.9 Efficiency

For 2-pole, 4-pole and 6-pole motors, compliance with Table 23 shall be confirmed at the rated voltage and frequency in accordance with IEC 60034-2-1:2024, Table 2.

NOTE Efficiency of motor with 8-pole and above is declared by the manufacturer.

Add new Table 23

Table 23 – Minimum efficiency of high-voltage motor

Power rating kW	2-pole motor efficiency value %	4-pole motor efficiency value %	6-pole motor efficiency value %
185	94,2	94,6	93,5 [a]
200	94,5	94,7	93,6 [b]
220	94,7	95,1	93,8 [b]
250	95,1	95,2	94,0 [b]
280	95,3	95,4	94,2 [b]
300	95,4	95,5	94,3 [a]
315	95,5	95,5	94,5 [b]
335	95,6	95,6	94,6 [a]
355	95,7	95,7	94,7 [b]
375	95,8	95,8	94,8 [a]
400 - 500	96,0	96,0	95,3 [a]
530 - 570	96,2	96,2	95,5 [a]
800 - 950	96,4	96,4	96,1 [a]
≥ 1 000	96,5	96,5	96,4 [a]

[a] These values are interpolated values that are not listed in IEC 60034-30-3:2024, Table 4.

[b] These values are adopted from IEC 60034-30-3:2024, Table 4.

6 Site conditions

Add new subclause

6.8 Degree of ingress protection

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

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

8 Thermal performance and tests

8.1 Thermal class

Replace first paragraph with

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

Add to subclause

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

8.6 Determination of winding temperature

8.6.1 Choice of method

Delete second paragraph (including NOTE)

Delete third paragraph

8.6.2 Determination by resistance method

8.6.2.3 Correction for stopping time

8.6.2.3.2 Short stopping time

Replace first paragraph with

The short stopping time shall be determined by the following steps.

a) Obtain the initial resistance reading after stabilization of the measuring device and within 120 s of switching off power.

b) Take additional readings at 30 s intervals over a period of 5 min following the first reading.

c) Calculate the resistance value at the time of switching off power by means of extrapolation.

d) Use the resistance value at the time of switching off power to confirm the winding temperature.

e) Measure the resistance between the same windings for all readings.

Table 6 – Time interval

Delete Table 6

8.6.2.3.3 Extended stopping time

Delete subclause 8.6.2.3.3

9 Other performance and tests

9.1 Routine tests

Add to subclause

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

Add to subclause

For flooded 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.

NOTE The terms "flooded lubrication" and "forced lubrication" may be used interchangeably.

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.

Add to subclause

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

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 in the manufacturer's factory

Replace Table 16 with

Test No.	Test description [i, j]	Reference standard	Remarks
Routine tests			
1	Visual inspection	Approved drawings and documents	
2 [f]	Measurement of ohmic resistance of stator windings referred to 25 °C	IEC 60034-2-1:2024, 5.7.1	
3	Measurement of insulation resistance of stator windings	IEC 60034-27-4	Test also carried out post withstand voltage test
4 [f]	Check of phase sequence/direction of rotation and terminal markings	IEC 60034-8:2014, 6.7	
5 [f]	No-load losses and current test at rated frequency [a]	IEC 60034-2-1:2024, 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 [f]	Withstand voltage test on stator windings	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 devices (RTDs)	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	
13	Measurement of electrical and mechanical run-out (measured at slow roll speed between 200 rpm to 300 rpm)	API Standard 541:2014, 6.3.3, IEC 60034-14:2018, Clause 9	Refer to API Standard 541 for test procedure. Test not applicable for rolling element bearings
Performance tests [g]			
1	No-load characteristic (saturation curve) at rated frequency [b]	IEC 60034-2-1:2024, 6.1.3.2.4	
2	Locked rotor current test	IEEE 112:2017, 7.2	Test for single-speed motor
3	Locked rotor torque test	IEEE 112:2017, 7.2.2	Test for single-speed motor

Table 16 *(continued)*

Test No.	Test description [i, j]	Reference standard	Remarks
4	Temperature rise test	IEC 60034-1:2022, Clause 8 or IEC 60034-29 [c]	
5	Sleeve bearing inspection	API Standard 541:2014, 6.3.2	
6	Determination of efficiency, power factor and slip at 100 %, 75 % and 50 % load	IEC 60034-2-1:2024, Clause 6	Test for single-speed motor
6A	Determination of efficiency, power factor and slip at 100 %, 75 % and 50 % load	IEC 60034-2-3:2020, Clause 6	Test for converter duty motor
Special tests [h]			
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	
3	Measurements of shaft voltage at no-load	IEEE 112:2017, 8.3	
4	Bearing temperature rise at no-load	API Standard 541:2014, 6.3.2	
5	Noise level at no load	ISO 1680	
6	Measurement of moment of inertia	Manufacturer's standard	
7	Measurement of torque and current as function of speed during starting	IEEE 112:2017, 7.3.2	
8	Dielectric dissipation test (tan δ) on stator windings	IEC 60034-27-3	Test performed with stator winding installed in frame
9	Partial discharge test on complete stator	IEC 60034-27-1, IEC 60034-27-2	Test performed with stator winding installed in frame
10	Sealed winding conformance test	ANSI/NEMA MG 1	In process test
11	Unbalanced response test	API Standard 541:2014, 6.3.5.3	
12	Bearing housing natural frequency test	API Standard 541:2014, 6.3.5.4	
13	Stator core test	API Standard 541:2014, 6.3.4.1	In process test
14	Surge comparison test (complete stator assembly)	IEEE 522	In process test
15	Sample coil test	API Standard 541:2014, 6.3.4.2, IEC 60034-15, IEC 60034-27-1, IEC 60034-27-3	
16	Heat exchanger performance verification test	API Standard 541:2014, 6.3.5.5	
17	Hydrostatic pressure test of heat exchanger tubing devices [d]	Design code [e]	
18	External discharge (Corona) test	IEEE 1799	

Table 16 *(continued)*

Test No.	Test description [i, j]	Reference standard	Remarks

[a] No stabilization of temperature required for measurement of no-load losses.

[b] The no-load characteristic shall be measured up to a minimum of 125 % of the rated voltage.

[c] IEC 60034-29 shall be used as the reference standard where testing to IEC 60034-1 is restricted due to the limitations of the test facilities.

[d] Heat exchanger testing is performed at the heat exchanger manufacturer's premises.

[e] Heat exchanger design code to be confirmed by the supplier.

[f] Tests listed in the original table.

[g] 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.

[h] The special tests required to be performed in IOGP S-704D shall be specified.

[i] Motor shall be rigidly mounted in accordance with IEC 60034-14, 6.3 for mechanical tests.

[j] Tests shall be performed with project-specific sensing, monitoring and protection devices mounted on the motor.

9.2 Withstand voltage test

In eighth paragraph, replace "7.3" with

7.4

9.4 Momentary excess torque for motors

9.4.1 Polyphase induction motors and DC motors

Delete seventh paragraph

10 Information requirements

10.3 Rating plate

Replace first sentence of first paragraph with

Rating and marking plates shall be made from 316L stainless steel.

Replace second sentence of first paragraph with

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

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

10.4 Information content

10.4.1 General

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

10.4.6

Delete third sentence of first paragraph

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

ll)

10.4.2 Minimum information requirements

Replace list item j) with

j) Efficiency at full load.

Replace list item k) with

k) The total mass of the motor.

Replace subclause 10.4.6 title with

10.4.6 Additional information

Replace list item gg) with

gg) On a separate rating plate, the types of 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 maximum and minimum oil temperature / pressure / flow rate for flooded lubricated bearings and oil viscosity.

Add new list item kk)

kk) For motors used in hazardous areas, the equipment marking on a separate nameplate applied to Ex equipment and/or Ex components in accordance with IEC 60079 (all parts).

Add new list item ll)

ll) Locked rotor current.

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.

Add to subclause

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

Add to subclause

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

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 4,0 and 6,5 times the rated current.

11.3.1.2

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

Add new Table 25

Table 25 – Number of re-starts of motors

Starting condition	Status	Minimum number of consecutive starts [a] per hour
With the initial temperature at or below the maximum ambient temperature	Cold	3
With the initial temperature above the maximum ambient temperature but not exceeding the maximum rated operating temperature	Hot	2
[a] The motor should coast to rest between consecutive starts.		

11.3.1.3

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

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.

11.3.1.5

The locked rotor withstand time under hot condition shall be greater than the time required to accelerate the specified driven load at 80 % of rated voltage at the motor terminals plus 5 s.

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.

11.3.1.7

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

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 0,2 s.

11.3.3 Pulsating torques

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

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 ± minimum 15 %.

NOTE Well-damped resonances with an amplification factor less than 2.5 are not considered critical speeds.

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 ± minimum 15 %.

11.3.4.3

When motors with sleeve bearings pass through a critical speed during starting or stopping, the peak-to-peak amplitude of vibration levels within ± 15 % of the critical speed shall be less than 75 % of the nominal bearing clearance.

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).

11.3.5.2

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

NOTE Noise abatement measures implemented to meet the noise limits are indicated on the drawings for approval by the purchaser.

11.3.5.3

Noise measurements shall be in accordance with ISO 1680.

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.

11.4.1.2

The motor shall be designed for continuous operation of at least six years.

NOTE Interim maintenance like lubricant replacement and filter cleaning at intervals recommended by the manufacturer may be required to achieve the continuous operation period.

11.4.1.3

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

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 a removable plug.

NOTE Ex-db motors are exempted from this requirement.

11.4.2.1.2

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

11.4.2.2 Mounting

11.4.2.2.1

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

11.4.2.2.2 Vertically-mounted motors

11.4.2.2.2.1

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

11.4.2.2.2.2

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.

11.4.2.2.3 Mounting surfaces and alignment

11.4.2.2.3.1

Mounting surfaces shall be machined to a finish of at least 6,3 µm arithmetic average roughness (Ra).

11.4.2.2.3.2

Mounting surfaces shall be machined within a flatness of 40 µm per linear meter of mounting surface.

11.4.2.2.3.3

Mounting surfaces shall be in the same horizontal plane within 125 µm.

11.4.2.2.3.4

The upper machined or spot faced surface shall be parallel to the mounting surface.

11.4.2.2.3.5

Mounting planes shall be parallel to each other within 0,17 mm per metre.

11.4.2.2.3.6

Horizontal motor mounting planes shall be parallel to the horizontal plane through the bearing centreline within 0,17 mm per metre.

11.4.2.2.3.7

The mounting surface on a vertical motor shall be machined perpendicular to the centreline of the motor.

11.4.2.2.3.8

The mounting surface on a vertical motor shall not deviate from the perpendicular plane by more than 0,17 mm per metre.

11.4.2.2.3.9

Hold-down bolt holes shall be drilled perpendicular to the mounting surfaces of the motor.

11.4.2.2.3.10

Hold-down bolt holes shall be machined or spot faced to a diameter of at least three times that of the bolt hole.

11.4.2.2.3.11

Hold-down bolt holes shall be 13 mm larger in diameter than the hold-down bolt.

11.4.2.2.3.12

Load-bearing washers shall remain in 360° contact with the mounting faces when the machine is aligned in its extreme position where the bolt is touching one side of its clearance hole.

11.4.2.2.3.13

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

11.4.2.3 Frame

11.4.2.3.1

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

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.

11.4.2.3.3

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

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.

Add new Table 26

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

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.

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

11.4.2.3.6

The frame of the assembled motor shall be free from structural resonance between 40 % and 60 % range of the operating speed.

11.4.2.3.7

The frame of the assembled motor shall be free from structural resonance within ± minimum 15 % around speed frequency, twice speed frequency, power frequency and twice power frequency.

11.4.2.3.8

The magnitude of the vibration on the motor frame, including the main terminal boxes, excluding the bearings, shall not exceed 4,5 mm/s (RMS) in any direction.

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.

11.4.2.4.2

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

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.

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.

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

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.

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.

11.4.3.2.2

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

11.4.3.2.3

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

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.

11.4.3.3.2

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

11.4.3.3.3

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

11.4.3.3.4

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

11.4.3.3.5

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

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.

11.4.4 Stator windings

11.4.4.1

Winding coils shall be of copper and form-wound, global vacuum pressure impregnated (VPI) construction.

11.4.4.2

Winding coils shall be insulated by mica tape.

11.4.4.3

For motors with a rated voltage of 3 kV and above, windings shall be provided with an anti-corona protection system in the slot of the coil.

11.4.4.4

For motors with a rated voltage of 6 kV and above, field stress grading tape shall be used for anti-corona protection.

11.4.4.5

Winding coils and terminals shall have uniform insulation levels throughout the winding length.

11.4.4.6

Winding coils shall be tightly wedged in stator slots prior to vacuum pressure impregnation.

11.4.4.7

The stator winding system including end windings, connections and circuit rings shall be securely and uniformly supported and braced in the radial and circumferential directions.

11.4.4.8

The terminal lead extensions from the stator winding to the terminal box shall be braced and supported securely in a manner that allows for thermal expansion and movement during starting, and prevent chafing.

11.4.4.9

The terminal lead extensions from the stator winding to the terminal box shall be insulated, and separated from terminal leads and surfaces of different potential.

11.4.4.10

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

11.4.4.11

The windings of the motor shall be star connected.

11.4.5 Rotor

11.4.5.1

The shaft of the rotor shall be manufactured from one of the following:

– hot-rolled and normalized steel;

– a single billet of heat-treated forged steel.

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.

11.4.5.3

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

11.4.5.4

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

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.

11.4.5.6

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

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.

11.4.5.8

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

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.

11.4.5.10

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

11.4.5.11

The proximity probe sensing areas on the rotor shaft shall be concentric with the bearing journal, free from stencil and scribe marks and from surface discontinuity.

11.4.5.12

The proximity probe sensing areas on the rotor shaft shall not be metallized, sleeved or plated.

11.4.5.13

The proximity probe sensing areas on the rotor shaft shall achieve a surface finish of maximum 0,8 µm arithmetic average roughness.

11.4.5.14

The electrical and mechanical runout of the rotor shaft supported on v-blocks shall be measured at least every 10° of rotation on each probe location with the rotor rotated through the full 360°.

11.4.5.15

The electrical and mechanical runout of the rotor shaft in the assembled machine shall be measured at least every 10° of rotation on each probe location with the rotor rotated through the full 360° at slow roll speed (200 rpm to 300 rpm).

11.4.5.16

Unless approved by the purchaser, components on the rotor assembly shall not be repaired by plating, plasma spray, metal spray, impregnation, or welding.

11.4.5.17

Rotor balance corrections shall be in accordance with API Standard 541:2021, 4.4.6.3.2.

11.4.5.18

Current carrying components on the rotor shall be copper, or copper alloy.

11.4.6 Terminals

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

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.

11.4.7.2

The main terminal box shall withstand for a duration of 0,1 s the pressure buildup resulting from the specified three-phase peak fault current at motor terminals.

11.4.7.3

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

11.4.7.4

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

11.4.7.5

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

11.4.7.6

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

11.4.7.7

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

11.4.7.8

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

11.4.7.9

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

11.4.7.10

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

11.4.7.11

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

11.4.8 Fans

11.4.8.1

Separable fans shall be permanently indexed angularly and axially.

11.4.8.2

Slip-fitted fans shall not be secured to the shaft only by means of set/grub screws.

11.4.8.3

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

11.4.8.4

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

11.4.8.5

Fan covers shall be made of ferrous metal.

11.4.9 Bearing and lubrication

11.4.9.1 Bearing insulation

11.4.9.1.1

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

11.4.9.1.2

When drive end and non-drive bearings are insulated, a shaft grounding system shall be provided at the drive end of the rotor shaft.

11.4.9.2 Sleeve bearings

11.4.9.2.1

Sleeve bearings shall be spherical seated and self-aligning.

11.4.9.2.2

Replacement of sleeve bearing liners, pads and 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.

11.4.9.2.3

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

11.4.9.2.4

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

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.

11.4.9.2.6

For flooded lubrication systems with a lube oil re-circulation circuit of sleeve bearings, a flow indicator shall be provided in the lube oil return lines.

11.4.9.2.7

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

11.4.9.2.8

Oil and bearing metal temperatures of sleeve bearings shall be in accordance with API Standard 541:2014, 4.4.7.1.14.

11.4.9.2.9

If the sleeve bearing flooded lubrication system fails or is switched off, the motor shall rundown safely.

11.4.9.3 Tilting pad bearings

11.4.9.3.1

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

11.4.9.3.2

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

11.4.9.3.3

For flooded lubrication systems with a lube oil re-circulation circuit of tilting pad bearings, a flow indicator shall be provided in the lube oil return lines.

11.4.9.3.4

Oil and bearing metal temperatures of tilting pad bearings shall be in accordance with API Standard 541:2014, 4.4.7.1.14.

11.4.9.3.5

If the tilting pad bearing flooded lubrication system fails or is switched off, the motor shall rundown safely.

11.4.9.4 Rolling element bearings

11.4.9.4.1

Rolling element bearings shall be regreasable with a minimum lubrication interval in accordance with Table 28.

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

11.4.9.4.2

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

11.4.9.4.3

The minimum L_{10h} bearing design lifetime in accordance with ISO 281 shall be in accordance with Table 29.

Add new Table 29

Table 29 – Minimum L_{10h} bearing design lifetime

Motor mounting type	**Minimum L_{10h} bearing design lifetime** h
Horizontal	50 000
Vertical	40 000

11.4.9.4.4

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

11.4.9.4.5

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.

11.4.9.4.6

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

11.4.9.4.7

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

11.4.9.4.8

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

11.4.9.4.9

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

11.4.9.4.10

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.

11.4.9.4.11

Rolling element bearings shall have a metallic cage.

11.4.9.4.12

Rolling element bearings shall be a metric size and conform to ISO 15 and ISO 492.

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.

11.4.11 Torsional analysis

When specified, torsional analysis shall be performed in accordance 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.

11.4.12.1.2

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

11.4.12.1.3

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

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.

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.

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.

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.

11.4.12.4.2.2

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

11.4.12.5 Partial discharge monitoring

11.4.12.5.1

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

11.4.12.5.2

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

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.

11.4.13.2

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

11.4.13.3

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

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.

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.

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.

11.4.15 Motors intended for use in hazardous area

11.4.15.1 Certification

11.4.15.1.1

Motors and their mounted components shall be certified for the specified protection level in accordance with IEC 60079 (all parts).

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.

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.

Add to subclause

11.4.15.3

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

11.4.15.4 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.

12 Tolerances

12.1 General

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

IEC Guide 115:2023

Bibliography

Add to start of Bibliography

The following documents are informatively cited in the text of this specification, IEC 60034-1, the PDS (IOGP S-704D) or the IRS (IOGP S-704L).

Add to Bibliography

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* Cited in IOGP S-704J only.

Delete from Bibliography

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