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Oil and gas industries including lower carbon energy — Submersible linear motor systems for artificial lift —

Part 1: **Submersible linear motor**

Industries du pétrole et du gaz, y compris les énergies à faible teneur en carbone — Systèmes de moteurs linéaires submersibles pour relevage assisté —

Partie 1: Moteur linéaire submersible

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Foreword

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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*.

A list of all parts in the ISO 6398 series can be found on the ISO website.

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.

Introduction

This document has been prepared by users/purchasers and suppliers/manufacturers of submersible linear motors and is intended for use in the petroleum and natural gas industries worldwide. This document provides requirements and information to both parties in the selection, manufacturing, testing and use of submersible linear motors. Further, this document addresses supplier specifications. This document provides the components composition diagram of the submersible linear motor, see Annex D.

This document provides the required levels for design validation, quality control and functional evaluation, allowing the user/purchaser to select each level for a specific application. According to different components, design confirmation is divided into two grades; quality control is divided into two grades; and functional evaluation is divided into two grades. For grades of design validation, quality control and functional evaluation, grade 2 is the lowest grade, and higher grades have additional requirements. The user/purchaser may specify supplementary specifications for these grades.

Oil and gas industries including lower carbon energy — Submersible linear motor systems for artificial lift —

Part 1: **Submersible linear motor**

1 Scope

This document provides requirements for the design, design verification and validation, quality control, functional evaluations and storage of submersible linear motor (SLM) systems.

This document is applicable to components of submersible linear motors including stators, movers and motor lead extension cables.

This document also specifies design validation performance rating requirements and functional evaluation for SLM.

Equipment not covered by this document includes pumps and other fittings, power cables and drive systems.

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.

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

ISO 10893-4, *Non-destructive testing of steel tubes — Part 4: Liquid penetrant inspection of seamless and welded steel tubes for the detection of surface imperfections*

ISO 10893-5, *Non-destructive testing of steel tubes — Part 5: Magnetic particle inspection of seamless and welded ferromagnetic steel tubes for the detection of surface imperfections*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ASTM E94, *Standard Guide for Radiographic Examination*

ASME BPVC, Section V, *Nondestructive Examination*

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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
bottom connection of stator
connecting part between the lower end of the *stator* (3.19) and the stator base

3.2
corrosive environment
environment that contains one or more corrosive agents

[SOURCE: ISO 8044:2020, 3.3]

3.3
cushion
terminal buffer for the *mover* (3.9) of a linear motor

3.4
design validation
process of proving a design by testing to demonstrate conformity of the product to design requirements and performance ratings

[SOURCE: ISO 15551:2023, 3.39]

3.5
design verification
process of examining the premise of a given design by calculation, comparison or investigation, to substantiate conformity with specified requirements

[SOURCE: ISO 15551:2023, 3.40]

3.6
maximum operating temperature
maximum ambient temperature at which the *submersible linear motor* (3.26) can be operated as specified by the supplier/manufacturer

3.7
motor lead extension cable
cable connected to the *pothead* (3.13) for splicing to the power cable

3.8
motor linear velocity
displacement of *mover* (3.9) running per unit time

3.9
mover
shaft-shaped component of the *submersible linear motor* (3.26) that carries on the back and forth movement in an operation

3.10
mover base
components with function of supporting the *mover* (3.9)

3.11
mover short joint
joints between *mover* (3.9) subs

3.12
mover straightness
maximum deviation distance between the *mover* (3.9) surface and the horizontal plane

3.13
pothead
power connector on the end of the *motor lead extension cable* (3.7) or power cable which mates to the motor

[SOURCE: ISO 15551:2023, 3.105]

3.14
qualified person
individual with characteristics 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

[SOURCE: ISO 15136-1:2009, 3.49]

3.15
rated power
output power of the *submersible linear motor* (3.26) under *rated voltage* (3.17), *rated current* (3.18) and *rated thrust* (3.16)

Note 1 to entry: Rated power is expressed in kW.

3.16
rated thrust
maximum *thrust* (3.27) value of the *submersible linear motor* (3.26) for long-term stable operation

3.17
rated voltage
optimal voltage of the *submersible linear motor* (3.26) for long-term stable operation

3.18
rated current
optimal current of the *submersible linear motor* (3.26) for long-term stable operation

3.19
stator
component of the *submersible linear motor* (3.26) that is usually composed of *stator core* (3.20), *stator electromagnetic winding* (3.21), inner cylinder and housing

Note 1 to entry: Generally, the *stator core* (3.20) and the *stator winding* (3.21) are placed in the oil filled sealing cavity composed of the inner cylinder and the shell.

Note 2 to entry: When the *submersible linear motor* (3.26) works, the stator remains stationary.

3.20
stator core
component of the *stator* (3.19) comprised of multiple steel lamination sheets through which copper or other electrical conducting material is wound and laminated to reduce eddy current loss

3.21
stator winding
conductive wire threaded through the *stator core* (3.20)

3.22
stator end cover
end cover at each end of a *stator* (3.19) sub

3.23
stator lead connector
lead connector of the series windings of the *stator* (3.19) of a *submersible linear motor* (3.26)

3.24
stator limit short section
joint that limits the *stator* (3.19) of a *submersible linear motor* (3.26)

3.25
stroke
maximum linear displacement of the *mover* (3.9) during operation

3.26
submersible linear motor
SLM
motor that directly converts electrical energy into mechanical energy for the linear motion needed to drive the plunger pump to do reciprocating work in a well

3.27
thrust
longitudinal acceleration force or deceleration force generated during operation of the *submersible linear motor* (3.26)

[SOURCE: IEC 62520-2011, 3.14]

3.28
top connection of mover
connecting part between the upper end of a *mover* (3.9) and the polished rod of a plunger pump

3.29
top connection of stator
uppermost connection part of the *stator* (3.19) sub in series

3.30
unique identifier
unique combination of alphanumeric characters to identify a specific component

[SOURCE: ISO 15136-1:2009, 3.70]

4 Symbols and abbreviations

4.1 Abbreviated terms

AWG American wire gauge

MD measured depth

NDE non- destructive examination

TVD true vertical depth

4.2 Symbols

K constant, is 234,5 for copper conductor

R_{UV} resistance value measured between U and V terminals of the winding

R_{VW} resistance value measured between V and W terminals of the winding

R_{WU} resistance value measured between W and U terminals of the winding

R_{med} sum of the three phase DC resistances

R_U U phase resistance of the winding

R_V V phase resistance of the winding

R_W W phase resistance of the winding

R_{mav} average of the three phase DC resistances

R single phase resistance of the winding

ε_{mR} imbalance rate of the three-phase DC resistance

R_{max} maximum value in R_U, R_V, R_W

R_{min} minimum value in $\mathrm{R_U}$, $\mathrm{R_V}$, $\mathrm{R_W}$

R_f resistance of the winding at the time of motor de-energization

R_b resistance of the winding before the test is started at a known stable temperature

T_{av} average winding temperature rise

T_b temperature at the time R_b is taken

T_f temperature at the time R_f is taken

5 Functional specification

5.1 General

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

SLM is designed for specific applications, when used in a new/different application, re-evaluation is required to ensure that the system works properly. The process used for this re-evaluation shall be no less stringent than that required for the initial application.

5.2 SLM type description

The user/purchaser shall request a SLM on the basis of the production requirements.

5.3 Functional requirements

5.3.1 General

The user/purchaser shall specify the known and anticipated application parameters and requirements. Operational issues that can have an effect on the systems operation and durability, such as rated power, rated voltage, rated current, rated thrust, stroke, minimum and maximum strokes per minute and other issues, shall also be specified.

5.3.2 Application parameters

5.3.2.1 General

While installed, the SLM system shall perform in accordance with its functional requirements, which are typically determined based on application parameters. These parameters include, but are not limited to, those listed in 5.3.2.2 to 5.3.2.3.

5.3.2.2 Well information

5.3.2.2.1 Requirement

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

a) operating environment, such as corrosive environment of downhole heavy oil and conventional oil production applications;

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 or shale;

e) reservoir recovery mechanism or process, such as water flooding, thermal recovery;

f) production information, such as but not limited to fluid production, minimum expected well fluid flow rate, maximum expected bottom temperature, oil pressure, and casing pressure;

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

h) service-life expectation, such as days and repair cycle.

5.3.2.2.2 Supplemental Information

The following well information shall be specified, if available:

a) well profile, such as inclination, “S shaped” and “U shaped”;

b) pertinent production history using SLM and other methods, such as other artificial lift methods or natural flow;

c) anticipated sand production rate;

d) potential for anticipated downhole wax formation;

e) potential for anticipated downhole scale formation, including radioactive scales.

5.3.2.3 Completion information

5.3.2.3.1 Requirement

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

a) proposed SLM setting depth in terms of MD and TVD of the upper end of the SLM mover;

b) existing or planned total well depth, such as plug back depth in terms of MD and TVD;

c) depth of producing intervals, top and bottom, in terms of MD and TVD;

d) casing/liner size including outside diameter and mass, connection type and grade of production casing;

e) minimum drift diameter through wellhead to bottom of the SLM assembly;

f) production tubing size including outside diameter, mass, connection type, and grade;

g) completion type, such as perforated casing or open hole.