



BSI Standards Publication

Petroleum and natural gas industries — Drilling and production equipment — Electric submersible pump systems for artificial lift

National foreword

This British Standard is the UK implementation of EN ISO 15551:2023. It is identical to ISO 15551:2023. It supersedes BS EN ISO 15551-1:2015, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PSE/17, Materials and equipment for petroleum, petrochemical and natural gas industries.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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English Version

**Petroleum and natural gas industries - Drilling and
production equipment - Electric submersible pump
systems for artificial lift (ISO 15551:2023)**

Industries du pétrole et du gaz naturel - Équipement de
forage et de production - Systèmes de pompes
submersibles électriques pour relevage artificiel (ISO
15551:2023)

Erdöl- und Erdgasindustrie - Bohr- und
Förderausrüstung - Elektrische Tauchpumpen zur
Förderung (ISO 15551:2023)

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CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

This document (EN ISO 15551:2023) has been prepared by Technical Committee ISO/TC 67 "Oil and gas industries including lower carbon energy" in collaboration with Technical Committee CEN/TC 12 "Oil and gas industries including lower carbon energy" the secretariat of which is held by NEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2024, and conflicting national standards shall be withdrawn at the latest by April 2024.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

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The text of ISO 15551:2023 has been approved by CEN as EN ISO 15551:2023 without any modification.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 67, *Oil and gas industries including lower carbon energy*, Subcommittee SC 4, *Drilling, production and injection equipment*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 12, *Oil and gas industries including lower carbon energy*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This first edition cancels and replaces ISO 15551-1:2015, which has been technically revised.

The main changes are as follows:

- the relationship between the design verification/validation activities and the functional specification/technical specification has been revised. In this document, the design verification/validation activities have been tied to a “basis of design” rather than to the functional specification/technical specification;
- [Annex E](#) has been augmented to incorporate additional details, guidelines and options for completing functional evaluation of assembled systems;
- [Annex L](#) is a “user’s guide”, which has been added to this document to provide a simplified view of the practical workflow of the document.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Petroleum and natural gas industries — Drilling and production equipment — Electric submersible pump systems for artificial lift

1 Scope

This document specifies requirements for the design, design verification and validation, manufacturing and data control, performance ratings, functional evaluations, handling and storage of tubing-deployed electrical submersible pump (ESP) systems. Additionally, this document provides requirements for assembled ESP system.

This document is applicable to those ESP related components meeting the definition of centrifugal pumps, including gas handling devices, discharge heads, seal chamber sections, intake systems, mechanical gas separators, asynchronous 3 phase - 2 pole induction motors (herein motor), shaft couplings, downhole power cables (herein power cables), motor lead extension, and pothead. Components supplied under the requirements of this document exclude previously used subcomponents, except where the use of such subcomponents is as defined in this document ([Clause 9](#)).

This document addresses design validation performance rating requirements by component (see [Annex A](#)), requirements for determining ratings as an assembled system (see [Annex B](#)), functional evaluation: single component (see [Annex C](#)) and cable reference information (see [Annex D](#)).

This document addresses functional evaluation guidelines for assembled ESP systems, establishing recommended operating range (ROR) of the ESP system (see [Annex F](#)), example user/purchaser ESP functional specification form (see [Annex G](#)), considerations for the use of 3-phase low and medium voltage adjustable speed drives for ESP applications (see [Annex H](#)), analysis after ESP use (see [Annex I](#)), downhole monitoring of ESP assembly operation (see [Annex J](#)), information on permanent magnet motors for ESP applications (see [Annex K](#)) and users guide (see [Annex L](#)).

This document also includes a user guide that offers a high-level process workflow when applying this document.

This document does not apply to: wireline and coiled tubing-deployed ESP systems, motor shrouds and pump shrouds, electric penetrators and feed-through systems, cable clamps and banding, centralizers, intake screens, passive gas separators, by-pass tools, check and bleeder valves, component adaptors, capillary lines, electric surface control equipment, downhole permanent magnet motors and non-conventionally configured ESP systems such as inverted systems. This document does not apply to Repair and redress equipment requirements.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60228, *Conductors of insulated cables*

ISO 9000, *Quality management systems — Fundamentals and vocabulary*

ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel*

API RP 11S2, *Electric Submersible Pump Testing*

API RP 11S6, *Recommended Practice for Testing of Electrical Submersible Pump Cable Systems*

API RP 11S7, *Recommended Practice of Application and Testing of Electric Submersible Pump Seal Chamber Section*

API RP 11S8, *Practice on Electric Submersible Pump System Vibrations*

ASTM B3, *Standard Specification for Soft or Annealed Copper Wire*

ASTM B8, *Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft*

ASTM B33, *Standard Specification for Tin Coated Soft or Annealed Copper Wire for Electrical Purposes*

ASTM B189, *Standard Specification for Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes*

ASTM B193, *Standard Test Method for Resistivity of Electrical Conductor Materials*

ASTM B258, *Standard Specification for Standard Nominal Diameters and Cross-Sectional Areas of AWG Sizes of Solid Round Wires Used as Electrical Conductors*

ASTM B496, *Standard Specification for Compact-Round Concentric-Lay-Stranded Copper Conductors*

ASTM D471, *Standard Test Method for Rubber Property — Effect of Liquids*

ASTM E8, *Standard Test Methods for Tension Testing of Metallic Materials*

ANSI/NEMA WC 53, *Standard Test Methods for Extruded Dielectric Power, Control, Instrumentation, and Portable Cables for Test*

ASTM D877, ASTM D877M, *Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes*

ASTM D1816, *Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using VDE Electrodes*

IEEE Std 1018, *Recommended Practice for Specifying Electric Submersible Pump Cable - Ethylene-Propylene Rubber Insulation*

IEEE Std 1019, *Recommended Practice for Specifying Electric Submersible Pump Cable-Polypropylene Insulation*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 9000 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1

adapter

device used to connect components that are not directly compatible

3.2

adjustable speed drive

device that controls an electric motor's speed by manipulating both the output voltage and the power frequency being supplied to the motor

3.3**ampacity**

maximum current that can pass through a power cable without exceeding its temperature limit for a specific operating environment

3.4**ampacity coefficient**

temperature rise of the power cable divided by the square of the amperage for a specific operating environment

3.5**armor**

outer covering to the power cable that can provide protection from mechanical damage and provides mechanical constraint against swelling or expansion of underlying materials on exposure to well fluids

3.6**assembled electrical submersible pump system****assembled ESP system**

assembly of electric submersible pump downhole equipment which includes some or all components such as centrifugal pumps, gas handling devices, discharge head, seal chamber sections, intake system, mechanical gas separators, motors, shaft couplings, power cable, motor lead extension, and pothead

3.7**auxiliary equipment**

equipment or components that are typically selected and/or installed by the user/purchaser

EXAMPLE Cable protectors, motor shrouds, by-pass tools and electrical penetrators.

3.8**axial flow stage**

type of stage with inlet and exit flow path essentially parallel to the shaft axis

3.9**positive seal element**

flexible subcomponent of a seal chamber section that functions as a positive barrier that isolates the wellbore production fluid from the motor fluid, commonly referred to as bag, bladder or bellows.

3.10**positive seal element chamber**

chamber that houses the positive seal element

3.11**barrier**

subcomponent of an electrical submersible pump power cable that can be applied over the insulated conductors and provides fluid protection, hoop strength or both

3.12**best efficiency point****BEP**

pump performance values at the flow rate where the pump efficiency is highest

3.13**bleeder valve**

valve placed above a check valve for the purpose of reducing pressure or draining the fluid from within the production tubing

3.14**braid**

supplementary layer of material used to provide mechanical performance characteristics to the power cable system such as hoop strength for gas decompression

3.15

bubble point

pressure at which gas begins to break out of under-saturated oil/fluid and form a free gas phase

3.16

by-pass tool

device that is installed into the wellbore along with the electrical submersible pump (ESP) assembly that divides the tubing system to permit the installation of additional tubing string parallel to the ESP

3.17

cable band

metal band that is used to secure electrical submersible pump power cable to production tubing

3.18

cable clamp

device, usually of rigid material, for strengthening or supporting power cable to production tubing

3.19

capillary line

independent tubing string commonly used for hydraulic control of safety valves and sliding sleeves or for chemical injection

3.20

casing

pipe extending from the surface and intended to line the walls of a drilled well

3.21

centralizer

device used to keep the electrical submersible pump assembly or other downhole equipment in the centre of the tubing, casing or wellbore

3.22

centrifugal pump

component of an electrical submersible pump system that uses rotating impeller(s) to impart kinetic energy (velocity) by centrifugal force to a fluid and stationary diffusers to convert the kinetic energy to potential energy (pressure)

3.23

chamber

subcomponent of the seal chamber section

3.24

check valve

device that allows one-directional flow of fluid when a differential pressure exists

3.25

coefficient of determination

statistic used to determine the strength of a fit between a mathematical model and a set of observed data values

3.26

coiled tubing

pipe typically supplied and installed in one continuous length and wound onto a reel or spool

3.27

common hardware

hardware that does not require traceability and is included as part of an electrical submersible pump component

EXAMPLE Bolts, washers, screws, and snap rings.

3.28**compact stranded**

electrical conductor configuration in which a multiple-strand conductor has been compacted to reduce its circumference while maintaining conductor area

3.29**component**

individual part of an assembly

EXAMPLE Pumps (including gas handling devices), discharge heads, seal chamber sections, intake systems, mechanical gas separators, induction motors, shaft couplings, downhole cables, motor lead extensions, and potheads.

3.30**compression pump**

configuration where the impeller is fixed to the shaft to prevent axial movement

3.31**conductor**

subcomponent of the power cable that functions to conduct electrical power

3.32**conductor shield**

layer adjacent to the conductor to distribute voltage stress evenly over the surface of the conductor

3.33**configuration**

component designation that identifies the end connection designs for attaching additional components in series

EXAMPLE Upper tandem, lower tandem, middle/centre tandem, and single tandem.

3.34**contraction capacity**

volume that a chamber or set of parallel chambers can draw in due to temperature and pressure cycles without allowing wellbore fluid ingress through the chamber or causing damage

3.35**coupling**

device that connects the shafts of electrical submersible pump components

3.36**conductor resistance test**

method for determining the cable conductor resistance value

3.37**deployment method**

method used to deploy the electrical submersible pump downhole equipment to its setting location

3.38**design basis**

documented set of conditions, needs, and requirements taken into account by the supplier/manufacturer in designing and establishing performance ratings of a facility or product

3.39**design validation**

process of proving a design by testing to demonstrate conformity of the product to design requirements and performance ratings

3.40

design verification

process of examining the premise of a given design by calculation, comparison or investigation, to substantiate conformity with specified requirements

3.41

deviation survey

measurement of a borehole's trajectory over the wellbore length for the purposes of electrical submersible pump design and application

3.42

diffuser

stationary stage segment of a centrifugal pump which converts the pumped fluid velocity (kinetic energy) to a pressure (potential energy)

3.43

discharge head

component on the output end of the pump for connecting to the production tubing

3.44

dogleg severity

total angular inclination and azimuth in the wellbore, casing or liner, calculated over a standard length

3.45

effective diameter

theoretical minimum diameter through which the assembled electrical submersible pump system passes, including installation of all required electrical submersible pump ancillary equipment

3.46

efficiency

output work divided by input work

3.47

elastomer

polymer with the property of viscoelasticity (elasticity), generally having a low Young's modulus and a high yield strain

3.48

electric penetrator

electrical connector that functions to transition power cable and/or instrument wires through a sealing barrier

EXAMPLE Wellhead, wellbore packer, electrical submersible pump pod or canister.

3.49

electric surface control equipment

electrical equipment used to control the operation of the electrical submersible pump assembly

Note 1 to entry: This electrical equipment is commonly referred to as an adjustable speed drive or switchboard.

3.50

electromagnetic region

region of an induction motor relative to the cylindrical boundary defined by the outside diameter of the stator laminations, and the axial length which encompasses all the coiled wire of the stator

3.51

electric submersible pump assembly

ESP assembly

assembly of ESP downhole equipment that includes some or all components such as centrifugal pumps, gas handling devices, discharge head, seal chamber sections, intake system, mechanical gas separators, motors, shaft couplings, power cable, motor lead extension, and pothead

3.52**enhanced oil recovery**

reservoir process involving the injection of materials not normally present in the reservoir to enhance the overall oil recovery from such reservoir

[SOURCE: ISO/TS 3250:2021, 3.1.10]

3.53**failed item**

item that can no longer perform its required function

3.54**failure mechanism**

process that leads to failure

Note 1 to entry: The process can be physical, chemical, logical, or a combination thereof.

[SOURCE: ISO 14224:2016, 3.29, modified — Note 2 to entry has been deleted.]

3.55**failure cause****root cause**

circumstances during design, manufacture or use, which have led to a failure. set of circumstances that leads to failure

Note 1 to entry: A failure cause can originate during specification, design, manufacture, installation, operation or maintenance of an item.

3.56**fault**

inability to perform as required, due to an internal state

Note 1 to entry: A fault of an item results from a failure, either of the item itself, or from a deficiency in an earlier stage of the life cycle, such as specification, design, manufacture or maintenance.

[SOURCE: ISO 14224:2016, 3.33, modified — Notes 2 and 3 to entry have been deleted.]

3.57**feed-through system**

fixture which allows the passage of electricity from one side of a barrier to another while maintaining a seal of gas or liquid through the barrier

3.58**floater type pump construction**

configuration where the impeller is not fixed to the shaft to permit limited axial movement

3.59**flowing pressure**

pressure in the wellbore at a specific vertical depth at a specific flow rate

3.60**fretting**

special wear process that occurs at the contact area between two materials under load and subject to minute relative motion by vibration or some other force

3.61**functional evaluation**

test(s) performed to confirm electrical submersible pump (ESP) component operation or assembled ESP system operation as per design

Note 1 to entry: Occasionally referred to as factory acceptance test in case of ESP component and as string test in case of assembled ESP system.

3.62

functional specification

document that describes the features, characteristics, process conditions, boundaries and exclusions defining the performance and use requirements of the product, process or service

Note 1 to entry: See ISO 13879 and ISO 13880.

3.63

gas handler

component of an electrical submersible pump system that conditions multiphase flow, without gas separation, to decrease the degradation of pump performance

3.64

gas oil ratio

GOR

produced gas-oil ratio

volumetric ratio of gas to oil at standard conditions

3.65

gas separator

component of an electrical submersible pump system that mechanically separates a portion of the free gas from the wellbore fluids prior to the fluids entering the pump or gas handler

3.66

head curve

amount of head generated by the pump as a function of flow rate for a specific speed

3.67

high potential test

test comprising of applying a DC voltage higher than the nominal voltage rating of the component for a specified amount of time

3.68

housing pressure rating

value of the maximum allowable difference of internal less external pressure

3.69

impeller

stage segment rotated by the shaft which adds kinetic energy (velocity) to the fluid being pumped

3.70

inclination

angle, measured in degrees, by which the wellbore or survey-instrumented axis varies from a true vertical line

3.71

induction motor

motor

component of an electrical submersible pump system where AC power input is transformed to mechanical torque by means of electromagnetic induction

3.72

intake

subcomponent of a pump which provides a flow path to the first impeller, constructed either integral to the pump or bolted-on to the pump

3.73

intake screen

attachment to the pump intake used to filter solid particles from the produced fluid to protect the internal components of the pump

3.74**insulation**

provision to isolate the electrical potential between conductors and other conducting materials and to minimize leakage current from the conductors

3.75**insulation AC discharge test**

test where a high AC voltage is applied until the insulation breaks down or fails

3.76**insulation resistance test**

DC voltage-based test to evaluate the general condition of an insulation system

Note 1 to entry: This test is performed by measuring total leakage current flowing through the insulation system by applying a DC test voltage lower than the nominal voltage rating of the component.

Note 2 to entry: For the purposes of this test, the DC voltage applied shall be approximately $(0,5 \times \text{nameplate voltage})$ but not less than 500 V.

3.77**inversion point**

water cut percentage at which the emulsion viscosity is at its maximum

3.78**inverted system**

electrical submersible pump system configured with the pump on the bottom and motor on the top

3.79**item**

subject being considered

Note 1 to entry: The item can be an individual part, component, subunit, equipment, system, plant or installation.

Note 2 to entry: The item may consist of hardware, software, people or any combination thereof.

[SOURCE: ISO 14224:2016, 3.43].

3.80**jacket**

subcomponent of an electrical submersible pump power cable that covers the insulated conductors and provides mechanical protection from the downhole environment

3.81**labyrinth chamber**

chamber which utilizes a vertical U-tube, maze-like or tortuous flow path to delay wellbore fluid ingress through the chamber

3.82**lamination**

thin electrical grade metallic subcomponents that form the magnetic core of the stator and the rotor(s)

3.83**liner**

pipe extending from the surface or another point lower in the wellbore to a depth within or below the existing casing

3.84**manufacturing**

process and action performed by an equipment supplier/manufacture that are necessary to provide finished component(s), assembly(ies) and related documentation, that fulfil the requests of the user/purchaser and meet the standards of the supplier/manufacture

3.85

mechanical seal

subcomponent used to prevent flow between a rotating shaft and a stationary body

3.86

megger

instrument that generates a high voltage to test the resistance of insulation

3.87

minimum allowable bending radius insulation discharge

high-voltage test which is applied to a cable at its minimum allowable bending radius until the insulation breaks down/fails

3.88

mixed flow stage

type of stage with inlet flow path essentially parallel to shaft axis and exit between perpendicular and parallel to the shaft axis

3.89

model

equipment with unique components and operating characteristics which differentiate it from other equipment of the same type

3.90

motor fluid

fluid internal to the motor and seal chamber section that provides lubrication to the bearing systems, heat transfer to the unit skin, and dielectric insulation for the motor

3.91

motor lead extension

MLE

cable connected to the pothead for splicing to the power cable

3.92

motor operating temperature

temperature at or near the coils of the stator when it is energized

3.93

motor shroud

tube which covers the motor length of the electrical submersible pump to promote fluid flow past the motor

3.94

net positive suction head

NPSH

head corresponding to the difference between the pump inlet pressure and the vapour pressure and the density of fluid and the gravitational acceleration

3.96

new subcomponent

subcomponent which meets all supplier/manufacturer specifications and that has not been previously utilized in a component that has been either operated or installed in a field environment

3.97

operator

user of the equipment

3.98

operator's manual

publication issued by the supplier/manufacturer which contains detailed data and instructions related to the design, installation, operation and maintenance of the equipment

3.99**operating environment**

set of downhole conditions to which the component is exposed during its full life cycle

3.100**parallel chambers**

configuration of at least two seal chambers that function together to increase contraction capacity

3.101**passive gas separator**

device intended to reduce the amount of free gas entering into the pump intake through a selective fluid intake point or directing fluid flow path

3.102**performance rating**

technical limit(s) of a product when functioned at defined operating condition(s) and exposed to defined environmental condition(s)

3.103**permanent identification**

marking that remains legible over the intended service life of the component and/or subcomponent

3.104**permanent magnet motor**

type of motor that uses permanent magnet rotor(s) instead of induction rotor(s) as a way to create torque

3.105**pothead**

power connector on the end of the motor lead extension or power cable which mates to the motor

3.106**power cable**

component of the electrical submersible pump (ESP) system that connects the motor lead extension (MLE) or ESP motor surface electrical equipment or electrical penetrator connector to the MLE or motor

3.107**primary failed item**

failed component within the electrical submersible pump (ESP) system responsible for initiating the failure of the ESP system

3.108**primary failure mechanism**

failure mechanism associated with the primary failed item

3.109**pump construction**

configuration of which the pump stages are assembled with respect to axial movement relative to the shaft such as compression, floater, modular

3.110**pump differential pressure**

difference between discharge and intake pressures

3.111**pump housing**

tube containing pump subcomponents pertaining to the impellers and diffusers and functioning as a pressure barrier

3.112

pump shroud

tube which covers the pump length of the electrical submersible pump intended to limit free gas migration into the pump intake

Note 1 to entry: This item is sometimes referred to as an inverted shroud.

3.113

qualified person

individual with or abilities gained through training or experience or both as measured against established requirements, such as standards or tests that enable the individual to perform a required function

3.114

radial flow stage

type of stage with inlet flow path essentially parallel to shaft and exit essentially perpendicular to the shaft axis

3.115

redress

activities performed to a component restricted to the replacement of parts that restores the equipment to its acceptable performance

3.116

recertified subcomponent

subcomponent that has been previously utilized in a component that has been operated or installed in a field environment and where the subcomponent has then been tested and/or inspected by the supplier/manufacturer using the same specifications and test equipment used in the evaluation of new subcomponents

3.117

reference fluid

water corrected to specific gravity of 1,0 at standard conditions

3.118

reference speed

shaft rotational speed at 60 Hz operation (3 500 r/min) and/or 50 Hz operation (2 918 r/min)

3.119

reference temperature

temperature set at 20 °C

3.120

repair

activity beyond the scope of redress that includes disassembly, re-assembly, and testing with or without the replacement of parts and can include machining, welding, heat treating or other manufacturing operations that restores the equipment to its original performance

3.121

reason for pull

motive for the electrical submersible pump assembly being pulled from the well

3.122

required function

function or a combination of functions of an item, which is considered necessary to provide a given service

3.123

rotor

subcomponent of a motor, mechanically attached to the shaft, whose magnetic field is induced by the magnetic field of the stator, resulting in torque applied to the shaft

3.124**safety factor**

defined measure of a reduced value from a known capacity

3.125**sand cut**

amount of sand or solid material in the wellbore fluid, typically expressed as a volumetric or mass percentage

3.126**seal chamber section**

component of an electrical submersible pump system that protects the interior of the motor from well fluids and other contaminants, carries the pump thrust, maintains pressure equalization with wellbore fluid pressure and/or transmits the motor torque to the component above it

3.127**semi-permanent identification**

marking that remains legible until the component and/or subcomponent is installed, such as, a metal stamped nameplate or tag

3.128**series**

component designation that identifies the outer diameter of its housing

3.129**shaft end play**

axial movement the component shaft has, generally measured from a reference point

3.130**shaft extension**

measurement of the component shaft end in relation to a reference point

3.131**shaft side play**

radial movement of a component shaft, resulting from clearances between rotating and stationary radial support components

3.132**shipping hardware**

auxiliary equipment that is shipped as part of an electrical submersible pump component to help protect the component during the shipping and handling process

3.133**slip**

difference between the AC motor synchronous speed and the actual operating speed divided by the synchronous speed, expressed in percentage

3.134**slugging**

well production characterized by cyclic flow of fluid mixtures of different densities, such as gas and liquid or two differing liquid viscosities

3.135**solution gas-oil-ratio**

amount of gas dissolved in the oil and increases with pressure until the bubble point pressure is reached, after which it is a constant

3.136**spline type**

machined configuration of the end of component shafts to allow connection by couplings to adjoining components, such as modified SAE and involute

3.137

stage

matched set of one impeller and one diffuser

3.138

stage name

nomenclature given to each pump stage type that typically defines its flowrate (best efficiency point), its size (diameter), and any special fluid handling characteristics

3.139

standard condition

condition set at 100 kPa (14,7 psia) and 15 °C (60 °F)

3.140

stator

subcomponent of the motor which contains laminations and coiled wire and housed in a tube

3.141

stock tank flow rate

wellbore fluid rate reported at standard conditions

3.142

subcomponent

portion of a component made up of one or more pieces

3.143

substantive design change

change to the design that is identified by the supplier/manufacturer as affecting the performance rating of the product

3.144

synchronous speed

supply power frequency divided by the number of poles of the AC motor

Note 1 to entry: When expressed in revolutions per minute, the formula to calculate synchronous speed is power frequency (expressed in Hz) times 120, divided by the number of poles.

3.145

tandem

designation that indicates where in the modular system an electrical submersible pump (ESP) component, such as a motor, would be used

Note 1 to entry: There are four different tandem designations for ESP components: upper tandem, middle tandem, lower tandem and single.

3.146

technical specification

document that prescribes the technical characteristics of the product, process or service to be provided to demonstrate its appropriateness to meet the requirements of the functional specification

3.147

test open flow

maximum pump flow rate attainable on test

3.148

thrust bearing

device to support axial load of a rotating part

3.149

thrust load bearing capacity

axial load capacity of a thrust bearing as defined by the bearing design, lubrication fluid and operating environment

3.150**thrust washer**

subcomponent mounted on an impeller which carries the axial thrust

3.151**torsional yield ratio**

ratio of the material yield point in torsion to the material yield point in tension

3.152**total demand distortion****TDD**

measure of the distortion of a current profile relative to its full load value

Note 1 to entry: It is calculated as the ratio of the root-mean-square total of the harmonic content to the full load value, expressed as a percentage. Using this measure, rather than total harmonic distortion (THD), allows for higher current THD when load is low.

3.153**total harmonic distortion****THD**

measurement of the harmonic distortion present in a voltage or current waveform

Note 1 to entry: It is calculated as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency.

Note 2 to entry: See H.2.

3.154**tubing-deployed electrical submersible pump****tubing-deployed ESP**

ESP system which is deployed into the wellbore using jointed tubing rather than by other deployment means such as wireline or coiled tubing

3.155**unique identifier**

unique combination of alphanumeric characters to identify a specific component

3.156**water cut**

ratio of produced water to produced liquids

Note 1 to entry: It is expressed as a percentage.

3.157**wireline deployed electrical submersible pump****wireline deployed ESP**

ESP system which is deployed into the wellbore using wireline rather than by other deployment means such as jointed tubing or coiled tubing

3.158**specified requirement**

design basis that the supplier/manufacturer uses for designing and establishing the performance ratings of the product

4 Symbols and abbreviated terms

AC	alternating current
ASD	adjustable speed drive
AWG	American wire gauge
BEP	best efficiency point
c	ampacity coefficient
C_{load}	de-rating factor
cP	centipoise
DC	direct current
dV/dt	change in voltage divided by change in time
E	efficiency
ESD	emergency shut down
ESP	electric submersible pump
F_a	adjusted thrust
F_n	thrust at test revolutions per minute
g	unit for g-force
G	gas volume fraction
GVF	gas volume fraction
H	head
H_a	adjusted head
H_n	head at test revolutions per minute
HP	horsepower
I	amperage
IEC	International Electrotechnical Commission
ID	internal diameter
K	extrapolated temperature for zero resistance
kVA	kilovolt-amperes
kW	kilowatt
L_t	thrust test load
L_0	nominal thrust load rating of bearing at 3 500 r/min and 5 cP lubricating fluid viscosity
MD	measured depth

MLE	motor lead extension cable
NEMA	National Electrical Manufacturers Association
NDE	non-destructive examination
OD	outside diameter
P_a	adjusted power
pH	potential of hydrogen
p_i	pump intake pressure
P_f	fluid power
PMM	permanent magnet motor
P_m	shaft mechanical power
P_n	power at test revolutions per minute
p_o	pump discharge pressure
PSD	pump setting depth
P_s	shaft power rating
P_{sc}	shaft coupling power rating expressed in kilowatt or horsepower
PVT	pressure, volume, temperature
PWM	pulse width modulated
Q	flow rate
Q_a	adjusted flow rate
Q_n	flow rate at test revolutions per minute
Q_{GGE}	gas flow rate out of gas exit
Q_{Gi}	intake gas flow rate
Q_{Li}	intake liquid flow rate
R^2	coefficient of determination
R_f	resistance of winding at the time of motor de-energization
R_b	resistance of winding before test at a known temperature
RMS	root mean square
ROR	recommended operating range
SCR	silicon controlled rectifier
T	temperature
T_{aw}	Average winding temperature rise

T_b	temperature at the time R_b is taken
T_f	temperature of the test fluid at the time of motor de-energization
THD	total harmonic distortion
TVD	true vertical depth
TVSS	transient voltage surge suppressors
UL	Underwriter's Laboratories
u_t	actual lubricating fluid test viscosity (absolute) in cP
v	rotational speed in revolutions per minute (r/min)
VDC	volts direct current
VFD	variable frequency drive
v_n	actual shaft rotational speed during test in revolutions per minute
v_r	reference revolutions per minute
VSD	variable speed drive
WAG	water alternating gas
Y_i	predicted value of the dependent variable as determined by the mathematical model
y_i	observed value of the dependent variable
$\bar{y}$	mean of the observed data y_i
β	Input power in kilowatts (kW)
ρ_f	fluid density
τ	torque

5 Functional specification

5.1 General

The user/purchaser shall prepare a functional specification when ordering components which conform to this document and shall specify the requirements and operating conditions as appropriate. This information is used by the supplier/manufacturer to recommend the components for the application. The user/purchaser shall specify the units of measurement for the data provided.

ESPs are designed for specific applications. When used in other applications, re-evaluation is required. The process used for this re-evaluation shall be no less stringent or documented than that required for the initial application, and shall be subject to approval.

The user/purchaser shall specify in the functional specification, whether the supplier/manufacturer technical specification response is based on supply of component(s) only or on component(s) and assembled system(s).

5.2 Component type

The user/purchaser shall request an ESP system on the basis of the following conditions:

- production profile for production period (i.e. the expected operating time period of the system);
- fluid characteristics;
- deployment method of the ESP, such as jointed tubing, wireline, coiled tubing.

5.3 Functional requirements

5.3.1 General

The user/purchaser shall specify the known and anticipated application parameters and requirements to the best of their knowledge. Operational issues that can have an effect on the systems operation and durability, such as frequency of shutdowns, power interruptions, production fluid changes, power quality and other issues, shall also be specified.

5.3.2 Application parameters

5.3.2.1 General

While installed, the ESP system shall perform in accordance with its functional requirements, which are typically determined based on application parameters.

5.3.2.2 Well information

5.3.2.2.1 Requirements

The following well information, whether planned or existing, shall be specified:

- a) geographical location;
- b) operating environment, such as heavy and conventional oil production, coal bed methane applications and source water production;
- c) well type, such as vertical, slant, deviated or horizontal;
- d) wellhead location, such as onshore, platform or subsea;
- e) reservoir type, such as carbonate, consolidated sandstone, unconsolidated sandstone, coal or shale;
- f) reservoir recovery mechanism or process, such as aquifer drive, solution gas drive, water flood, thermal or coal dewatering;
- g) enhanced oil recovery, such as CO₂ flood, water-alternating-gas or polymer flood;
- h) existing or planned power supply details, such as generator/utility, volts, frequency, kVA/Amp supply limitations;
- i) existing or planned surface equipment details, such as switchboard, 6-step ASD, PWM ASD, filtered PWM ASD, space restrictions.

5.3.2.2.2 Supplemental Information

The following well information shall be specified, if available:

- a) well profile, such as “S shaped”, “U shaped”, sinusoidal or multilateral;

- b) geothermal gradient/profile;
- c) pertinent production history using ESP's and other methods, such as other artificial lift methods or natural flow.

5.3.2.3 Completion information

5.3.2.3.1 Requirements

The following completion information, whether planned or existing, shall be specified:

- a) proposed pump setting depth in terms of MD and TVD of the pump intake;
- b) existing or planned total well depth, such as plug back depth in terms of MD and TVD;
- c) depth(s) of producing interval(s), top and bottom, in terms of MD and TVD;
- d) casing/liner size including outside diameter and weight, connection type and grade of production casing;
- e) minimum drift diameter through wellhead to bottom of the ESP assembly;
- f) production tubing size(s) including outside diameter, mass (weight), connection type, and grade;
- g) completion type, such as perforated casing or open hole;
- h) sand control measures, such as none, slotted liner, gravel pack or sand screen;
- i) ESP system configuration, such as single, dual back-up/boost or y-tool.

5.3.2.3.2 Supplemental information

The following completion information shall be specified, if available:

- a) well deviation survey; or, if not provided, as a minimum:
 - inclination and estimated dogleg severity at pump setting depth;
 - maximum dogleg severity between wellhead and pump setting depth for each casing or liner segment that the ESP has to pass through during installation;
- b) production tubing inner coating type and thickness;
- c) completion thermal characteristics, such as heat transfer coefficients for completion, insulated tubing/annulus, or flowing temperature profile;
- d) completion diagram.

5.3.2.4 Operating and production information

5.3.2.4.1 Requirements

The following operating and production information shall be provided over the life cycle of the system, such as early life, mid-life and late life:

- a) expected well production flow performance, including, as a minimum, expected flow rate such as stock tank flow rate or pump discharge rate, flowing bottom-hole pressure or fluid level at expected flow rate for a specified depth, and any maximum drawdown limitations;
- b) water cut;
- c) tubing head flowing pressure;

- d) casing head pressure;
- e) static temperature at a reference depth;
- f) total producing gas-oil-ratio;
- g) special operational conditions, such as unloading heavy completion fluids, sand face control limitations, delayed start-up, unusual anticipated duty cycles (stops and starts);
- h) minimum expected bottom-hole temperature;
- i) maximum expected bottom-hole temperature.

5.3.2.4.2 Supplemental information

The following operating and production information shall be provided over the life cycle of the system, such as early life, mid-life and late life, if available:

- a) sand cut;
- b) wellhead flowing fluid temperature;
- c) flowing temperature at a reference depth;
- d) slugging tendency, such as gas, water, solids or steam;
- e) desired operating frequency range and desired operating frequency at target rate.

5.3.3 Environmental compatibility

The user/purchaser shall specify the environmental compatibility requirements and preferred fluid property correlations by providing the following parameters:

- a) oil:
 - 1) density at standard temperature and pressure or API gravity;
 - 2) viscosity at standard conditions;
 - 3) bubble point pressure at reservoir temperature;
 - 4) solution gas-oil-ratio;
- b) water:
 - 1) pH;
 - 2) density;
 - 3) chloride concentration/salinity;
 - 4) other corrosives, if applicable;
- c) gas:
 - 1) Composition, such as:
 - i) CO₂ concentration (mole percentage);

- ii) H₂S concentration (mole percentage);
- 2) specific gravity;
- d) solids:
 - 1) history of solids related problems (e.g. erosion, plugging, wear);
 - 2) erosional velocity limit, if known;
 - 3) morphology, such as size, structure, angularity, composition;
 - 4) if sand control system is present, expected particle size distribution that will be present in production fluid;
 - 5) scale deposition tendency;
 - 6) asphaltene deposition tendency;
 - 7) paraffin deposition tendency.
- e) other:
 - 1) emulsion properties, such as:
 - i) inversion point data (percentage water cut);
 - ii) emulsion viscosity at downhole operating conditions over predicted pump life;
 - iii) emulsion forming tendency;
 - 2) foamy oil behaviour, such as that affecting annular fluid level;
 - 3) other fluid types and concentrations, such as diluent, corrosion/scale inhibitor, completion fluid, dispersants and injection points in the wellbore.

5.3.4 Compatibility with related well equipment and services

5.3.4.1 General

The user/purchaser shall specify related well equipment and service considerations that can impact the compatibility of the proposed component for the well such as material requirements, dimensional limitations, transportation, and installation restrictions, to ensure that the component conforms to the intended application.

5.3.4.2 Accessory equipment and well operation

The following topics shall be considered for the application:

- a) dimension of chemical injection tubing/string line and injection point such as above pump, below pump, annulus, tubing string;
- b) surface instrumentation dimension and location such as above or below pump as applicable;
- c) surface equipment dimensions, location relative to the pump and attachment to the pump such as by pass systems, clamps, shrouds, pod, tail pipes, backflow valves, swages;
- d) well intervention limitations such as; maximum allowable pump length, maximum coiled tubing diameter;
- e) packer type, location in the wellbore relative to ESP assembly;
- f) casing gas venting scheme such as vented to atmosphere, vented to production flow line, no venting;

- g) other completions related equipment that might impact the deployment and/or operation of the ESP system.

5.4 User/purchaser selections

5.4.1 General

[Table 1](#) provides the compiled list of the selection criteria for ESP components that shall be selected by the user/purchaser. The grades can vary by component as selected by the user/purchaser. Guidelines on the selections available is provided in [5.4.2](#), [5.4.3](#) and [5.4.4](#).

Table 1 — User/purchaser grade selections

Component	Selected grades								
	Design validation (Annex A)			Functional evaluation (Annex C)			Quality control (7.4)		
	V1	V2	V3	F1	F2	F3	Q1	Q2	Q3
Bolt-on discharge				a	a	a			
Pump and gas handlers									
Bolt-on intake					a	a			
Mechanical gas separators						a			
Seal chamber sections									
Motor									
Cable, MLE and pothead									
Assembled ESP system	Annex B ^b			Annex E					
^a Unavailable sections.									
^b Indicates that component has no grade selections.									

5.4.2 Design validation

This document provides three design validation grades as indicated in [Table A.1](#), of which one shall be selected by the user/purchaser:

- V1: highest grade;
- V2: intermediate grade;
- V3: basic grade.

5.4.3 Component functional evaluation

The user/purchaser shall specify a component functional evaluation grade for each component as indicated in [Table 1](#). This document provides requirements for three functional evaluation grades, noting that some components can have fewer:

- F1: highest level of functional evaluation;
- F2: intermediate level of functional evaluation;
- F3: basic level of functional evaluation.

For assembled systems, guidelines for completing a functional evaluation are provided in [Annex E](#).

5.4.4 Quality grades

The user/purchaser shall specify one of the following three quality grades, which are detailed in [Clause 7](#):

- Q1: highest level of quality;
- Q2: intermediate level of quality;
- Q3: basic level of quality.

5.4.5 Shipping, handling and storage

The user/purchaser shall specify environmental conditions and projected storage duration as well as any special shipping and handling requirements for the components.

5.4.6 Operator's manual

The user/purchaser shall specify if an operator's manual for the ESP system as specified in [7.2.3](#) is required.

5.4.7 Subcomponent condition classifications in manufacture of components

The user/purchaser shall apply the following as it pertains to subcomponent classification use in the manufacture of components:

- All Q2 and Q1 specified equipment shall be manufactured using “new” subcomponents only.
- For Q3 specified equipment the subcomponent condition classifications shall be specified as either “new only” or “new and/or recertified” as specified in [Clause 9](#).

5.4.8 Additional documentation

The user/purchaser may specify additional documentation, testing, and acceptance criteria as necessary to meet their requirements.

6 Technical specification

6.1 General

The supplier/manufacturer shall prepare a technical specification, which responds to the requirements in the functional specification set forth by the user/purchaser or which identifies in detail where variance(s) to the requirements in the functional specification exist or are offered.

The technical specification comprises three classes of information relating to obligation for disclosure of these documents by the supplier/manufacturer to the user/purchaser:

- Public information: this information should be identified as such and provided without restrictions (e.g. an ASTM material specification and published performance curves).
- Confidential information: this information should be identified as such (e.g. an engineering drawing) and may be either provided or made available for inspection.
- Trade secrets: this information should be identified as such (e.g. a secret formula or process), in which there is no obligation to disclose it to the user/purchaser.

The timing of disclosure may be governed by agreement between the supplier/manufacturer and the user/purchaser, considering the development time required. The documentation and disclosure requirements of this clause are separate from the requirements of other (sub)clauses, e.g. [7.2](#).

The supplier/manufacturer shall document a summary of the technical specification response to the functional specification in accordance with [6.13](#).

Where a covered component or system includes a non-covered component, the inclusion of the non-covered component shall not cause the specified requirements or performance ratings of the component or systems as established under this document to be invalidated. The evidence supporting this shall be documented by the supplier/manufacturer. Components or systems not covered in this document can be addressed in other national or international standards.

This document is not intended to inhibit a supplier/manufacturer from offering, or the user/purchaser from accepting, alternative equipment or engineering solutions. This can be particularly applicable where there is innovative or developing technology. Where an alternative is offered, the supplier/manufacturer shall clearly and completely identify any variations from the requirements of this document.

6.2 Design criteria

6.2.1 General

The supplier/manufacturer shall demonstrate conformance to the design basis and performance rating(s) of the component as per [6.2.5](#) and [6.2.6](#). Manufacturing requirements are detailed in [Clause 7](#).

6.2.2 Design documentation

Documentation of the design process for each type, size and model of component shall at least include:

- a) design criteria with references to the essential variables considered when designing the component conforming to the requirements of the design basis;
- b) engineering drawings and bill of materials;
- c) applicable specifications and standards;
- d) validation testing procedures, acceptance criteria, and approved results (see [Annex A](#));
- e) design verification and acceptance criteria;
- f) published performance curves, where applicable;
- g) design changes and design change justifications.

6.2.3 Materials

6.2.3.1 General

Metallic and non-metallic materials shall be specified by the supplier/manufacturer and shall be appropriate for the requirements in the functional specification. The supplier/manufacturer shall have documented specifications for all materials in critical subcomponents. All materials used shall conform with these specifications.

Critical subcomponents include those whose function includes any of the following:

- containment of pumping pressure, e.g. pump housing, head, base, bolting;
- possible containment of well pressure, e.g. sealed vessels that well pressure can leak into in service and that can still contain well pressure after pulling;
- transmission of torque between the ESP components, e.g. shaft, coupling, housings, head and base;
- radial or axial support of rotating components, e.g. radial bearing, bearing;

- weight support, e.g. housing, head, base, body (of seal chamber section), bolting, tubing crossover;
- sealing element, e.g. o-ring, bag, mechanical shaft seal faces and bellows;
- power electrical conductors, e.g. conductors in cable, leads, magnet wire, terminals;
- primary power electrical insulation, e.g. insulation on cable, leads, magnet wire, terminals/connectors.

As an exception, material substitutions in validated equipment designs are allowed without validation testing, provided that the change in material does not constitute a substantive design change and that the supplier/manufacturer's material selection criteria are documented and approved by a qualified person and meet all other requirements of this document.

6.2.3.2 Metallic materials

6.2.3.2.1 General

The supplier's/manufacturer's specifications shall define for all metallic materials where applicable to the specific use of the material:

- a) chemical composition according to an applicable standard or to a supplier's/manufacturer's internal specification;
- b) chemical composition limits;
- c) mechanical property limits, to include as a minimum:
 - 1) tensile strength;
 - 2) yield strength;
 - 3) elongation;
 - 4) hardness.
- d) electrical properties:
 - 1) resistivity or conductivity.
- e) magnetic properties:
 - 1) magnetic permeability;
 - 2) core loss.

6.2.3.2.2 Welds, brazing, and soldering

Welds, brazing and soldering shall be specified appropriate to the material, function, and service of the component and/or assembly. The supplier's/manufacturer's specification shall include the applicable parameters of the process and the resulting joint, including but not limited to:

- a) industry standards applied to the welding procedure, process, method, etc. (e.g. ASME BPVC Section IX or AWS B2.1/AWS B2.1M);
- b) standard weld symbols;
- c) basic process;
- d) filler metal;
- e) preparation, such as joint dimensions, tolerance, and contour;

- f) process parameters, such as temperature, amperage, polarity, heat treatment;
- g) final parameters, such as dimensions, tolerance, contour, and defect criteria.

6.2.3.3 Coatings or surface treatments

Coatings or surface treatments shall be in response to the operating environment specified in the functional requirements. Coatings and surface treatments addressed by this subclause are limited to those that provide performance enhancements to erosion, anti-friction and corrosion of subcomponent materials, which are designed to be in direct contact with production fluids as specified in the design basis. The supplier's/manufacture's specifications shall specify, where applicable, the characteristics and acceptance criteria of the coatings or surface treatments including but not limited to:

- a) basic coating type, trade name or surface treatment composition;
- b) corrosion and/or chemical resistance;
- c) hardness;
- d) minimum and maximum coating thickness;
- e) roughness;
- f) application process;
- g) bond strength;
- h) coupon testing;
- i) defect criteria, e.g. holidays.

6.2.3.4 Non-metallic materials

6.2.3.4.1 Polymers

The supplier's/manufacture's specifications shall define for all polymer materials where applicable to the specific use of the material:

- a) type of polymer;
- b) mechanical property limits:
 - 1) tensile strength, new and aged;
 - 2) elongation at rupture, new and aged;
 - 3) durometer (hardness) or modulus;
 - 4) thermal conductivity;
 - 5) thermal expansion coefficient;
 - 6) minimum and maximum recommended service temperature.
- c) electrical properties:
 - 1) volume resistivity;
 - 2) dielectric constant;
 - 3) dielectric strength;

- 4) dissipation factor at 60 Hz.
- d) fluid compatibility.

6.2.3.4.2 Ceramics

The supplier's/manufacturer's specifications shall define for all ceramic materials where applicable to the specific use of the material:

- a) ceramic type, name and grade;
- b) chemical composition;
- c) mechanical properties:
 - 1) grain size;
 - 2) density;
 - 3) hardness;
 - 4) transverse rupture strength;
 - 5) compressive strength;
 - 6) fracture toughness.
- d) thermal properties:
 - 1) thermal expansion coefficient;
 - 2) thermal conductivity.
- e) electrical properties:
 - 1) volume resistivity;
 - 2) dielectric constant;
 - 3) dielectric strength;
 - 4) dissipation factor at 60 Hz.
- f) minimum and maximum recommended service temperature.

6.2.3.4.3 Motor fluid

The supplier's/manufacturer's specifications shall define for the motor fluid:

- a) viscosity/temperature curve;
- b) density;
- c) flash point;
- d) coefficient of thermal expansion;
- e) pour point;
- f) dielectric strength and testing standard utilized for measurement;
- g) minimum and maximum service temperature.

6.2.4 Dimensional information

6.2.4.1 Dimensional information for components

Dimensional information shall be provided for component(s) supplied, except cable (see [6.2.4.2](#)). For each component, the supplier/manufacturer shall specify:

- a) maximum component OD;
- b) component schematic, including external dimensional information;
- c) component mass (weight) and length as installed and shipped.

6.2.4.2 Dimensional information for cable

For the cable, the supplier/manufacturer shall specify:

- a) weight per unit length;
- b) profile and outer dimensions;
- c) shipping weight and dimensions, including reel;
- d) size of each conductor in terms of total diameter equivalent.

6.2.5 Component and assembled system design verification

Design verification shall be performed by the supplier/manufacturer to verify that the component and assembled system (if applicable) design conforms to the supplier's /manufacturer's design basis. Design verification activities are conducted to ensure that the design outputs meet the design basis input requirements. Design verification includes documented activities, such as review of design calculations, component testing and comparison with similar designs and historical records of defined operating conditions. Empirical methods and/or physical testing used in design verification shall be fully documented and supported with drawings and material specifications. All design verification documentation shall be included in the component design file and shall be approved by a qualified person other than the design's originator.

6.2.6 Component design validation

Design validation testing shall be performed to verify that the component design conforms to the component performance rating as per [Annex A](#). Design validation activities are conducted to ensure the component performance meets the intended application or use as defined by the supplier's/manufacturer's design basis. The design validation grade specifies the process of proving a design by testing to demonstrate conformity of the product to design requirements for each validation grade per [Annex A](#), which provides a detailed description of the three validation grades (V1, V2 and V3) in this document.

6.2.7 Component functional evaluation requirements

Functional evaluations shall be performed in accordance with [Annex C](#) and shall be approved by a qualified person to verify that each component manufactured meets the supplier's/manufacturer's documented requirements, technical specification and the functional specification. The results of these evaluations shall be documented and shall become a portion of the quality documentation for that component.

6.2.8 Assembled system functional evaluation

When selected by the user/purchaser, functional evaluation should be performed in accordance with [Annex E](#) and should be approved by a qualified person to verify that the assembled system meets

the supplier's/manufacturer's documented requirements. The results of these evaluations should be documented and should become a portion of the quality documentation for that system.

6.2.9 Design changes

All design changes shall be documented and reviewed against the design verification and design validation to determine if the change is a substantive design change. A design that undergoes a substantive design change becomes a new design requiring design verification as specified in [6.2.5](#) and design validation as specified in [6.2.6](#).

Changes to a component identified as a substantive design change require design validation. Design change(s) shall be validated and verified through the same methods utilized for the original component or subcomponent. Where testing is performed on subcomponent(s), the test(s) shall simulate the design criteria conditions of the component at its rated limits. The supplier/manufacturer shall document the detailed test results and analysis that demonstrate that the component or subcomponent(s) test adequately simulates the required range of design criteria conditions.

6.3 Technical specification — All components

6.3.1 Technical characteristics

The component shall be compatible with related well equipment and services as specified in [Clause 5](#).

While installed and operated in accordance with the functional specification, the component shall perform in accordance with the functional specification.

6.3.2 Performance rating

6.3.2.1 Shaft power rating

The supplier/manufacturer shall specify the shaft power rating, where applicable, at the reference speed and temperature, typically reported as horsepower at 60 Hz (3 500 r/min) or 50 Hz (2 918 r/min). The shaft power rating shall be determined through validation testing as outlined in [6.2.6](#) and detailed in [Annex A](#).

6.3.2.2 Shaft coupling rating

The supplier/manufacturer shall specify the shaft coupling rating, where applicable, at the reference speed and temperature, typically reported as horsepower at 60 Hz (3 500 r/min) or 50 Hz (2 918 r/min). The shaft coupling power rating shall be determined through validation testing as outlined in [6.2.6](#) and detailed in [Annex A](#).

6.4 Technical specification — Bolt-on discharge

6.4.1 General

The supplier/manufacturer shall prepare the technical specification for the bolt-on discharge that responds to the functional requirements. The supplier/manufacturer shall provide to the user/purchaser the component data as defined in [7.2](#).

6.4.2 Technical characteristics for the discharge

The discharge shall serve as a connection between the top of the ESP pump section and the well production tubing.

6.4.3 Performance ratings

The supplier/manufacturer shall provide the following performance characteristics in accordance with [Annex A](#):

- a) the maximum recommended flow capacity rating of the bolt-on discharge;
- b) the pressure rating of the bolt-on discharge.

6.4.4 Scaling of design validation

Scaling of design for bolt-on discharge is not allowed.

6.5 Technical specification — Pump and gas handler

6.5.1 General

The supplier/manufacturer shall prepare the technical specification for the pump and gas handler that responds to the functional requirements. The supplier/manufacturer shall provide to the user/purchaser the component data as defined in [7.2](#).

6.5.2 Technical characteristics for the pump and gas handler

The pump shall move fluid against a differential pressure.

The gas handler shall move fluid against a differential pressure and/or condition the fluid to change the properties or characteristics of the fluid.

Requirements for bolt-on intake and bolt-on discharge do apply when integral to the pump or gas handler.

6.5.3 Performance ratings

The supplier/manufacturer shall provide the following performance characteristics in accordance with [Annex A](#):

- a) the design performance curves – water only;
- b) the maximum GVF rating of the pump and gas handler;
- c) the pump stage thrust;
- d) the housing pressure rating.

6.5.4 Scaling of design validation

Scaling of design for the pump and gas handler is not allowed. Changes to the number of stages in a given pump housing is not considered scaling.

6.6 Technical specification — Bolt-on intake

6.6.1 General

The supplier/manufacturer shall prepare the technical specification for the bolt-on intake that responds to the functional requirements. The supplier/manufacturer shall provide to the user/purchaser the component data as defined in [7.2](#).

6.6.2 Technical characteristics for the bolt-on intake

The bolt-on intake shall:

- a) provide a flow path from the well bore to the inlet of the pump, gas handler or gas separator;
- b) contain a shaft to transmit torque and thrust.

6.6.3 Performance ratings

The supplier/manufacturer shall provide the maximum flow capacity and pressure rating of the bolt-on intake in accordance with [Annex A](#).

6.6.4 Scaling of design validation

Scaling of design for the bolt-on intake is not allowed.

6.7 Technical specification — Mechanical gas separators

6.7.1 General

The supplier/manufacturer shall prepare the technical specification for the mechanical gas separator that responds to the functional requirements. The supplier/manufacturer shall provide to the user/purchaser the component data as defined in [7.2](#).

6.7.2 Technical characteristics

The mechanical gas separator shall:

- a) separate free gas from the fluid entering the ESP pump or gas handler section and vent to bypass the pump or gas handler;
- b) contain a shaft to transmit torque and thrust.

Requirements for bolt-on intake also apply when it is integral to the mechanical gas separator.

6.7.3 Performance ratings

The supplier/manufacturer shall provide the mechanical gas separator performance curve in accordance with [Annex A](#).

6.7.4 Scaling of design validation

Scaling of design for the mechanical gas separator is not allowed.

6.8 Technical specification — Seal chamber sections

6.8.1 General

The supplier/manufacturer shall prepare the technical specification for the seal chamber section that responds to the functional requirements. The supplier/manufacturer shall provide to the user/purchaser the component data as defined in [7.2](#).

6.8.2 Technical characteristics

The seal chamber section shall:

- a) prevent contamination of the ESP motor with well fluid;

- b) provide a means for compensating for changes in the volume of motor fluid due to changes in temperature and pressure;
- c) provide a means for regulating pressure differential between the interior and exterior pressures of the seal chamber section in keeping with the volume expansion and contraction limits;
- d) handle axial thrust generated by the pump and motor, as required by design.

When the seal chamber section contains the shaft, the shaft shall provide a means for transferring the required torque and, where applicable, thrust.

6.8.3 Performance ratings

The supplier/manufacture shall provide the following performance characteristics for the seal chamber section in accordance with [Annex A](#):

- a) the volume contraction capacity;
- b) the operation deviation limits;
- c) the thrust bearing load capacity;
- d) the minimum operating speed for the thrust bearing;
- e) the horsepower requirement.

6.8.4 Scaling of design validation

Scaling of design for the seal chamber section is not allowed.

6.9 Technical specification — Motors

6.9.1 General

The supplier/manufacture shall prepare the technical specification for the motor that responds to the functional requirements. The supplier/manufacture shall provide to the user/purchaser the component data as defined in [7.2](#).

6.9.2 Technical characteristics

The motor shall convert input electrical power to the required torque needed to rotate all coupled ESP components at the required design frequency.

6.9.3 Performance ratings

The supplier/manufacture shall provide the following performance characteristics in accordance with [Annex A](#):

- a) the motor voltage for minimum current;
- b) the motor performance parameters:
 - 1) motor amperage;
 - 2) speed;
 - 3) torque;
 - 4) input kilowatts;
 - 5) efficiency;

- 6) power factor;
- 7) winding temperature rise at 100 % rated output power.
- c) the minimum and maximum internal motor operating temperature limits;
- d) the locked rotor current, torque and power factor values.

6.9.4 Scaling of design validation

Scaling of the design of the motor is allowed in accordance with [A.3.7.4](#)

6.10 Technical specifications — Power and motor lead extension cable

6.10.1 General

The supplier/manufacturer shall prepare the technical specification for the power cable and MLE cable, hereafter referred to as “cable” that responds to the functional requirements. The supplier/manufacturer shall provide to the user/purchaser the component data as defined in [7.2](#).

6.10.2 Technical characteristics

The cable shall:

- a) conduct electricity from the surface to the downhole motor;
- b) insulate the voltage supplied to the downhole motor.

6.10.3 Performance ratings

The supplier/manufacturer shall provide the following performance characteristics in accordance with [Annex A](#):

- a) the cable voltage rating;
- b) the cable temperature rating;
- c) the cable ampacity coefficients;
- d) the cable conductor size;
- e) the cable acceptable minimum bending radius rating.

6.10.4 Scaling of design validation

Scaling of the design of the cable is not allowed.

6.11 Technical specifications — Pothead

6.11.1 General

The supplier/manufacturer shall prepare the technical specification for the pothead that responds to the functional requirements. The supplier/manufacturer shall provide to the user/purchaser the component data as defined in [7.2](#).

6.11.2 Technical characteristics

The pothead shall:

- a) conduct electricity from the cable to the downhole motor;

- b) insulate the voltage supplied to the downhole motor;
- c) seal the connection to prevent motor contamination by well fluid.

6.11.3 Performance ratings

The supplier/manufacturer shall provide the following performance characteristics in accordance with [Annex A](#):

- a) the pothead voltage rating;
- b) the pothead temperature rating;
- c) the pothead ampacity coefficients;
- d) the pothead differential pressure performance rating;
- e) the pothead thermal cycling performance rating.

6.11.4 Scaling of design validation

Scaling of the design of the pothead is not allowed.

6.12 Assembled ESP system – Additional requirements

6.12.1 General

When an assembled ESP system is supplied, the supplier/manufacturer shall prepare additional technical specification information for the assembled ESP system which responds to the requirements in the functional specification set forth by the user/purchaser or identifies in detail where variance(s) to the requirements in the functional specification exist or are offered. The supplier/manufacturer shall provide to the user/purchaser the component data as defined in [7.2](#).

The supplier/manufacturer shall document a summary of the assembled ESP system technical specification response to the functional specification in accordance with [6.13](#).

6.12.2 Technical characteristics

The ESP assembled system shall be designed to convert input electrical power into hydraulic power to move fluid to a point.

6.12.3 System capabilities

6.12.3.1 System capabilities characteristics

The supplier/manufacturer shall provide the following system capabilities characteristics in accordance with [Annex B](#):

- a) the axial strength and bending tensile load capability;
- b) the surface temperature rating;
- c) the maximum amperage rating;
- d) the dogleg severity limits;
- e) the maximum deviation limits which the ESP assembly may be run through and operating at;
- f) the installed operating temperature range;

- g) the maximum pressurization and depressurization rates;
- h) the input surface power required to the power cable at the wellhead;
- i) the assembled ESP system motor fluid percentage utilization of each seal chamber contraction capacity;
- j) the minimum and maximum operating speed.

6.12.3.2 Dimensional information

The supplier/manufacturer shall specify the following dimensional information for the assembled system and auxiliary components:

- a) effective diameter;
- b) system schematic;
- c) total mass (weight) with and without cable;
- d) total length;
- e) bending stress analysis based on the wellbore and other pertinent information supplied in the functional specification.

6.13 Technical specification response guideline – ESP components

[Table 2](#) provides a general guideline as to how the supplier/manufacture shall respond to the functional specification. [Table 2](#) is intended to provide a summary of the supplier/manufacturer response and does not replace the requirement to provide documentation in accordance with [6.1](#).

Table 2 — Technical specification response guideline

Case/Scenario description:			
Component recommendations	Description	Model name	Part number
Bolt-on discharge			
Pump(s) 1			
Pump(s) 2			
Gas handler			
Mechanical gas separator			
Bolt-on intake			
Seal chamber section(s)			
Motor			
Motor lead extension			
Power cable			
Accessories			
Functional specification response	Conformance with functional specification		Description of functional specification(s) that cannot be met
Bolt-on discharge	☐ Yes	☐ No	
Pump(s) 1	☐ Yes	☐ No	
Pump(s) 2	☐ Yes	☐ No	
Gas handler	☐ Yes	☐ No	
Mechanical gas separator	☐ Yes	☐ No	
Bolt-on intake	☐ Yes	☐ No	