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

*Industries du pétrole et du gaz naturel — Équipement de forage et
de production — Systèmes de pompes submersibles électriques pour
relevage artificiel*

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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