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Petroleum and natural gas industries — Drilling and production equipment

Part 1: Electric submersible pump systems for artificial lift

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee PSE/17/-/4, Drilling and production equipment for petroleum and natural gas industries.

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

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Published by BSI Standards Limited 2015

ISBN 978 0 580 70785 8

ICS 75.180.10

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 May 2015.

Amendments/corrigenda issued since publication

Date	Text affected

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN ISO 15551-1

May 2015

ICS 75.180.10

English Version

Petroleum and natural gas industries - Drilling and production equipment - Part 1: Electric submersible pump systems for artificial lift (ISO 15551-1:2015)

Industries du pétrole et du gaz naturel - Équipement de forage et de production - Partie 1: Systèmes électriques de pompes submersibles pour l'ascension artificielle (ISO 15551-1:2015)

Erdöl- und Erdgasindustrie - Bohrloch-Ausrüstungen - Teil 1: Elektrische Tauchpumpen zur Förderung (ISO 15551-1:2015)

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Foreword

This document (EN ISO 15551-1:2015) has been prepared by Technical Committee ISO/TC 67 “Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries” in collaboration with Technical Committee CEN/TC 12 “Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries” the secretariat of which is held by AFNOR.

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of an identical text or by endorsement, at the latest by November 2015, and conflicting national standards shall be withdrawn at the latest by November 2015.

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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 documents 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 on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword — Supplementary information.

The committee responsible for this document is ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 4, *Drilling and production equipment*.

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Introduction

This part of ISO 15551 has been developed by users/purchasers and suppliers/manufacturers of electric submersible pumps and is intended for use in the petroleum and natural gas industry worldwide. This part of ISO 15551 provides requirements and information to both parties in the selection, manufacturing, testing, and use of electric submersible pumps as defined in the scope. Further, this part of ISO 15551 addresses supplier requirements, which set the minimum parameters for claiming conformity with this International Standard.

This part of ISO 15551 provides grades of requirements for design validation, quality control, and functional evaluations allowing the user/purchaser to select each for a specific application. There are two grades of design validation, three grades of quality control, and up to three grades of functional testing, depending on the component. Design validation grade V2 is restricted to legacy products, and the highest grade is V1. Quality control grade 3 is the standard grade and grades 2 and 1 provide additional requirements. Of the three functional evaluation grades, the lowest grade is the standard grade and higher grades provide additional requirements. The user/purchaser can specify requirements supplemental to these grades.

Users of this International Standard are informed that requirements above those outlined in this International Standard can be needed for individual applications. This International Standard 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.

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Petroleum and natural gas industries — Drilling and production equipment —

Part 1: Electric submersible pump systems for artificial lift

1 Scope

This part of ISO 15551 provides 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 as defined herein. This part of ISO 15551 is applicable to those components meeting the definition of centrifugal pumps including gas handling devices, discharge heads, seal chamber sections, intake systems, mechanical gas separators, induction motors (herein motor), shaft couplings, motor lead extension, pothead, and power cables, as defined herein. Components supplied under the requirements of this part of ISO 15551 exclude previously used subcomponents. Additionally, this International Standard provides requirements for assembled ESP systems.

This part of ISO 15551 includes normative annexes addressing design validation performance rating requirements by component, requirements for determining ratings as an assembled system, functional evaluation: single component and cable reference information.

This part of ISO 15551 includes informative annexes addressing functional evaluation guidelines for assembled ESP systems, establishing recommended operating range (ROR) of the ESP system, example user/purchaser ESP functional specification form, considerations for the use of 3-phase low and medium voltage adjustable speed drives for ESP applications, analysis after ESP use, downhole monitoring of ESP assembly operation, and information on permanent magnet motors for ESP applications.

Equipment not covered by this part of ISO 15551 includes wireline and coiled tubing-deployed ESP systems, motor 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 equipment, downhole permanent magnet motors, and non-conventionally configured ESP systems such as inverted systems. Repair and redress equipment requirements are not covered in this part of ISO 15551.

The terminologies used within this part of ISO 15551 are; “ESP assembly” for a system of products combined into an operational machine, “component” for individual products such as, pumps or seal chamber sections, and “subcomponent” for individual parts or subassemblies that are used in the construction of an individual component.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 29001, *Petroleum, petrochemical and natural gas industries — Sector-specific quality management systems — Requirements for product and service supply*

API RP 11S2, *Electric Submersible Pump Testing*

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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, *Rubber Property — Effect of Liquids, Test Method for*

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

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

3 Terms and definitions

For the purposes of this document, the following definitions shall apply. For quality system related terms used in this document and not defined below, see ISO 29001.

3.1
adapter
device used to connect components that are not directly compatible

3.2
adjustable speed drive
device which controls an electric motor's speed by manipulating the power frequency being supplied to the motor

Note 1 to entry: The term "adjustable speed drive" is interchangeable with other common industry names for this device such as "variable frequency drive" or "variable speed drive".

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

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3.6
assembled ESP system
assembly of downhole equipment which includes some or all components as identified in this part of ISO 15551

3.7
auxiliary equipment
equipment or components that are outside the scope of this part of ISO 15551 and are typically selected and/or installed by the user/purchaser

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

3.8
axial stage type
type of stage with inlet and exit flow path essentially parallel to the shaft axis

3.9
bag
bladder
bellows
flexible subcomponent of a seal chamber section that functions as a positive barrier that isolates the wellbore production fluid from the motor fluid

3.10
bag chamber
bladder chamber
bellows chamber
chamber which houses the bag/bladder/bellows

3.11
barrier
subcomponent of an ESP 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 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 which is used to secure ESP power cable to production tubing

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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

Note 1 to entry: This device is also commonly referred to as a chemical injection line or control line.

3.20
casing
pipe extending from the surface and intended to line the walls of a drilled well

3.21
casing size
nominal casing outside diameter (od), mass (weight), inside diameter (id), and/or drift diameter as specified in ISO 11960

3.22
centralizers
device used to keep the ESP assembly or other downhole equipment in the centre of the tubing, casing, or wellbore

3.23
centrifugal pump
component of an ESP 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)

3.24
chamber
subcomponent of the seal chamber section

3.25
check valve
device that allows one-directional flow of fluid when a differential pressure exists

3.26
coefficient of determination
statistic used to determine the strength of a fit between a mathematical model and a set of observed data values

Note 1 to entry: The coefficient of determination is typically calculated using the following equation:

$$R^2 = 1 - \frac{\sum_{i=1}^{n} \left(Y_i - y_i \right)^2}{\sum_{i=1}^{n} \left(y_i - \bar{y}_i \right)^2}$$

3.27
coiled tubing
pipe typically supplied and installed in one continuous length and wound onto a reel or spool

3.28
coiled tubing deployed ESP
ESP system which is deployed into the wellbore using coiled tubing rather than by other deployment means such as jointed tubing or wireline

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3.29
common hardware
hardware that does not require traceability and is included as part of an ESP component

EXAMPLE Bolts, washers, screws, and snap rings.

3.30
compact stranded cable
electrical conductor configuration in which a multiple-strand conductor has been compacted to reduce its circumference while maintaining conductor area

3.31
compression pump construction
configuration where the impeller is fixed to the shaft to prevent axial movement

3.32
conductor
subcomponent of the power cable that functions to conduct electrical power

3.33
conductor shield
layer adjacent to the conductor to distribute voltage stress evenly over the surface of the conductor

3.34
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.

3.35
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

3.36
coupling
device which connects the shafts of ESP components

3.37
deployment method
conveyance method
method used to deploy the ESP downhole equipment to its setting location

3.38
design validation
process of proving a design by testing to demonstrate conformity of the product to design requirements

3.39
design verification
process of examining the premise of a given design by calculation, comparison, or investigation, to substantiate conformity with specified requirements

3.40
deviation survey
measurement of a borehole's trajectory over the wellbore length for the purposes of ESP design and application

3.41
diffuser
stationary stage segment of a centrifugal pump which converts the pumped fluid velocity (kinetic energy) to a pressure (potential energy)

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3.42
discharge head
component on the output end of the pump for connecting to the production tubing

3.43
dogleg severity
total angular inclination and azimuth in the wellbore, casing or liner, calculated over a standard length such as degrees per 30 metres, or degrees per 100 feet

3.44
effective diameter
theoretical minimum diameter through which the assembled ESP system passes including installation of all required ESP ancillary equipment

3.45
efficiency
output work divided by input work

3.46
elastomer
polymer with the property of viscoelasticity (elasticity), generally having a low Young's modulus and a high yield strain

3.47
electric penetrator
electrical connector that functions to transition power cable and/or instrument wires through a sealing barrier

EXAMPLE Wellhead, wellbore packer, ESP pod, or canister.

3.48
electric surface control equipment
electrical equipment used to control the operation of the ESP assembly commonly referred to as an adjustable speed drive or switchboard

3.49
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

3.50
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

3.51
floating pump construction
configuration where the impeller is not fixed to the shaft to permit limited axial movement

3.52
flowing pressure
pressure in the wellbore at a specific vertical depth at a specific flow rate

3.53
functional evaluation
test(s) performed to confirm 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.

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3.54
gas handler
component of an ESP system that conditions multiphase flow, without gas separation, to decrease the degradation of pump performance

3.55
gas-oil ratio
produced gas-oil ratio
volumetric ratio of gas to oil at standard conditions

3.56
gas separator
component of an ESP system that mechanically separates a portion of the free gas from the wellbore fluids prior to the fluids entering the pump or gas handler

3.57
head curve
amount of head generated by the pump as a function of flow rate for a specific speed

3.58
housing pressure rating
value of the maximum allowable difference of internal less external pressure

3.59
impeller
stage segment rotated by the shaft which adds kinetic energy (velocity) to the fluid being pumped

3.60
inclination
angle, measured in degrees, by which the wellbore or survey-instrumented axis varies from a true vertical line

3.61
induction motor
component of an ESP system where alternating current power input is transformed to mechanical torque by means of electromagnetic induction

Note 1 to entry: Also referred to as an asynchronous or squirrel cage motor.

3.62
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

3.63
intake screen
attachment to the pump intake used to filter solid particles from the produced fluid to protect the internal components of the pump

3.64
insulation
isolates the electrical potential between conductors and other conducting materials and minimizes leakage current from the conductors

3.65
inversion point
water cut percentage at which the emulsion viscosity is at its maximum

3.66
inverted system
ESP system configured with the pump on the bottom and motor on the top

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3.67
jacket
subcomponent of an ESP power cable that covers the insulated conductors and provides mechanical protection from the downhole environment

3.68
labyrinth chamber
chamber which utilizes a vertical U-tube, maze-like, or tortuous flow path to delay wellbore fluid ingress through the chamber

3.69
lamination
thin electrical grade metallic subcomponents that form the magnetic core of the stator and the rotor(s)

3.70
liner
pipe extending from the surface or another point lower in the wellbore to a depth within or below the existing casing

3.71
manufacturing
process and action performed by an equipment supplier/manufacturer 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/manufacturer

Note 1 to entry: Manufacturing begins when the supplier/manufacturer receives the order and is completed at the moment the component(s), assembly(ies), and related documentation are surrendered to a transportation provider.

3.72
mechanical seal
subcomponent used to prevent flow between a rotating shaft and a stationary body

3.73
megger
instrument that generates a high voltage in order to test the resistance of insulation, etc.

3.74
mixed flow stage type
type of stage with inlet flow path essentially parallel to shaft axis and exit between perpendicular and parallel to the shaft axis

3.75
model
equipment with unique components and operating characteristics which differentiate it from other equipment of the same type

3.76
modular pump construction
configuration that utilizes both compression and floating pump constructions within the same single component

3.77
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

3.78
motor lead extension
MLE
cable connected to the pothead for splicing to the power cable

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3.79
motor operating temperature
temperature at or near the coils of the stator when it is energized

3.80
motor shroud
tube which covers the motor length of the ESP to promote fluid flow past the motor

3.81
non-conformance
non-fulfilment of a specified requirement such as a disagreement between equipment, part, practice, or procedure with an established standard

3.82
operator
user of the equipment

3.83
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

3.84
operating environment
set of downhole conditions to which the component is exposed during its full life cycle

3.85
parallel chambers
configuration of at least two seal chambers that function together to increase contraction capacity

3.86
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

3.87
permanent identification
marking that remains legible over the intended service life of the component and/or subcomponent

3.88
permanent magnet motor
type of motor that uses permanent magnet rotor(s) instead of induction rotor(s) as a way to create torque

3.89
pothead
power connector on the end of the MLE or power cable which mates to the motor

3.90
power cable
component of the ESP system that connects the surface electrical equipment or electrical penetrator connector to the MLE or motor

3.91
pump construction
configuration of which the pump stages are assembled with respect to axial movement relative to the shaft such as compression, floater, or modular

3.92
pump differential pressure
difference between discharge and intake pressures

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3.93
pump housing
tube containing pump subcomponents pertaining to the impellers and diffusers and functioning as a pressure barrier

3.94
pump shroud
tube which covers the pump length of the ESP intended to limit free gas migration into the pump intake

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

3.95
qualified part
part manufactured under an authorized quality assurance program produced to meet or exceed the performance of the original part

3.96
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

3.97
radial stage type
type of stage with inlet flow path essentially parallel to shaft and exit essentially perpendicular to the shaft axis

3.98
redress
activities performed to a component restricted to the replacement of qualified parts that restores the equipment to its original performance

3.99
reference fluid
water corrected to specific gravity of 1,0, at standard conditions

3.100
reference temperature
20 degrees centigrade

3.101
repair
activity beyond the scope of redress that includes disassembly, re-assembly, and testing with or without the replacement of qualified parts and may include machining, welding, heat treating, or other manufacturing operations that restores the equipment to its original performance

3.102
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

3.103
safety factor
defined measure of a reduced value from a known capacity

3.104
sand cut
amount of sand or solid material in the wellbore fluid, typically expressed as a volumetric or mass percentage

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3.105
seal chamber section
component of an ESP system that provides one or more of the following functions: protects the interior of the motor from well fluids and other contaminants, carries the pump thrust, maintains pressure equalization with wellbore fluid pressure, and transmits the motor torque to the component above it

3.106
semi-permanent identification
marking that remains legible until the component and/or subcomponent is installed, such as, a metal stamped nameplate or tag

3.107
series
component designation that identifies the outer diameter of its housing

3.108
series chambers
configuration of at least two seal chambers that function redundantly to increase protection to the subcomponents below them

3.109
shaft end play
axial movement the component shaft has generally measured from a reference point

3.110
shaft extension
measurement of the component shaft end in relation to a reference point

3.111
shaft side play
radial movement of a component shaft resulting from clearances between rotating and stationary radial support components

3.112
shipping hardware
auxiliary equipment that is shipped as part of an ESP component to help protect the component during the shipping and handling process

3.113
slip
difference between the AC motor synchronous speed and the actual operating speed divided by the synchronous speed expressed in percentage

3.114
slugging
well production characterized by cyclic flow of fluid mixtures of different densities, such as gas and liquid or two differing liquid viscosities

3.115
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 an constant

3.116
spline type
machined configuration of the end of component shafts to allow connection by couplings to adjoining components, such as modified SAE, involute, and others

3.117
stage
matched set of one impeller and one diffuser

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3.118
stage name
nomenclature given to each pump stage type that typically defines its flowrate (bep), its size (diameter), and any special fluid handling characteristics

3.119
standard conditions
1 atmosphere (14,7 psia) and 15 °C (60 °F)

3.120
stator
subcomponent of the motor which contains laminations and coiled wire and housed in a tube, also known as wound stator

3.121
stock tank flow rate
wellbore fluid rate reported at standard conditions

3.122
subcomponent
portion of a component made up of one or more pieces

3.123
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 times 120 divided by the number of poles.

3.124
tandem
designation that indicates where in the modular system an 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.

3.125
test open flow
maximum pump flow rate attainable on test

3.126
thrust bearing
device to support axial load of a rotating part

3.127
thrust load bearing capacity
axial load capacity of a thrust bearing as defined by the bearing design, lubrication fluid, and operating environment

3.128
thrust washer
subcomponent mounted on an impeller which carries the axial thrust

3.129
torsional yield ratio
ratio of the material yield point in torsion to the material yield point in tension

3.130
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

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3.131
unique identifier
unique combination of alphanumeric characters to identify a specific component

3.132
water cut
ratio of produced water to produced liquids, expressed as a percentage

3.133
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

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}	derating 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
GOR	gas oil ratio
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

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id	inside 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
mu_t	actual lubricating fluid test viscosity (absolute) in cP
NEMA	Nationalal Electrical Manufacturers Association
NDE	non-destructive examination
od	outside diameter
P_a	adjusted power
P_n	power at test revolutions per minute
pH	potential of hydrogen
p_i	pump intake pressure
p_o	pump discharge pressure
ρ_f	fluid density
P_f	fluid power
PID	programmable input digital controller
PMM	permanent magnet motor
P_s	shaft power
PSD	pump setting depth
PVT	pressure, volume, temperature
PWM	pulse width modulated
$P_{sc,\,kW}$	shaft coupling power rating expressed in kilowatt
$P_{sc,\,HP}$	shaft coupling power rating expressed in horsepower
P_{shaft}	shaft power rating
Q	flow rate
Q_a	adjusted flow rate
Q_n	flow rate at test revolutions per minute

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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_f	temperature of the test fluid at the time of motor de-energization
T_b	temperature at the time R_b is taken
τ	torque
THD	total harmonic distortion
TVD	true vertical depth
TVSS	transient voltage surge suppressors
UL	Underwriter's Laboratories
VI	percentage of free gas
VDC	volts direct current
VSD	variable speed drive
VFD	variable frequency drive
v_r	rotational speed in revolutions per minute
$v_{r,ref}$	reference revolutions per minute
$v_{r,n}$	test revolutions per minute
WAG	water alternating gas
ω_t	actual shaft rotational speed during test in revolutions per minute
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

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5 Functional specification

5.1 General

The user/purchaser shall prepare a functional specification when ordering components which conform to this part of ISO 15551 and specify the requirements and operating conditions as appropriate. This information is used by the supplier/manufacturer to recommend the components for the application. 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 that re-evaluation shall be no less stringent or documented and approved than that required for the initial application.

5.2 Component type

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

— production requirements;

— fluid characteristics.

5.3 Functional requirements

5.3.1 General

User/purchaser shall specify the known and anticipated application parameters and requirements to the best of their knowledge. Operational issues such as frequency of shut-downs, power interruptions, production fluid changes, electrical current changes, and other issues that might have an effect on the systems operation and durability 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) operating environment such as heavy and conventional oil production, coal bed methane applications, and source water production;

b) well type such as vertical, slant, deviated, or horizontal;

c) wellhead location such as onshore, platform, or subsea;

d) reservoir type such as carbonate, consolidated sandstone, unconsolidated sandstone, coal, or shale;

e) reservoir recovery mechanism or process such as aquifer drive, solution gas drive, water flood, thermal, coal dewatering;

f) enhanced oil recovery such as CO_2 flood, water-alternating-gas, or polymer flood;

g) existing or planned power supply details such as generator/utility, volts, frequency, kVA/Amp supply limitations;

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h) 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, multilateral;

b) geothermal gradient/profile;

c) pertinent production history using ESPs 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 well 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, y-tool;

5.3.2.3.2 Supplemental information

The following completion information shall be specified, if available:

a) well deviation survey; if not provided, provide the following 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.

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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 of the system, such as early, mid, and late life.

a) expected well production flow performance, which shall include, as a minimum, expected flow rate such as stock tank flow rate or pump discharge rate and flowing pressure or fluid level at expected flow rate for a specified depth;

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 bottomhole temperature;

i) maximum expected bottomhole temperature.

5.3.2.4.2 Supplemental information

The following operating and production information shall be provided over the life of the system, such as early, mid, 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, steam;

e) desired operating frequency range and desired operating frequency at target rate.

5.3.3 Environmental compatibility

User/purchaser shall specify the environmental compatibility requirements and preferred fluid property correlations. The following parameters shall be supplied:

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;

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3) chloride concentration/salinity.

c) Gas

1) composition such as:

i) CO_2 concentration (mole percentage);

ii) H_2S concentration (mole percentage);

2) specific gravity.

d) Solids

1) history of solids related problems such as erosion, plugging, wear;

2) morphology such as size, structure, angularity, composition;

3) scale deposition tendency;

4) asphaltene deposition tendency;

5) 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;

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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.

5.4 User/purchaser selections

5.4.1 General

Table 1 is the compiled list of required selection criteria for ESP components which shall be selected by the user/purchaser. The grades can vary by component as selected by the user/purchaser. General guidance on the selections available is provided in 5.4.2, 5.4.3, and 5.4.4.

5.4.2 Design validation

This part of ISO 15551 provides two design validation grades, one of which shall be selected by the user/purchaser.

— V1 Highest grade

— V2 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 part of ISO 15551 provides requirements for three functional evaluation grades noting that some components can have fewer. For assembled systems, guidelines for completing a functional evaluation are provided in Annex E.

— F1 Highest level of functional evaluation

— F2 Intermediate level of functional evaluation

— F3 Basic level of functional evaluation

5.4.4 Quality grades

The user/purchaser shall specify one of the following quality grades. This part of ISO 15551 provides three quality grades as detailed in Clause 7.

— Q1 Highest level of quality;

— Q2 Intermediate level of quality;

— Q3 Basic level of quality.

Table 1 summarizes the list of components and the grades that are applicable for each under this part of ISO 15551. This table provides guidance to the user/purchaser in identifying the desired grades for each component.

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Table 1 — User/purchaser grade selections

Component	Selected grades							
	Design validation (Annex A)		Functional evaluation (Annex C)			Quality control (7.4)		
	V1	V2	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[c]					

[a] Unavailable sections.

[b] Indicates that component has no grade selections.

[c] Indicates an informative Annex.

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 Additional documentation or requirements

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

6 Technical specification

6.1 General

The supplier/manufacturer shall provide to the user/purchaser a technical specification that conforms to the requirements defined in the functional specification, or identifies in detail where variance(s) are offered. The supplier/manufacturer shall also provide to the user/purchaser the documentation required by 7.2.

Where a covered component or system includes a non-covered component, the inclusion of the non-covered component shall not cause the defined requirements or performance ratings of the component or systems as established under this International Standard to be invalidated. The evidence supporting this shall be documented by the supplier/manufacturer. Components or systems not covered in this part of ISO 15551 can be addressed in other national or international standards.

This International Standard 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 International Standard.

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6.2 Design criteria

6.2.1 General

The supplier/manufacturer shall conform to the functional specifications when designing the component conforming to the technical specifications. 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 include, as a minimum, the following:

a) design criteria: refers to the essential variables considered when designing the component conforming to the requirements of the technical specifications and functional requirements;

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 written specifications for all materials and all materials used shall comply with these specifications.

Material substitutions in validated equipment designs are allowed without validation testing, provided that the supplier/manufacturer's material selection criteria are documented and approved by a qualified person and meet all other requirements of this part of ISO 15551.

6.2.3.2 Metallic materials

6.2.3.2.1 General

The supplier/manufacturer's specifications shall define the following for all metallic materials:

a) chemical composition according to an applicable standard such as AISI (American Iron and Steel Institute), ASTM, NACE, or to a supplier/manufacturers' internal specification;

b) chemical composition limits;

c) mechanical property limits, to include as a minimum:

   1) tensile strength;

   2) yield strength;

   3) elongation;

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4) hardness;

d) electrical properties where applicable:

1) resistivity or conductivity;

e) magnetic properties where applicable:

1) magnetic permeability;

2) core loss.

Material certificates or test reports provided by the material supplier can be used to verify compliance of the material to the specifications.

6.2.3.2.2 Welds, brazing, and soldering

Welds, brazing, and soldering shall be in accordance with the supplier/manufacturer's specifications as defined or referenced in 7.6.3. Weld identification and examination shall be in accordance with the specified quality grade. The supplier/manufacturer shall maintain documentation for qualified personnel performing these operations.

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. The supplier/manufacturer's specifications shall specify, where applicable, the characteristics and acceptance criteria of the coatings or surface treatments including but not limited to the following:

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.

6.2.3.4 Non-metallic materials

6.2.3.4.1 Polymers

The supplier/manufacturer's specifications shall define the following for all polymer materials, where applicable:

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;

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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.

Material test reports or certificates of compliance provided by the material supplier or the supplier/manufacturer shall be used to verify compliance of the material to the specifications.

6.2.3.4.2 Ceramics

The supplier/manufacturer's specifications shall define the following for all ceramic materials:

a) ceramic type, name, and grade;

b) chemical composition;

c) mechanical:

1) grain size (if applicable);

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 (if applicable):

1) volume resistivity;

2) dielectric constant;

3) dielectric strength;

4) dissipation factor at 60 Hz;

f) minimum and maximum recommended service temperature.

Material test reports or certificates of compliance provided by the material supplier or the supplier/manufacturer shall be used to verify compliance of the material to the specifications.

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6.2.3.4.3 Motor fluid

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

a) fluid classification or type;

b) viscosity/temperature curve;

c) density;

d) flash point;

e) coefficient of thermal expansion;

f) pour point;

g) dielectric strength;

h) minimum and maximum service temperature.

Material test reports or certificates of compliance provided by the motor fluid supplier or the supplier/manufacturer shall be used to verify compliance of the motor fluid to the specifications.

6.2.4 Dimensional information

6.2.4.1 Dimensional information for assembled system

Dimensional information for the assembled system and auxiliary components shall be provided. An analysis can be necessary to calculate the stresses for deviated or high dogleg severity wellbores. The supplier/manufacturer shall specify the following:

a) effective diameter;

b) system schematic;

c) total mass (weight) with and without cable;

d) total length;

e) bending stress analysis.

6.2.4.2 Dimensional information for system components except cable

For each component, the supplier/manufacturer shall specify the following:

a) maximum component OD;

b) component schematic including external dimensional information;

c) component mass (weight) and length as installed and shipped.

6.2.4.3 Dimensional information for cable

For the cable, the supplier/manufacturer shall specify the following:

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.

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6.2.5 Component and assembled system design verification

Design verification shall be performed by the supplier/manufacturer to verify that the component design meets the technical specifications. 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 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 meets the technical specifications. 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. Annex A provides a detailed description of the two validation grades (V1 and V2) in this part of ISO 15551.

6.2.7 Component functional evaluation requirements

Functional evaluations shall be performed in accordance with Annex C and approved by a qualified person to verify that each component manufactured meets the supplier/manufacturer's documented requirements, technical specification, and the functional specification. The results of these evaluations shall be recorded and 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 is performed in accordance with Annex E and approved by a qualified person to verify that the assembled system meets the supplier/manufacturer's documented requirements. The results of these evaluations shall be recorded and 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 change. A design that undergoes a substantive 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 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 following criteria shall be met.

a) The components shall be compatible with related well equipment and services as defined in Clause 5.

b) While installed and operated, the components shall perform in accordance with the functional specification.

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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. 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. 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 also provide to the user/purchaser component data 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

6.4.3.1 Maximum flow capacity

The supplier/manufacturer shall provide the maximum recommended flow capacity rating of the bolt-on discharge in accordance with Annex A.

6.4.3.2 Pressure rating

The supplier/manufacturer shall provide the pressure rating in accordance with Annex A.

6.4.4 Scaling of design validation

Scaling of design for this component 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 also provide to the user/purchaser component data 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 condition the fluid to change the properties or characteristics of the fluid.

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

6.5.3 Performance ratings

6.5.3.1 Design performance curves — Water only

The supplier/manufacturer shall provide the design performance curves – water only in accordance with Annex A.

6.5.3.2 Maximum gas volume fraction (GVF) rating

The supplier/manufacturer shall provide the maximum gas volume fraction rating in accordance with Annex A.

6.5.3.3 Pump stage thrust

The supplier/manufacturer shall provide the pump stage thrust in accordance with Annex A.

6.5.3.4 Housing pressure rating

The supplier/manufacturer shall provide the housing pressure rating in accordance with Annex A.

6.5.4 Scaling of design validation

Scaling of design for this component 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 also provide to the user/purchaser component data defined in 7.2.

6.6.2 Technical characteristics for the intake

The following criteria shall be met.

a) The intake shall provide a flow path from the well bore to the inlet of the pump, gas handler, or gas separator.

b) The intake shall contain a shaft to transmit torque and thrust.

6.6.3 Performance ratings

The supplier/manufacturer shall provide the maximum flow capacity in accordance with Annex A.

6.6.4 Scaling of design validation

Scaling of design for this component is not allowed.

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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 also provide to the user/purchaser component data defined in 7.2.

6.7.2 Technical characteristics

The following criteria shall be met.

a) The gas separator shall separate free gas from the fluid entering the ESP pump or gas handler section and vent to bypass the pump or gas handler.

b) The gas separator shall contain a shaft to transmit torque and thrust.

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

6.7.3 Performance ratings

The supplier/manufacturer shall provide the gas separator performance curve in accordance with Annex A.

6.7.4 Scaling of design validation

Scaling of design for this component 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 also provide to the user/purchaser component data defined in 7.2.

6.8.2 Technical characteristics

The following criteria shall be met.

a) The seal chamber sections shall prevent contamination of the ESP motor with well fluid.

b) The seal chamber sections shall provide a means for pressure compensation between the interior and exterior pressure of the seal chamber sections.

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

d) The seal chamber sections shall handle axial thrust generated by the pump and motor, as required by design.

6.8.3 Performance ratings

6.8.3.1 Volume contraction capacity

The supplier/manufacturer shall provide the volume contraction capacity in accordance with Annex A.

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6.8.3.2 Operating deviation limits

The supplier/manufacturer shall provide the operation deviation limits in accordance with Annex A.

6.8.3.3 Thrust bearing load capacity

The supplier/manufacturer shall provide the thrust bearing load capacity in accordance with Annex A.

6.8.3.4 Minimum operating speed for thrust bearing

The supplier/manufacturer shall provide the minimum operating speed for the thrust bearing in accordance with Annex A.

6.8.3.5 Number and severity of pressure cycles

The supplier/manufacturer shall provide the number and severity of pressure cycles in accordance with Annex A.

6.8.4 Scaling of design validation

Scaling of design for this component is not allowed.

6.8.5 Horsepower requirement

The supplier/manufacturer shall provide the horsepower requirement in accordance with Annex A.

6.9 Technical specification — Motors

6.9.1 General

The supplier/manufacturer shall prepare the technical specification for the motor that responds to the functional requirements. The supplier/manufacturer shall also provide to the user/purchaser component data 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

6.9.3.1 Motor voltage for minimum current

The supplier/manufacturer shall provide the motor voltage for minimum current in accordance with Annex A.

6.9.3.2 Motor performance parameters

The supplier/manufacturer shall provide the following motor performance parameters: motor amperage, speed, torque, input kilowatts, efficiency, power factor, and winding temperature rise at 100 % rated output power. These parameters shall be in accordance with Annex A.

6.9.3.3 Motor operating internal temperature limits

The supplier/manufacturer shall provide the minimum and maximum internal motor operating temperature limits in accordance with Annex A.

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6.9.3.4 Locked rotor current, torque, and power factor

The supplier/manufacturer shall provide the locked rotor current, torque and power factor values in accordance with Annex A.

6.9.4 Scaling of design validation

Scaling of the design of this component is allowed per 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 motor lead extension (MLE) cable, hereafter referred to as "cable" that responds to the functional requirements. The supplier/manufacturer shall also provide to the user/purchaser component data defined in 7.2.

6.10.2 Technical characteristics

The following criteria shall be met.

a) The cable shall conduct electricity from the surface to the downhole motor.

b) The cable shall insulate the voltage supplied to the downhole motor.

6.10.3 Performance ratings

6.10.3.1 Cable voltage rating

The supplier/manufacturer shall provide the cable voltage rating in accordance with Annex A.

6.10.3.2 Cable temperature rating

The supplier/manufacturer shall provide the cable temperature rating in accordance with Annex A.

6.10.3.3 Cable ampacity coefficients

The supplier/manufacturer shall provide the cable ampacity coefficients in accordance with Annex A.

6.10.3.4 Cable conductor size

The supplier/manufacturer shall provide the cable conductor size in accordance with Annex A.

6.10.3.5 Cable acceptable minimum bending radius rating

The supplier/manufacturer shall provide the cable acceptable minimum bending radius rating in accordance with Annex A.

6.10.4 Scaling of design validation

Scaling of the design of this component is not allowed.

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