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**Petroleum and natural gas industries —  
Progressing cavity pump systems for  
artificial lift —**

**Part 2:  
Surface-drive systems**

*Industries du pétrole et du gaz naturel — Pompes de fond à cavité  
progressive pour activation des puits —*

*Partie 2: Systèmes d'entraînement en surface*



Reference number  
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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 15136-2 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 4, *Drilling and production equipment*.

ISO 15136 consists of the following parts:

- *Downhole equipment for petroleum and natural gas industries — Progressing cavity pump systems for artificial lift — Part 1: Pumps*
- *Petroleum and natural gas industries — Progressing cavity pump systems for artificial lift — Part 2: Surface-drive systems*

## Introduction

This part of ISO 15136 has been developed by users/purchasers and suppliers/manufacturers of progressing cavity pump surface-drive systems and is intended for use in the petroleum and natural gas industry worldwide. ISO 15136-2 provides requirements and information to both parties in the selection, manufacturing, testing, and using progressing cavity pump surface-drive systems as defined in the scope. Further, ISO 15136-2 addresses supplier requirements, which set the minimum parameters with which suppliers shall comply to claim conformity with this International Standard.

ISO 15136-2 has been structured to allow for grades of increased requirements in quality control documentation. These variations allow the user/purchaser to select the grade that is required for a specific application.

There are two quality control documentation grades, which provide the user/purchaser the choice of requirements to meet their preference or application. Quality control documentation grade Q2 is the standard grade offered and quality control documentation grade Q1 provides additional documentation. Additional requirements can be specified by the user/purchaser as supplemental requirements.

Users of this International Standard should be aware that requirements above those outlined in this International Standard may 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 may be particularly applicable where there is innovative or developing technology. Where an alternative is offered, the vendor should identify any variations from this part of ISO 15136-2 and provide details.



# Petroleum and natural gas industries — Progressing cavity pump systems for artificial lift —

## Part 2: Surface-drive systems

### 1 Scope

This part of ISO 15136 provides requirements for the design, design verification and validation, manufacturing and data control, performance ratings and repair of progressing cavity pump surface-drive systems for use in the petroleum and natural gas industry. This part of ISO 15136 is applicable to those products meeting the definition of surface-drive systems. Additionally, informative annexes provide information on brake system selection, installation, and operation; and sucker rod selection and use.

Equipment not covered by this part of ISO 15136, unless integral by design, includes bottom drive systems, sucker rods, polished rod clamps, stuffing boxes, electrical controls, instrumentation, external power transmission devices, auxiliary equipment, such as belts, sheaves and equipment guards. These items might or might not be covered by other International Standards.

### 2 Normative references

The following referenced documents are indispensable for the application 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 2859-1, *Sampling procedures for inspection by attributes — Part 1: Sampling schemes indexed by acceptance quality level (AQL) for lot-by-lot inspection*

ISO 2859-2, *Sampling procedures for inspection by attributes — Part 2: Sampling plans indexed by limiting quality (LQ) for isolated lot inspection*

ISO 3601-1, *Fluid power systems — O-rings — Part 1: Inside diameters, cross-sections, tolerances and size identification code*

ISO 3601-3, *Fluid power systems — O-rings — Part 3: Quality acceptance criteria*

ISO 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method*

ISO 6507-1, *Metallic materials — Vickers hardness test — Part 1: Test method*

ISO 6508-1, *Metallic materials — Rockwell hardness test — Part 1: Test method (Scales A, B, C, D, E, F, G, H, K, N, T)*

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

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

## ISO 15136-2:2006(E)

ISO 15156 (all parts), *Petroleum and natural gas industries — Materials for use in H<sub>2</sub>S-containing environments in oil and gas production*

ASTM A370, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

ASTM D1415, *Standard Test Method for Rubber Property — International Hardness*

ASTM D2240, *Standard Test Method for Rubber Property — Durometer Hardness*

ASTM E140, *Standard Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, and Scleroscope Hardness*

MIL STD 105E, *Sampling Procedures and Tables for Inspection by Attributes*

### 3 Terms and definitions

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

- 3.1 applied torque**  
torque that is applied to the top of the drive string by the surface-drive system
- 3.2 auxiliary equipment**  
equipment or components that are outside the scope of this part of ISO 15136 and are typically selected and/or installed by the user/purchaser; examples are sheaves and belts, motors, polished rod clamps, guards, motor controllers and torque limiting devices
- 3.3 axial-load capacity**  
maximum allowable load that can be supported by the structure independent of auxiliary equipment capabilities
- 3.4 backspin**  
process by which the progressing cavity pump, the drive string and the power train turn in the direction opposite to normal operation and which is driven by the release of the torsional and fluid potential energy
- 3.5 backspin-resisting torque**  
torque applied to the drive string to resist backspin
- 3.6 brake-engagement speed**  
rotational speed at which the brake system engages during backspin
- 3.7 bottom-drive system**  
PCP drive system utilizing a downhole prime mover
- 3.8 brake system**  
system that provides controlled resistance to backspin
- 3.9 drive string**  
device transmitting power (usually sucker rods) between the surface-drive system and the PCP



**3.10****dynamic fluid level**

depth from the wellhead to the top of the liquid column in the casing-tubing annulus under dynamic conditions

**3.11****direct drive**

type of surface-drive system with no internal gear reduction

**3.12****driver sheave**

pulley mounted on the prime mover shaft in belt driven surface-drive systems

**3.13****driven sheave**

pulley mounted on the main shaft in belt-driven surface-drive systems

**3.14****flow rate**

volume of fluid pumped per unit of time

**3.15****fluid potential energy**

energy stored in the production system due to the difference in fluid levels between the production tubing and the tubing-casing annulus

**3.16****fluid head**

pressure exerted by the fluid above the downhole pump

**3.17****friction torque**

resistance to rotation of the drive string (inside the tubing) and the rotor (inside the stator) that is dependent upon factors including (but not limited to) well depth and trajectory, pump geometry and interference fit between rotor and stator, and stuffing box characteristics

**3.18****gear-reduction drive**

type of surface-drive system with an internal gear reduction

**3.19****heat capacity**

total energy absorbed by the surface-drive system divided by the change in surface-drive system temperature

**3.20****heat dissipation rate**

rate at which energy is dissipated from the surface-drive system to its surroundings in the form of heat

**3.21****hydraulic drive**

type of surface-drive system powered by a hydraulic prime mover

**3.22****hydraulic torque**

torque induced by the differential pressure across the PCP acting on its effective cross-sectional area

**3.23****input power rating**

maximum allowable power, which may be supplied to the surface-drive system

**3.24**

**job lot**

batch of material or components that have undergone the same process or series of processes

**3.25**

**job-lot traceability**

the ability of parts to be identified as originating from a job lot which identifies the included heat(s)

**3.26**

**main shaft**

central shaft of the surface drive that is connected to the drive string

**3.27**

**maximum backspin speed**

maximum speed allowed at the main shaft that will not compromise the integrity of the surface-drive system or auxiliary equipment

**3.28**

**maximum dynamic fluid level**

maximum operating fluid level in the annulus as measured from the surface that ensures that, after a shutdown, the rotating speed does not exceed the maximum backspin speed for the surface-drive system

**3.29**

**maximum operating torque**

maximum allowable operating torque applied at the main shaft as specified by the supplier/manufacturer

**3.30**

**moment of inertia**

ratio of the torque applied to the rotating components of the surface-drive system divided by the angular acceleration of those components about a common axis

**3.31**

**operating speed range**

range defined by the minimum and maximum operating speeds for the surface-drive system as specified by the supplier/manufacturer

**3.32**

**operating temperature range**

range defined by the minimum and maximum operating temperatures for the surface-drive system as specified by the supplier/manufacturer

**3.33**

**polished-rod stick-up**

length of polished rod extending above the top of the polished rod clamp

**3.34**

**power train**

components of the surface-drive system and auxiliary equipment which transmit power from the prime mover into the drive string

NOTE Includes belts, sheaves, gears, direct coupling or other combinations to achieve the required output.

**3.35**

**prime mover**

motor (typically hydraulic, electric or internal combustion) providing the torque to the power train

**3.36****production system**

assembly of equipment that includes the downhole pump, drive string, production tubing, well casing, surface-drive system, and auxiliary equipment

**3.37****progressing cavity pump**

pump consisting of a stator and rotor whose geometry of assembly is such that it creates two or more series of lenticular, spiral, separated cavities

**3.38****repair**

activities that include disassembly, re-assembly and testing with or without the replacement of parts and can include, machining, welding, heat treating or other manufacturing operations

**3.39****surface-drive system**

assembly of equipment that, when installed, transmits torque from a prime mover into a progressing cavity pump drive string, supports the loads transmitted by the drive string and controls backspin of the drive string as applicable

**3.40****thrust bearing**

device within a surface-drive system that supports the axial load transmitted by the drive string while allowing it to rotate

**3.41****thrust-bearing rating**

bearing manufacturer's published statistical ratings that serve as guidelines in the prediction of bearing life expectancies under given conditions

**3.42****torque-limiting device**

device that prevents the surface-drive system from applying a torque to the drive string greater than a prescribed value

**3.43****torsional energy**

energy stored in the drive string due to torque-induced elastic deformation

**4 Abbreviated terms**

ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AQL	Acceptance quality limit
IEC	International Electrotechnical Commission
mo	month
NACE	National Association of Corrosion Engineers
NDE	Nondestructive examination
PCP	Progressing cavity pump

SAE	Society of Automotive Engineers
SNT (ASNT)	American Society for Nondestructive Testing
yr	year

## 5 Functional specification

### 5.1 General

The user/purchaser shall prepare a functional specification to order products which conform to this part of ISO 15136 and shall specify the following requirements and operating conditions as appropriate, and/or identify the supplier's/manufacture's specific product. This information is used by the supplier/manufacture to recommend the surface-drive systems and/or components for the application. These requirements and operating conditions may be conveyed by means of a dimensional drawing, data sheet, or other suitable communication in a format that conforms to this part of ISO 15136. An example of a functional specification form for this information is provided as Annex F.

The user/purchaser shall ensure that the expected operating axial load, torque, speed, surface-drive system temperature, power and braking requirements (where required) do not exceed the surface-drive system's ratings. The maximum operating torque and the maximum dynamic fluid level are a function of the ability of the surface-drive system to dissipate the energy stored in the production system after a shutdown, and may be determined by using the data provided with the surface-drive technical specifications in an analytical backspin model, such as the one described in Annex B.

### 5.2 Surface-drive system type selection

The user/purchaser shall select a drive system type (exclusive of prime mover type):

- a) gear-reduction drive;
- b) direct drive;
- c) hydraulic drive.

### 5.3 Functional characteristics

#### 5.3.1 General

The user/purchaser shall provide the operating speed and input power (torque), and axial load.

#### 5.3.2 Application parameters

Functional characteristics are typically determined based on application parameters. These parameters may include but are not limited to

- a) anticipated flow rate, tubing head pressure at surface of produced fluid and pump intake pressure;
- b) produced fluid composition (constituents, viscosity, specific gravity, temperature, *et al.*);
- c) anticipated PCP model to be used;
- d) PCP setting depth;
- e) tubular sizes/weights/materials;
- f) drive string diameter, type and material.

#### 5.4 Environmental compatibility

User/purchaser shall specify the environmental compatibility requirements. The following are typical topics for consideration:

- a) ambient temperature;
- b) surface-drive start-up temperature;
- c) high ultraviolet exposure;
- d) high relative humidity (high dew point);
- e) dusty or sandy environment;
- f) areas with unique environmental or safety concerns;
- g) areas with salt spray;
- h) noise considerations;
- i) hazardous location classification.

#### 5.5 Compatibility with related well equipment

The user/purchaser shall specify, where applicable, the interface connection designs and material requirements, and external dimensional limitations, needed to assure that the product shall conform to the intended application:

- a) size, type, material, configuration and interface dimensions of the connection between the product and other well equipment such as: stuffing box, polished rod, wellhead, *et al.*;
- b) size, type and configuration of other products passing through or over the product such as polished rod, sucker rods (see Annex H), *et al.*;
- c) size, type and configuration of other products used with or in conjunction with this product;
- d) proximity of unrelated equipment that can impact the delivery, installation, operation, servicing or removal of the product;
- e) wellhead-angle from the vertical;
- f) prime mover interface requirements.

#### 5.6 Design validation and product functional testing

Design validation and product functional requirements are provided for these products; the user/purchaser is not required to select a grade for these requirements.

#### 5.7 Quality control documentation

Two quality control documentation grades are stipulated in 7.4. The user/purchaser shall specify one of the following quality control documentation grades. If no quality control documentation grade is specified, grade Q2 shall be supplied.

- Q1: enhanced quality control documentation requirements, which include the requirements of Q2;
- Q2: standard quality control documentation requirements.

## 6 Technical specification

### 6.1 General requirements

The supplier/matrixufacturer shall prepare the technical specification that responds to the requirements defined in the functional specification.

### 6.2 Technical characteristics

The following data are included, as applicable, with units of measure:

- a) surface-drive system type;
- b) speed range;
- c) maximum operating torque;
- d) axial load capacity;
- e) sheave size range;
- f) main shaft dimensions;
- g) polished rod size capability;
- h) wellhead/drive connection type;
- i) main shaft type (hollow vs. solid);
- j) physical dimensions and weight;
- k) prime mover type and interface requirements;
- l) gear reduction ratio;
- m) operating temperature range;
- n) responses to special requirements requested by the user/purchaser as specified in Clause 5;
- o) system body maximum pressure, where applicable.

### 6.3 Design criteria

#### 6.3.1 Materials

The supplier/matrixufacturer shall state that the defined materials have performance characteristics that are suitable for all parameters specified in the functional specification. This applies to metallic and non-metallic components. The supplier/matrixufacturer shall have documented specifications for all materials used in the manufacture of the product.

#### 6.3.2 Performance ratings

##### 6.3.2.1 General

The supplier/matrixufacturer shall establish the performance ratings of the surface drivehead, in the product's operating manual as applicable for the surface-drive system based upon objective evidence and evaluation. These include, as a minimum, the performance ratings listed below.

### **6.3.2.2 Brake system characteristics**

#### **6.3.2.2.1 General**

The following parameters shall be supplied to the user/purchaser to aid in the evaluation of the suitability of the surface-drive system for the specific application.

#### **6.3.2.2.2 Backspin-resisting torque**

Mathematical expression, typically expressed in newton metres (foot-pounds), or graphical representation of the backspin-resisting torque, which is stated as a function of backspin speed and surface-drive system temperature.

#### **6.3.2.2.3 Heat-dissipation rate**

Mathematical expression or graphical representation of the heat dissipation rate, which is typically expressed in units of watts per degree Celsius (horsepower per degree Fahrenheit).

#### **6.3.2.2.4 Heat capacity**

Numeric value of the heat capacity, which is typically expressed in units of joules per degree Celsius (BTU per degree Fahrenheit).

#### **6.3.2.2.5 Brake-engagement speed**

Numeric value of the brake system engagement speed, which is typically expressed in units of revolutions per minute.

#### **6.3.2.3 Moment of inertia**

Numeric value of the moment of inertia, which is typically expressed in terms of square kilograms metre-square (pounds foot-square).

#### **6.3.2.4 Thrust-bearing rating**

Numeric value of the thrust-bearing rating, which is typically expressed in terms of kilonewtons (pounds) for a specified set of conditions.

#### **6.3.2.5 Input-power rating**

Numeric value of the input-power rating, which is typically expressed in units of kilowatt.

#### **6.3.2.6 Maximum operating torque**

Numeric value of the maximum operating torque, which is typically expressed in units of newton metre (foot-pounds).

#### **6.3.2.7 Operating temperature range**

Numeric value of the operating temperature range, which is typically expressed in units of degrees Celsius (degrees Fahrenheit).

#### **6.3.2.8 Operating speed range**

Numeric value of the operating speed range, which is typically expressed in units of revolutions per minute.

### 6.3.3 Environmental related issues

The supplier/manufacturer shall ensure that the supplied product is compatible with the environmental requirements defined by the user/purchaser in accordance with 5.4. Implementation of these requirements shall allow the surface-drive system to meet or exceed the requirements of this part of ISO 15136.

## 6.4 Design verification

Design verification shall be performed by the supplier/manufacturer to verify that the product design meets the supplier/manufacturer's technical specifications. Design verification includes documented activities such as design reviews, design calculations, product testing and comparison with similar designs and historical records of defined operating conditions. These evaluations shall include but are not limited to the topics listed in 6.3.2. Empirical methods and/or physical testing used in design verification shall be fully documented and supported with drawings and material specifications.

## 6.5 Design validation

Validation of a product design is achieved following the successful completion of the requirements of 6.4 and 6.6.2. The supplier/manufacturer shall document the functional test procedures (see 6.6) and results of the product testing and shall have on file material certifications and drawings that show all the applicable dimensions, materials and tolerances of parts contained in the tested product. If a particular size, type and model fails a validation test, that basic design and materials of construction shall not be submitted for retest until the manufacturer has determined and documented the corrective measures. Pre-test and post-test dimensional verification of functionally critical dimensions as defined by the manufacturer shall be within the established criteria.

## 6.6 Product functional test

### 6.6.1 Testing requirements

Each surface-drive system produced in accordance with this part of ISO 15136 shall be functionally tested.

### 6.6.2 Functional test

Functional tests shall verify that the product meets the supplier/manufacturer's technical specifications and the user/purchaser's functional specifications. Functional tests shall include detailed evaluations of general drive head operations, speed versus backspin resisting torque and brake system engagement. Each facet of the design shall perform within the manufacturer's stated design capabilities during these evaluations. In the case of a test nonconformance, the manufacturer shall be responsible for determining the cause of the nonconformance.

The surface-drive systems produced in accordance with this part of ISO 15136 supplier/manufacturer shall be documented as having passed the acceptance criteria defined by functional test procedures and results of the supplier/manufacturer product testing and shall have on file material certifications and drawings, which show all the applicable dimensions, materials and tolerances of parts contained in the tested product. The evaluations, including acceptance criteria, testing results and disposition of nonconforming products, shall have documented procedures.

### 6.6.3 General

Product functional testing shall be performed on each product to ensure that it meets the supplier/manufacturer's technical specifications and the user/purchaser's functional specifications. These tests shall include detailed evaluations of: general drive head operations, speed versus backspin resisting torque and brake system engagement. Each facet of the design shall perform within the manufacturer's stated design capabilities during these evaluations. In the case of a test nonconformance, the manufacturer shall be responsible for determining the cause of the nonconformance.



## 6.7 Additional testing

Some applications may require additional testing to be agreed upon between the user/purchaser and supplier/manufacture.

## 6.8 Allowable design changes

All design changes shall be documented and reviewed by the supplier/manufacture against the original design verification and product validation to determine if the change is a substantive change. A substantive design change is a change to the design identified by the supplier/manufacture that affects the performance of the product. A design that undergoes a substantive change becomes a new design requiring design verification as specified in 6.4 and design validation as specified in 6.5. Justifications for design changes that are identified as non-substantive shall be documented. The supplier/manufacture shall, as a minimum, consider the following in evaluating each design change:

- a) stress levels of the modified or changed components;
- b) material changes;
- c) functional changes.

## 6.9 Design scaling

Scaling is not applicable to this product.

# 7 Supplier requirements

## 7.1 General

The supplier/manufacture shall meet the following requirements in designing, manufacturing, evaluating, testing and delivering surface-drive systems that are covered by this part of ISO 15136. Clause 7 contains the detailed requirements to verify that each product manufactured meets the requirements of the functional and technical specifications for that specific product. As a minimum, each of the following topics shall be addressed.

## 7.2 Documentation and data control

### 7.2.1 General

The supplier/manufacture shall establish and maintain documented procedures to control all documents and data that relate to the requirements of this part of ISO 15136. These documents and data shall be maintained to demonstrate conformance to specified requirements. All documents and data shall be legible and shall be sorted and retained in such a way that they are retrievable in facilities that provide a suitable environment to prevent damage or deterioration and to prevent loss.

Documents and data may be in any type of media, such as hard copy or electronic media. All documents and data shall be available and auditable by the user/purchaser. All design verification, product validation, traceability, manufacturing and quality documents and data shall be maintained by the supplier/manufacture for five years after date of last manufacture of that product. This information shall include, as a minimum, the following:

- a) engineering drawings;
- b) engineering specifications;
- c) material specifications;

- d) product assembly and disassembly instructions;
- e) design verifications;
- f) product validations;
- g) operating manuals.

### **7.2.2 Operating manual requirements**

An operating manual shall be available to the user/purchaser for all products supplied in accordance with this part of ISO 15136. The operating manual shall contain at least the following information:

- a) manual reference number;
- b) bill of materials;
- c) technical specifications as listed in Clause 6;
- d) representative illustration(s) identifying major components, significant dimensions and configurations;
- e) pre-installation inspection and pre-service procedures;
- f) operating instructions (see Annex D) including precautions as applicable for safe and environmentally acceptable operation;
- g) lubricant selection guidelines;
- h) maintenance requirements and procedures (including spare parts where applicable);
- i) name and address of supplier/manufacturer;
- j) supplier/manufacturer product identification (including product number, type);
- k) overall dimensions and weight;
- l) handling and storage guidelines;
- m) installation guidelines (see Annex C);
- n) details of the interface connections such as: thread type, size and weight;
- o) performance ratings as specified in 6.3.2.

### **7.2.3 Delivery documentation**

Product documentation supplied at delivery of each surface-drive system to the user/purchaser shall include as a minimum:

- a) name and address of supplier/manufacturer;
- b) supplier/manufacturer product identification (including product number, type);
- c) quality-control documentation grade and information as applicable;
- d) overall dimensions and weight;
- e) technical/operating manual identification;
- f) product technical specifications;
- g) product validation information.

### 7.3 Product identification

Each product furnished in accordance with this part of ISO 15136 shall be permanently identified according to the supplier/manufacturer's specifications. The supplier/manufacturer's specifications shall define the type, method of application and location of the identifications. The following information is the minimum that shall be marked on each product:

- a) supplier/manufacturer's identification;
- b) date (month and year) of final acceptance by the supplier/manufacturer;
- c) supplier/manufacturer's part/model number and serial number;
- d) thrust bearing rating;
- e) maximum operating torque;
- f) maximum input power;
- g) operating speed range.

### 7.4 Quality control documentation

#### 7.4.1 General

This part of ISO 15136 provides for two grades of quality control documentation (objective evidence) to be selected by the user/purchaser. The product hardware quality and manufacturing operations remain unchanged with the selection of Q1 or Q2.

#### 7.4.2 Quality control documentation grades

Q2 is the standard level of quality control documentation conforming to the requirements of 7.2. Quality control documentation grade Q1 provides the user/purchaser the delivery documentation for Q2 plus the following product specific records: material certifications, inspection reports, additional processes documentation and the operating manual. The documentation requirements for Q1 shall be maintained by the supplier/manufacturer as specified in 7.2.1.

#### 7.4.3 Raw materials

##### 7.4.3.1 Material certifications

Raw material used in the manufacture of components shall be traceable to one of the following:

- a) certificate of conformance stating that the raw material meets the supplier/manufacturer's documented specifications;
- b) material test report that verifies that the raw material meets the material supplier's documented specifications, which have been approved by the supplier/manufacturer.

##### 7.4.3.2 Mechanical and physical properties

###### 7.4.3.2.1 Metallic materials

Mechanical property test procedures and practices shall be in accordance with ASTM A370 or an equivalent national or international standard for metallic materials. Manufacturer shall have documented criteria for testing acceptance.

#### 7.4.3.2.2 Elastomers and non-metallic materials

Mechanical property test procedures and inspection requirements for elastomeric and non-metallic materials shall be in accordance with Annex A.

#### 7.4.3.2.3 Inspection requirements, metallic materials

Inspection requirements for metallic materials shall be conducted as detailed in the supplier/manufacturer's written specifications, which include acceptance criteria.

### 7.4.4 Additional processes applied to components

#### 7.4.4.1 Material certifications

Certifications of processes applied to components, e.g. heat treatment, welding, coatings, et al., shall meet the following requirements:

- a) certificate of conformance stating that the materials and processes meet the supplier/manufacturer's documented specifications and acceptance criteria;
- b) material test report so that the manufacturer can verify that the materials and processes meet the supplier/manufacturer's documented specifications and acceptance criteria.

#### 7.4.4.2 Coatings and overlays

Coatings and overlays shall be controlled by the supplier/manufacturer's documented processing instructions, which include acceptance criteria.

#### 7.4.4.3 Welding and brazing

Welding and brazing procedures and personnel qualification shall be in accordance with a national or international standard such as the following:

- ASME Boiler and Pressure Vessel Code Section IX;
- American Welding Society D1.1/D1.1M Structural Welding Code – Steel;
- ANSI/AWS B2.1 Standard for Welding Procedure and Performance Qualification.

Supplier/manufacturer shall have documented criteria for acceptance.

#### 7.4.4.4 Heat treating requirements

Heat treating of production parts shall be performed with heat treating equipment that has been instrumented, calibrated and surveyed in accordance with an applicable national or international standard such as SAE AMSH6875:1998, Section 5 or BS 2M 54.

### 7.4.5 Job-lot traceability

All components, weldments, subassemblies and assemblies shall be traceable to a job lot. Components and weldments shall also have their included heat(s) or batch lot(s) identified. All components and weldments in a multi-heat or multi-batch lot shall be rejected if any heat or batch does not comply with the specified requirements.

#### 7.4.6 Calibration systems

Measuring equipment shall be selected and verified as having the capability to meet the required measurement type and ranges for the applicable use. Calibration of measuring equipment used for final acceptance shall be identified, controlled, calibrated, and adjusted in accordance with a national or international standard for the required measurement ranges and accuracies.

Calibration intervals shall be established based on repeatability and degree of usage. Calibration intervals shall be a maximum of three months until recorded calibration history can be established. Intervals may be lengthened or shortened based on calibration history. Calibration intervals shall then be established based on repeatability, degree of usage and documented calibration history. The calibration interval cannot be increased by more than twice the previous interval. Calibration of measuring equipment used for final acceptance shall be identified, controlled and adjusted in accordance with a national or international standard that is no less stringent than the requirements included herein.

#### 7.4.7 Non-destructive examination requirements

##### 7.4.7.1 General

When specified by the supplier/manufacturer or user/purchaser, non-destructive examinations (NDE) shall be performed and accepted according to the supplier/manufacturer's documented specifications that shall include the requirements defined in 7.4.7. When the supplier/manufacturer's specifications allow sample lot examinations, they shall be on a minimum sample lot that is 5 % of the job lot with one product as the absolute minimum.

Non-destructive examination instructions shall be detailed in manufacturer's documented procedures and comply with the requirements of this part of ISO 15136. NDE acceptance criteria and individual test results shall be documented and approved by authorized personnel. All NDE instructions shall be approved by the applicable manufacturer's accepted ISO 9712 Level III examiner.

NOTE For the purposes of this provision, ASNT RP SNT-TC-1A is equivalent to ISO 9712.

All welds and adjacent heat-affected zones of the sample lot shall be non-destructively examined by one or more of the following methods: radiography, magnetic particle, ultrasonic, or liquid penetrant as designated in the supplier/manufacturer's specifications.

When the inspection produces an unacceptable indication, one additional product from the job lot shall be inspected. If it also is found unacceptable, then 100 % of the job lot shall be inspected to verify compliance. Any unacceptable indications shall be removed, and if repaired, shall be re-examined using the original NDE method and acceptance criteria.

##### 7.4.7.2 Acceptance

Acceptance of all materials/documents shall be permanently indicated either on the materials/documents or in records directly traceable to them.

##### 7.4.7.3 Hardness testing of metallic components

Hardness testing and hardness conversion to other measurement units shall be in accordance with ISO 6506-1, ISO 6507-1, ISO 6508-1, ASTM E140 or equivalent national or international standards, with the exceptions noted in ISO 15156 (all parts) for materials that are intended for use in wells where corrosive agents can be expected to cause stress corrosion cracking. Manufacturer shall have documented criteria for hardness testing acceptance.

NOTE For the purposes of this provision ASTM E10 is equivalent to ISO 6506-1, ASTM E18 is equivalent to ISO 6508-1, ASTM E92 is equivalent to ISO 6507-1 and NACE MR 0175/ISO 15156 (all parts) is equivalent to ISO 15156 (all parts).

**7.4.7.4 Radiographic inspection**

Radiographic inspections shall meet the requirements of a national or international standard such as ASTM E94. Acceptance criteria shall be in accordance with a national or international standard such as ASME Boiler and Pressure Vessel Code, Section VIII, Division I, UW-5I. Manufacturer shall have documented criteria for radiographic inspection acceptance.

**7.4.7.5 Ultrasonic inspection**

Ultrasonic inspections shall meet the requirements of a national or international standard such as ASME Boiler and Pressure Vessel Code Section V, (Nondestructive Examination), Article 5. Acceptance criteria shall be in accordance with a national or international standard such as ASME Boiler and Pressure Code, Clause VIII, Division 1, Appendix 12. Manufacturer shall have documented criteria for ultrasonic inspection acceptance.

**7.4.7.6 Magnetic particle inspection**

Magnetic particle inspections shall be in accordance with a national or international standard such as ASTM E709. Manufacturer shall have documented criteria for magnetic particle inspection acceptance.

**7.4.7.7 Liquid penetrant inspection**

Liquid penetrant inspections shall be in accordance with a national or international standard such as ASTM E165. Manufacturer shall have documented criteria for liquid penetrant inspection acceptance.

**7.4.7.8 Surface defect inspection**

Before assembly, the supplier/manufacturer shall visually inspect all accessible surfaces for defects to ensure that the technical specification is met. Manufacturer shall have documented criteria for surface defect inspection acceptance.

**7.4.7.9 Personnel qualifications**

Personnel performing and accepting NDE shall be qualified in accordance with a national or international standard such as ISO 9712, Level II as a minimum for evaluation and interpretation. Personnel performing visual examinations shall have an annual eye examination in accordance with ISO 9712, as applicable to the discipline to be performed.

NOTE For the purposes of this provision, ASNT RP SNT-TC-1A is equivalent to ISO 9712.

**7.4.8 Component dimensional inspection**

All components shall be dimensionally inspected to assure compliance with design criteria and specifications. Inspection shall be performed during or after the manufacture of the components but prior to assembly. This inspection shall be documented.

**7.4.9 Manufacturing nonconformance**

The supplier/manufacturer shall establish and maintain documented procedures to ensure that an assembly or component that does not conform to specified requirements is prevented from unintended use or installation. This control shall provide for the identification, documentation, evaluation, segregation and disposition of nonconforming components or assemblies.

Responsibility for review and authority for disposition of nonconforming assemblies or components shall be defined by the supplier/manufacturer.

## 7.5 Design verification

### 7.5.1 General

Design verification shall be performed in accordance with Clause 6.

### 7.5.2 Design validation testing

Design testing shall be performed using calibrated test equipment and shall address all the reported product performance ratings (see 6.3.2) and the results shall be recorded, dated, and signed by qualified personnel performing the test. The testing details and acceptance criteria are defined by the supplier/manufacturer's documented procedures. Suggested test procedures for determining braking system characteristics are presented in informative Annex G.

## 7.6 Product functional testing

Product functional testing shall be performed by the supplier/manufacturer on each product manufactured in accordance with this part of ISO 15136. Product functional test results shall be recorded, dated, and signed by the personnel performing the test. The testing details and acceptance criteria are defined by the supplier/manufacturer's documented procedures. Product functional testing shall include, at a minimum, but is not limited to, the items listed in 6.6.

## 8 Repair

Repair activities to surface-drive systems shall return the product to a condition meeting the requirements stated in this part of ISO 15136 or the edition in effect at the time of its original manufacture. A successful and documented product validation test in accordance with the requirements of this part of ISO 15136 shall be required prior to the shipment of each repaired product.

Each repaired product shall be permanently identified as such. This identification shall include the repair centre, date of repair and traceable test records. Manufacturer shall have a documented process for documenting and tracking such repair details.

## 9 Preparation for shipment

Surface-drive systems shall be packaged for transit in accordance with the written specifications of the manufacturer of the product to prevent typically induced loads and contamination from harming the equipment. These specifications shall address the protection of exposed threaded connections and access port(s) from contamination by fluids and debris. All components provided for protection during transit shall be prominently identified as such and removed prior to the product's use.

## 10 Product application changes

Surface-drive systems are designed for specific applications; their transfer to new applications requires a detailed evaluation by the user/purchaser to ensure that the system will operate properly in all aspects of that new application. The process used for that evaluation shall be no less stringent or documented and approved than that required for the initial application.

## Annex A (normative)

### Requirements for elastomers and non-metallic materials

#### A.1 General

All elastomers and non-metallic materials shall be inspected according to the requirements of this annex.

#### A.2 Elastomeric and non-metallic materials

Each component material shall comply with the supplier/manufacturer's written specifications. The supplier/manufacturer providing equipment to this specification shall be responsible for the following. The supplier/manufacturer shall have written procedures and documentation of test results, for testing sealing materials to the limits for which the equipment is rated. The supplier/manufacturer's written specifications for non-metallic compounds shall define those characteristics critical to the performance of the material such as the following:

- a) compound type;
- b) mechanical properties, as a minimum:
  - 1) tensile strength (at break);
  - 2) elongation (at break);
  - 3) tensile modulus (at 50 % or 100 %, as applicable);
- c) compression set;
- d) durometer hardness or international hardness;
- e) chemical resistance to product exposure;
- f) allowable temperature range.

#### A.3 Tolerances

The tolerances of O-rings shall be in compliance with ISO 3601-1. Other seal elements shall meet dimensional tolerances of the manufacturer's written specifications. Sampling procedures for inspection, and the basis for acceptance or rejection of a batch lot, shall be in accordance with MIL STD 105E, General Inspection Level II at a 2,5 AQL for O-rings and at a 1,5 AQL for other seal elements, ISO 2859-1 or ISO 2859-2.

NOTE For the purposes of this provision, SAE AS568 is equivalent to ISO 3601-1.

#### A.4 Hardness

The durometer or international hardness of elastomeric materials shall be measured in accordance with ASTM D1415 or ASTM D2240. The preferred method is to conduct the hardness test on a test specimen from



each batch and cure cycle rather than testing individual seals. In the event such tests are conducted on individual seals, sampling procedures for inspection and the basis for acceptance or rejection of a batch lot shall be in accordance with those cited above for O-rings or other seal elements, respectively.

### **A.5 Visual inspection**

O-rings shall be visually inspected in accordance with ISO 3601-3. Other seal elements shall be visually inspected according to the manufacturer's written inspection procedures and includes such items as lip damage, flashing, breaks, cracks, or other visible damage. Sampling procedures for inspection and the basis for acceptance or rejection of a batch lot shall be in accordance with a documented material acceptance plan, which shall define the applicable AQL levels as they relate to the frequency of rejected components.

### **A.6 Handling and storage**

Many of the elastomeric and nonelastomeric materials require special handling and storage procedures. The manufacturer's written specifications shall include handling and storage requirements, including shelf life appropriate for each specific compound and seal design.

### **A.7 Other non-metallic materials**

Non-metals other than elastomers shall comply with the manufacturer's written specifications, which shall include material compound requirements, mechanical properties, inspections, tolerances, handling, storage, and traceability.

### **A.8 Traceability**

Traceability requirements shall be documented by the manufacturer and shall be sufficient to ensure and verify that all individual parts are manufactured from materials that satisfy the manufacturer's written specifications. Traceability of piece parts is required only until parts are used in subassemblies or assemblies.

### **A.9 Dimensional inspection**

Seal elements shall be dimensionally inspected according to the manufacturer's written inspection procedures, including all relevant aspects of the design as per the design drawing. Sampling procedures for inspection and the basis for acceptance or rejection of a batch lot shall be in accordance with a documented material acceptance plan, which shall define the applicable AQL levels (where allowed) as they relate to the frequency of rejected components.

## Annex B (informative)

### Brake system evaluation method

#### B.1 General

This annex provides one method for evaluating brake system performance of a surface-drive system in a specific application. The brake system performance is evaluated based on the backspin speed and duration, the increase in surface-drive temperature and the residual stored energy. The application shall be defined in terms of a specific well configuration, brake system performance and well operating conditions. Other methods for performing brake system evaluations may be applied. The method presented here describes the basic engineering approaches that should be considered in evaluating these systems. The output of these models can contribute to evaluating whether the brake system is appropriate for a particular application.

Many factors influence the amount of energy stored and the rate at which it can be released from the production system during backspin. This rate of energy release determines the requirements for the brake system. Therefore, it is necessary to use a comprehensive numerical model of the backspin process to determine the brake system requirements for each application of a surface-drive system. This analysis can be completed by the user/purchaser or by the supplier/manufacturer based on information provided in compliance with 6.3.2.

Progressing cavity-pump surface-drive systems store a significant amount of energy in the system during normal operation. When a well is shut down for any reason, the torsional energy stored in the drive string and the fluid potential energy in the production tubing can be released, turning the drive string and moving parts in the surface-drive system in the reverse direction. Usually, a brake system is installed in the surface-drive system to safely dissipate the energy stored in the production system. Where included, the brake system shall:

- limit backspin speed so that no component of the surface-drive or production system exceeds the rated rotational speed of that component during backspin;
- limit the duration of backspin to minimize the impact on well operation;
- minimize the energy stored in the surface-drive and production system at the completion of backspin;
- dissipate or absorb the energy released from the production system without heating any component of the surface-drive or production system to a temperature in excess of that allowable for explosive atmospheres as prescribed in a national or international standard, such as ISO 6184 or EN 13463.

#### B.2 Theoretical modelling of the backspin process

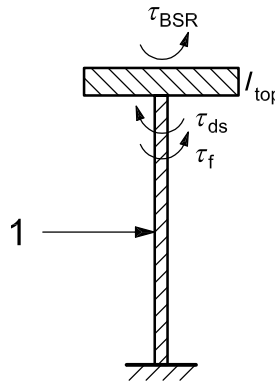
##### B.2.1 General

Backspin can occur in two different scenarios: the seized-pump case and the normal-shutdown case. The theoretical models for these two cases are presented in B.2.2 and B.2.3. Definition of symbols used in the equations can be found in Table B.7.

##### B.2.2 Seized-pump case

In this case, the fluid in the production tubing cannot flow back into the well annulus/reservoir through the pump because the pump is seized. The only energy released is the torsional energy stored in the drive string.

The physical system for the seized pump case can be represented by a disc-spring system as shown in Figure B.1.



**Key**

1 spring

**Figure B.1 — Seized pump**

The only backspin loading torque in the seized pump case is the torque stored in the drive string,  $\tau_{ds}$ . This torque is resisted during backspin by the resisting torque generated by the brake,  $\tau_{BSR}$ , and friction in the production system,  $\tau_f$ . The net torque,  $\tau_{acctop}$ , available to accelerate the power train can be expressed as given in Equation (B.1):

$$\tau_{acctop} = \tau_{ds} - \tau_{BSR} - \tau_f \quad (B.1)$$

The number of elastic twists in the drive string is a function of torque in the drive string. For solid circular cross section drive strings, the polar moment,  $J$ , is given by Equation (B.2):

$$J = \frac{\pi}{32} D_{ds}^4 \quad (B.2)$$

At shut down, the number of twists,  $\theta_{shutdown}$ , in the drive string is expressed as given in Equation (B.3):

$$\theta_{shutdown} = \frac{\tau_{shutdown}}{GJ} L_{ds} \quad (B.3)$$

During backspin, these turns are released causing the torque in the drive string to decline. For a given number of turns,  $\theta_{top}$ , of the drive string during backspin, the remaining torque,  $\tau_{ds}$ , is defined as given in Equation (B.4):

$$\tau_{ds} = \frac{GJ}{L_{ds}} (\theta_{shutdown} - \theta_{top}) \quad (B.4)$$

The backspin resisting torque generated by the brake system,  $\tau_{BSR}$ , is a function of the backspin speed and, in some cases, the drive temperature, as given in Equation (B.5):

$$\tau_{BSR} = f(\theta_{top}, T_{drv}) \quad (B.5)$$

The brake system performance is defined in the surface drive performance information provided by the supplier/manufacturer in compliance with 6.3.2. The backspin resisting torque,  $\tau_{BSR}$ , is specifically provided under 6.3.2.2.2. Friction in the production system,  $\tau_f$ , also resists backspin. This includes friction in the thrust bearing, stuffing box and between the rod/tubing.

The acceleration of the drive, sheaves, motor and half of the drive string is expressed as given in Equation (B.6):

$$\ddot{\theta}_{top} = \tau_{acctop} / I_{top} \tag{B.6}$$

The total moment of inertia,  $I_{top}$ , includes several different components of the power train that can be rotating at different speeds during backspin. The moment of inertia,  $I_i$ , of each component shall be referenced to the polished-rod speed in terms of the speed ratio,  $N_i$ , as given in Equation (B.7):

$$I_{top} = I_1 + N_2^2 I_2 + N_2^2 N_3^2 I_3 + \dots \tag{B.7}$$

where

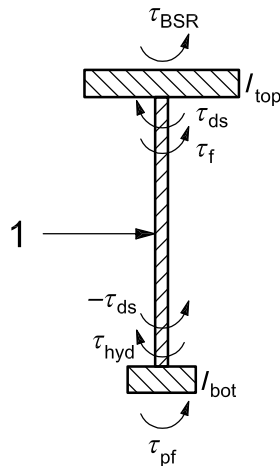
$I_1$  is the moment of inertia of equipment rotating at the polished rod speed;

$I_2$  is the moment of inertia of equipment rotating at a speed  $N_2$  times the speed of component  $I_{n-1}$ ;

$N_i = \frac{\dot{\theta}_i}{\dot{\theta}_{i-1}}$  is the flux.

### B.2.3 Normal shutdown case

The physical system for the normal shutdown case can be represented by a two-disc-spring system as shown in Figure B.2.



**Key**

1 spring

**Figure B.2 — Normal shutdown case**

During the normal shut down case, the hydraulic torque (caused by the differential pressure across the pump) acts with the drive string torque to accelerate the power train and drive string. The fluid in the production tubing flows through the pump and into the well annulus. It is assumed that the fluid flows from the well annulus into the reservoir and that the fluid level in the annulus does not change from the operating fluid level immediately prior to shutdown. The dynamic equations for the second stage of backspin are as given in Equations (B.8) and (B.9):

$$\tau_{acctop} = \tau_{ds} - \tau_{BSR} - \tau_f \tag{B.8}$$

$$\tau_{accbot} = \tau_{hyd} - \tau_{ds} - \tau_{pf} \tag{B.9}$$

Since the pump rotor turns, the torque,  $\tau_{ds}$ , in the drive string becomes a function of the number of turns of the top of the drive string,  $\theta_1$ , and the rotor,  $\theta_2$ , as given in Equation (B.10):

$$\tau_{ds} = \frac{GJ}{L_{ds}} \left[ \theta_{\text{shutdown}} - (\theta_{\text{top}} - \theta_{\text{bot}}) \right] \quad (\text{B.10})$$

The hydraulic torque,  $\tau_{\text{hyd}}$ , depends on the pump geometry (as provided by the pump supplier/manufacturer) and is a function of the differential pressure across the pump expressed by the net fluid level above the pump  $L_{\text{fluid}}$ , as given in Equation (B.11):

$$\tau_{\text{hyd}} = f(L_{\text{fluid}}) \quad (\text{B.11})$$

Friction,  $\tau_{\text{pf}}$ , in the pump also resists turning of the rotor in the stator.

The acceleration of the rotor and half of the drive string is expressed as given in Equation (B.12):

$$\ddot{\theta}_{\text{bot}} = \tau_{\text{accbot}} / I_{\text{bot}} \quad (\text{B.12})$$

The acceleration of the drive, sheaves, motor and half of the drive string is expressed as in Equation (B.6).

### B.3 Initial conditions

The conditions at the start of backspin are as given in the Equations (B.13):

$$\begin{aligned} t &= 0 \\ \tau_{ds} &= \tau_{\text{shutdown}} \\ \theta_{\text{top}} &= \theta_{\text{bot}} = 0 \\ \dot{\theta}_{\text{top}} &= \dot{\theta}_{\text{bot}} = 0 \end{aligned} \quad (\text{B.13})$$

## B.4 Braking system performance

### B.4.1 Backspin resisting torque

The surface-drive backspin resisting torque plays a key role in the backspin process. As shown in Equation (B.4), it is related to the surface-drive backspin speed and the surface-drive temperature. The functional relationship between these three variables shall be determined by the test methods described in Annex G.

### B.4.2 Heat dissipation

The backspin process releases the torsional energy stored in the drive string and the fluid potential energy. This energy is absorbed by the surface-drive causing the drive temperature to rise. When the surface-drive temperature exceeds the ambient temperature, heat is dissipated to the surroundings. The drive temperature at any time is directly related to how much energy the drive can absorb (heat capacity) and how fast heat can be dissipated to the surroundings (heat dissipation rate).

The surface-drive heat capacity and heat dissipation rate shall also be determined by the test methods described in Annex G.

## B.5 Input parameters

### B.5.1 General

Inputs to the calculations to characterize the surface drive application can be categorized as relating to either the surface-drive system or the application.

### B.5.2 Surface-drive system

Surface-drive systems are categorized by the following criteria:

- moment of inertia of surface rotating equipment including gears, sheaves and motor;
- backspin resisting torque as a function of speed and temperature;
- heat capacity;
- heat dissipation rate.

### B.5.3 Application

Surface-drive systems applications include the definition of the following criteria:

- drive string and tubing size;
- drive string material properties;
- well geometry;
- pump seating depth;
- pump displacement;
- pump volumetric efficiency;
- pump and other production system component friction;
- shutdown torque;
- initial surface drive temperature;
- ambient temperature;
- operating fluid level;
- pumped fluid density and viscosity.

## B.6 Calculation steps

The calculation steps required for estimating backspin speed and duration as a function of the energy stored in the production system are as follows:

- a) Start with the initial conditions as in Equations (B.13).
- b) Calculate acceleration of the production system components using Equations (B.1) to (B.7) or (B.8) to (B.12).
- c) Calculate backspin speed of the driven sheave and rotor a small time later [based on rotational acceleration calculated in b)].
- d) Calculate the backspin resisting torque using Equation (B.5).
- e) Calculate the work performed by the brake.
- f) Calculate the heat dissipation rate.
- g) Calculate the new brake temperature (based on brake heat capacity).
- h) Calculate the new turning angles (top and bottom of drive string).
- i) Calculate the volume of fluid leaked through pump.
- j) Calculate new fluid level in the production tubing.
- k) Calculate new drive string torque using Equations (B.4) or (B.10) and hydraulic torque Equation (B.11).
- l) Repeat process [starting at step b)] until backspin stops.

## B.7 Model outputs

The model output should include the following:

- a) backspin speed as a function of time;
- b) surface-drive/brake temperature as a function of time;
- c) residual fluid levels at the end of backspin.

Based on this information, the following parameters are obtained:

- maximum backspin speed;
- maximum surface drive temperature;
- backspin duration;
- residual fluid level in the production tubing.

These outputs can be used to evaluate the suitability of a surface-drive braking system for the intended application by comparing the predicted maximum backspin speed and drive temperature against equipment ratings.

The uncertainty associated with each input variable should be considered to determine the magnitude of the effect of that uncertainty on the model outputs.

## B.8 Model verification

### B.8.1 General

Any models developed for evaluating brake systems may be verified against the benchmark test cases provided below. Each test case specifies the inputs describing the well configuration and operating conditions and provides example outputs from a theoretical model based on the approach outlined in this annex. The four scenarios cover a range of braking requirements that are typical of PC pumping applications.

### B.8.2 Seized-pump examples

#### B.8.2.1 Example 1 — Seized-pump, low operating torque

The data in Table B.1 describe the equipment configuration and operating conditions for a seized pump shutdown.

**Table B.1 — Model input data**

Application parameters	Value
well geometry	vertical
$D_{ds}$	25,4 mm
$G$	75 GPa
$D_{tub}$	N/A
$L_{ds}$	914 m
$V_{pump}$	N/A
$\epsilon_{pump}$	N/A
$\tau_{pf}$	N/A
$\tau_f$	13,6 N·m
$\tau_{shutdown}$	1 088 N·m
$T_{drv}$	40 °C
$T_{amb}$	20 °C
$L_{fluid}$	N/A
$\rho_{fluid}$	N/A
$\mu_{fluid}$	N/A
$I_{bot}$	N/A
Surface drive parameters	
$I_{top}$	33,71 kg·m <sup>2</sup>
$C_{drv}$	127 kJ/°C



The torque generated by the surface-drive braking system is calculated for eight different rotational speeds and five different initial temperatures as shown in Table B.2. The heat dissipation rate is also calculated for three differential temperatures as shown in Table B.3.

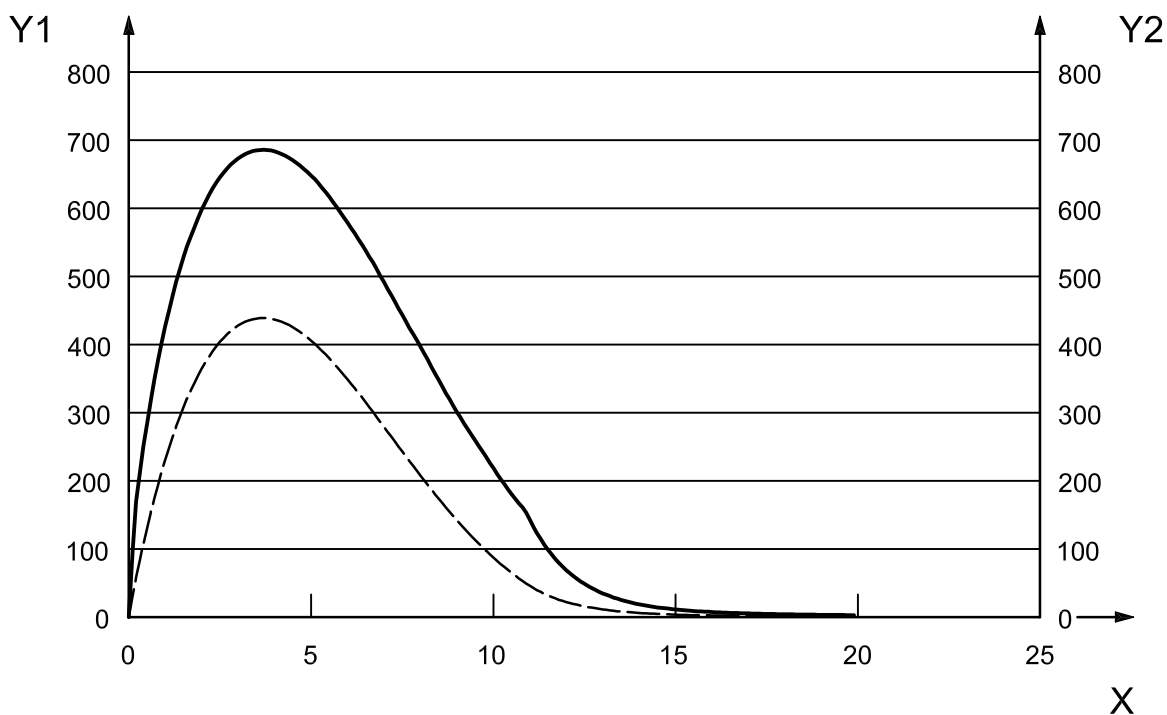
**Table B.2 — Surface-drive brake-resisting torque**

Rod speed r/min	Break torque at rod N·m				
	Temperature °C				
	0	25	50	75	100
0	0	0	0	0	0
50	220	171	145	129	118
100	350	267	221	194	175
200	578	434	354	306	410
300	782	584	475	407	362
400	974	724	586	502	445
600	1 327	984	793	677	599
700	1 496	1 106	891	759	673
800	1 664	1 228	988	842	746

**Table B.3 — Surface-drive heat dissipation rate**

Differential temperature ( $\Delta^{\circ}\text{C}$ )	40	80	120
Heat dissipation rate (kW)	0,42	0,84	1,25

As shown in Figure B.3, the model simulation predicts that the maximum surface-drive backspin speed is 439 r/min and the maximum drive brake torque is 686 N·m.



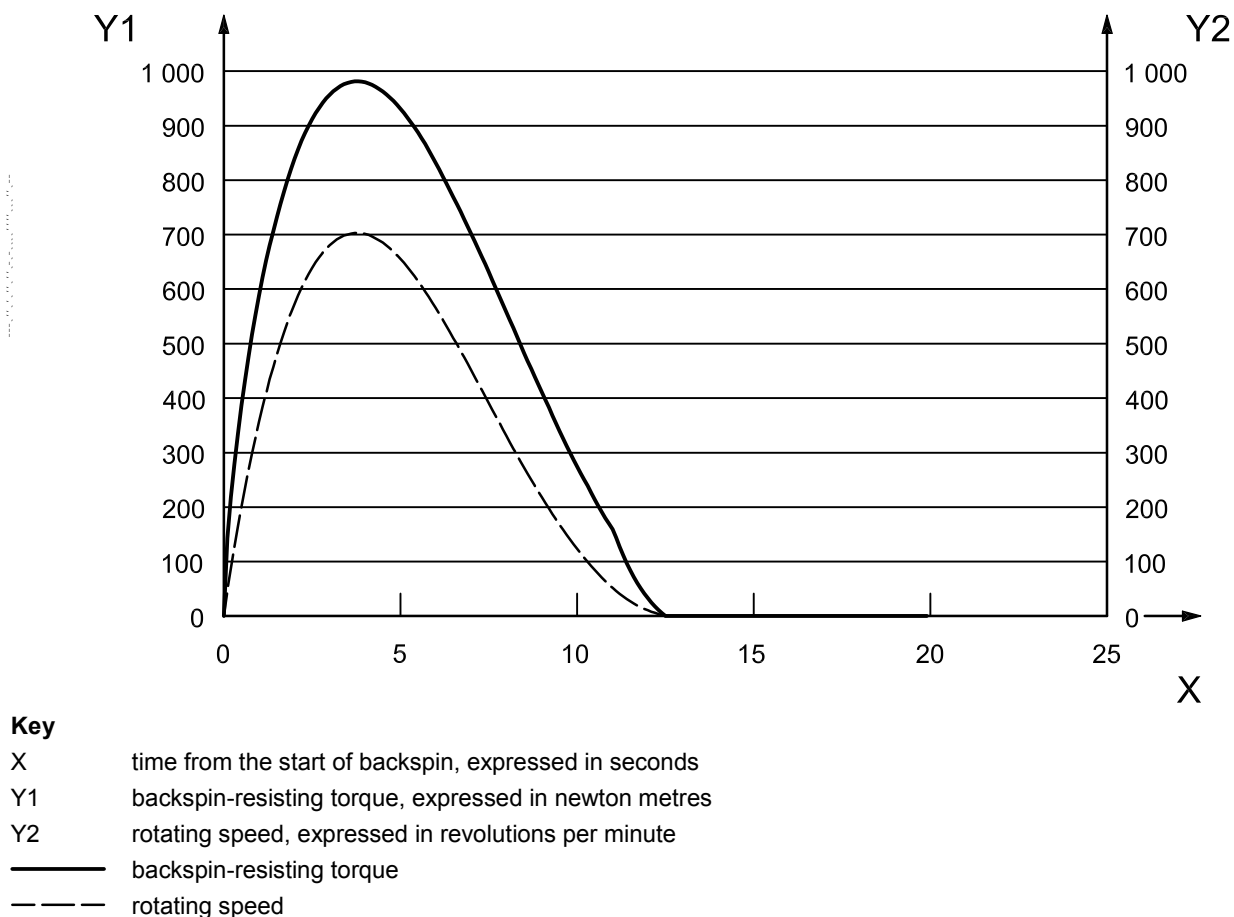
- Key**
- X time from the start of backspin, expressed in seconds
  - Y1 backspin-resisting torque, expressed in newton metres
  - Y2 rotating speed, expressed in revolutions per minute
  - backspin-resisting torque
  - - - rotating speed

**Figure B.3 — Seized pump simulation results — Example 1**

**B.8.2.2 Example 2 — Seized-pump, high-operating torque**

Input parameters are the same as example 1 except that the shutdown torque is increased to 1 627 N·m.

As shown in Figure B.4, the model simulation predicts that the maximum drive backspin speed is 703 r/min and the maximum surface drive brake torque is 981 N·m.



**Figure B.4 — Seized-pump simulation results — Example 2**

**B.8.3 Normal shutdown example — Example 3 — Normal shutdown**

The data in Table B.4 describe the equipment configuration and operating conditions for a normal shutdown. Tables B.5 and B.6 show the brake torque characteristics and heat dissipation rate, respectively.

**Table B.4 — Model input data**

<b>Application parameters</b>	<b>Value</b>
well geometry	vertical
$D_{ds}$	25,4 mm
$G$	75 GPa
$D_{tub}$	76 mm
$L_{ds}$	914 m
$V_{pump}$	95 m <sup>3</sup> /day/100 r/min
$\varepsilon_{pump}$	75 %
$\tau_{pf}$	136 N·m
$\bar{\tau}_f$	13,6 N·m
$\tau_{shutdown}$	1 627 N·m
$T_{drv}$	45 °C
$T_{amb}$	35 °C
$L_{fluid}$	914 m
$\rho_{fluid}$	1 000 kg/m <sup>3</sup>
$\mu_{fluid}$	1 cP
$I_{bot}$	1,66 kg·m <sup>2</sup>
<b>Surface drive parameters</b>	
$I_{top}$	33,71 kg·m <sup>2</sup>
$C_{drv}$	127 kJ/°C

**Table B.5 — Surface-drive brake-resisting torque**

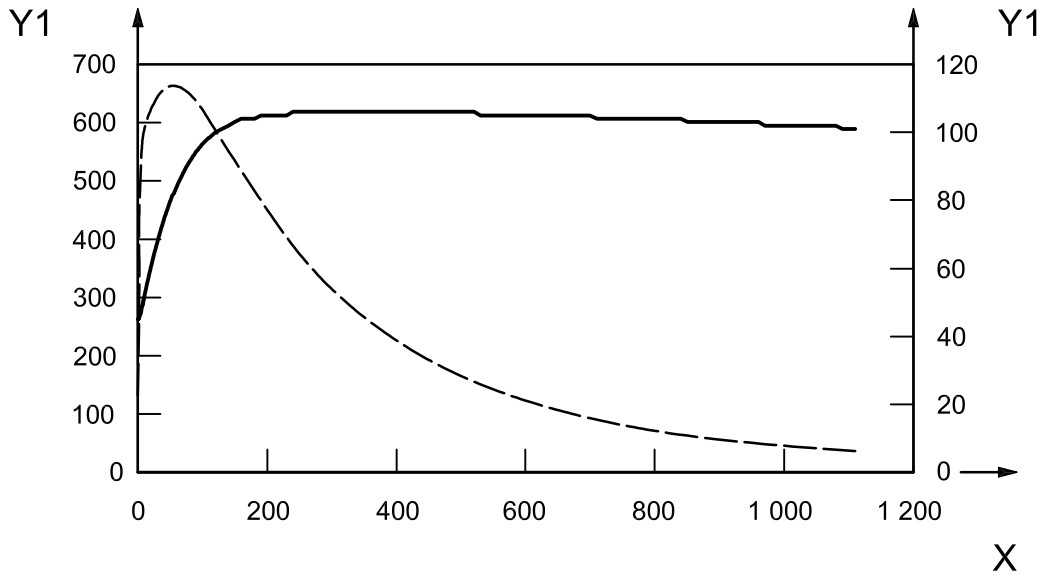
Rod speed r/min	Break torque at rod N·m				
	Temperature °C				
	0	25	50	75	100
0	0	0	0	0	0
50	220	171	145	129	118
100	350	267	221	194	175
200	578	434	354	306	410
300	782	584	475	407	362
400	974	724	586	502	445
600	1 327	984	793	677	599
700	1 496	1 106	891	759	673
800	1 664	1 228	988	842	746

**Table B.6 — Surface-drive heat dissipation rate**

Differential temperature ( $\Delta$ °C)	40	80	120
Heat dissipation rate (kW)	0,42	0,84	1,25

NOTE The fluid level in the well annulus is assumed to remain constant throughout backspin.

As shown in Figure B.5, the model simulation predicts that the maximum drive temperature is 105 °C and the maximum backspin speed is 672 r/min.



- Key**
- X time, expressed in seconds
  - Y1 drive backspin speed, expressed in revolutions per minute
  - Y2 drive temperature, expressed in degrees Celsius
  - drive temperature
  - - - - drive speed

Figure B.5 — Normal shutdown simulation results — Example 3

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Table B.7 — Table of symbols

Symbol	Description	Units
$C_{drv}$	surface-drive heat capacity	kJ/°C
$D_{ds}$	drive string diameter	mm
$D_{tub}$	production tubing inside diameter	mm
$G$	modulus of rigidity	Pa
$J$	polar moment of inertia of the drive string cross-section	m <sup>4</sup>
$I_{top}$	total moment of inertia of drive, sheaves, motor and half of the drive string	kg·m <sup>2</sup>
$I_{bot}$	total moment of inertia of pump rotor and half of the drive string	kg·m <sup>2</sup>
$I_i$	total moment of inertia of individual components of the power train that rotate during backspin	kg·m <sup>2</sup>
$L_{fluid}$	net fluid level	m
$L_{ds}$	length of drive string	m
$N_i$	speed ratio between power train component (i) and component (i-1)	
$t$	Time	s
$T_{amb}$	ambient temperature	°C
$T_{drv}$	drive temperature	°C
$V_{pump}$	pump displacement	m <sup>3</sup> /day per 100 r/min
$\tau_{accbot}$	torque available to accelerate the pump rotor and half of the drive string	N·m
$\tau_{acctop}$	torque available to accelerate the drive, sheaves, motor and half of the drive string	N·m
$\tau_{BSR}$	backspin resisting torque generated by the brake system	N·m
$\tau_{ds}$	backspin loading torque acting on the surface drive due to the elastic deformation of the drive string	N·m
$\tau_f$	torque required to overcome friction in the production system (not including pump friction)	N·m
$\tau_{hyd}$	backspin loading torque produced by fluid flowing through PCP	N·m
$\tau_{pf}$	torque required to overcome friction in the pump	N·m
$\tau_{shutdown}$	torque applied to the drive string immediately before shutdown	N·m
$\epsilon_{pump}$	volumetric pump efficiency	%
$\theta_{top}$	turning angle of the surface drive from shutdown position	rad
$\dot{\theta}_{top}$	surface-drive backspin speed	rad/s
$\ddot{\theta}_{top}$	acceleration of surface drive	rad/s <sup>2</sup>
$\theta_{bot}$	turning angle of the rotor from the shutdown position	rad
$\dot{\theta}_{bot}$	rotor backspin speed	rad/s
$\ddot{\theta}_{bot}$	acceleration of rotor	rad/s <sup>2</sup>
$\theta_{shutdown}$	total turning angle (number of twists) of the drive string at shutdown	rad
$\rho_{fluid}$	density of fluid in the production tubing	kg/m <sup>3</sup>
$\mu_{fluid}$	viscosity of fluid in the production tubing	cp

## Annex C (informative)

### Installation guidelines

#### C.1 General

The installation of a surface-drive system requires a detailed plan that includes appropriate safety and operational precautions that meet the requirements of all the related equipment and all applicable regulations. Install the surface-drive system and auxiliary equipment in accordance with the requirements provided by the supplier/manufacturer of the equipment.

The following issues are offered as a preliminary listing of major points to consider. This is not intended to be a comprehensive list as there are likely other topics of consideration and local requirements. However, it is strongly suggested that the products and equipment installed use the practices defined for the specific equipment and application. The selection of an appropriate surface-drive system and auxiliary equipment requires that the structural, power transmission and backspin-speed control capabilities be considered and evaluated to ensure safe and durable operation of the system.

#### C.2 Lifting the surface-drive system

To avoid damage to equipment or injury to personnel, care should be taken when lifting the surface-drive system. Many surface-drive systems are equipped with lifting points so that a balanced lift can be achieved. Whenever possible, it is advised that slings and shackles be attached to at least two lifting points. The surface-drive system can then be balanced, for lifting, by “choking” the sling (with a third shackle) at the appropriate location on the sling (approximately halfway up).

#### C.3 Mounting the seal unit

Before mounting the seal unit onto the wellhead, it is necessary to establish how much polished rod extension is required above the flow tee. To do this, first determine the overall height of the surface-drive system, including the seal unit assembly and the polished rod clamp. Keep the amount of stick-up above the polished rod clamp to a minimum (less than 0,3 m). Excessive stick-up can cause serious whipping and eccentric shock loading during backspin.

- a) Lubricate the polished rod as per supplier/manufacturer’s guidelines before mounting the seal unit.
- b) Use a polished rod “bullet” as per supplier/manufacturer’s guidelines when running the polished rod through the seal unit to prevent seal unit/rod thread damage. Slide the seal unit over the polished rod and connect to the flow tee as required.

#### C.4 Drive belts and sheaves installation

When installing the sheaves on the surface-drive system, it is often more convenient to mount the taper lock bushings on the backside of the sheaves. Also be sure to align the faces of the driver and driven sheaves.

Tension is set in the belts by increasing the distance between the centres of the driven and driver sheaves until the belts are snug.



Operate the surface-drive system a few minutes to seat the belts in the sheaves. Observe the surface-drive system under its highest load condition (usually start-up). A slight bowing of the slack side of the belts typically indicates proper tension. If the slack side remains tight during the peak load, the belts are too tight. Excessive bowing or slippage indicates insufficient tension. The drive should be stopped and the belts tightened.

Check the belt tension frequently by observing the slack side of the belt span. After a few days of operation, the belts will further seat themselves in the sheave and it can become necessary to retighten the tension so that the belts again show a slight bow on the slack side.

### **C.5 Polished rod clamp installation**

Split polished rod clamps typically have a hollowed bottom portion that engages two machined flats on the top of the driven shaft. While tightening the polished rod clamp, an even gap between the two halves shall be maintained to ensure that the sides of the hollowed portion are not binding on the drive flats of the driven shaft. The polished rod clamp cannot hold the polished rod securely if the drive flats are binding.

### **C.6 Support columns and support plate system installation**

When support columns are required, they serve two purposes: to prevent threaded wellhead fittings from backing off during a backspin cycle and to help support the side-load created by an offset electric motor prime mover. Support columns generally extend down to a support plate that is bolted to the surface casing head flange.

### **C.7 Flow line check valve**

It is recommended that the user/purchaser install a check valve in the flow line, just downstream of the wellhead, to ensure that fluid cannot flow back from a lease tank or flow line into the well when the PCP production system is shut down. Uncontrolled flow into the tubing and through the downhole pump prolongs backspin and causes undue hazard by potentially degrading the brake system performance.

## Annex D (informative)

### Operation guidelines

#### D.1 General

The selection of an appropriate surface-drive system and auxiliary equipment requires that the structural, power transmission and backspin-speed control capabilities be considered and evaluated to ensure safe and durable operation of the system. The operation of a surface-drive system requires a detailed plan that includes appropriate safety and operational precautions that meet the requirements of all the related equipment and all applicable regulations. Operate the surface-drive system and auxiliary equipment in accordance with the requirements provided by the supplier/manufacturer of the equipment.

The following issues are offered as a preliminary listing of points to consider. This is not intended to be a comprehensive list as there are likely other topics of consideration and local requirements. This includes, as a minimum, warnings describing the following hazards.

#### D.2 Residual energy

If, following backspin, the energy stored in the production system is not completely dissipated, it may be released when the surface-drive system is disassembled. It is strongly recommended that operators and well servicing personnel be provided with, and fully implement, the procedures for releasing this residual energy in a controlled and safe manner.

#### D.3 Surface drive overheating

Surface drive brake systems can overheat due to high ambient temperatures or due to repeated restart attempts of a seized or tight pump. Brake or surface-drive temperatures in excess of the recommended operating temperature can degrade brake performance and pose an explosion hazard if in contact with explosive gas mixtures. It is strongly recommended that efforts be made to prevent system operation at temperatures outside the range of operational temperatures specified by the surface drive supplier/manufacturer.

#### D.4 Low temperature operation

Low ambient temperatures can hamper surface-drive brake-system engagement and/or performance. It is recommended that the operating manual for the specific surface-drive system should clearly indicate the operating temperature range for the surface drive. All efforts shall be used to prevent system operation at temperatures outside the operating temperature range specified by the surface drive supplier/manufacturer.

#### D.5 Manually adjustable brake systems

Manually adjustable brake systems permit the user/purchaser to adjust the brake to suit the current braking requirements. A potential hazard exists in the case where the range of adjustment permits the user to “lock in” energy by stopping the backspin process before the fluid potential energy is sufficiently released. This residual energy can be released suddenly if the brake is readjusted or if the surface-drive system is disassembled. Likewise, improper adjustment of the brake can result in backspin speeds in excess of the maximum operating speed, thus creating a hazard. It is recommended that precautions be implemented to prevent improper adjustment of these brake systems.

## D.6 Polished rod stick-up

During backspin, high centrifugal forces can cause the segment of the polished rod above the polished rod clamp to bend, while the drive string continues to rotate, creating a significant safety hazard. It is recommended that the polished rod stick-up not exceed the surface drive supplier/manufacturer's suggested length (typically less than 0,3 m).

## D.7 Changing operating conditions

Changes in well operating conditions such as fluid properties, pump speed, fluid level, pressure and downhole pump size can impact backspin speed and duration. It is recommended that if the operating conditions change, the operator confirm that the new operating conditions are within the specifications for the surface-drive system.

## D.8 Changing environmental conditions

Changes in well environmental conditions such as ambient temperature, airflow, ultraviolet light exposure, dusty or sandy conditions, salt spray or other related issues can impact surface-drive system performance. It is recommended that before installing and operating the surface-drive system in a new environment, the operator confirm that the environmental conditions are within the specifications for the surface-drive system.

## D.9 Changing auxiliary equipment

Changes in the auxiliary equipment can reduce the operating range of the surface-drive system. It is recommended that any changes to auxiliary equipment other than those allowed by the guidelines set forth by that equipment's operating manual be authorized by an engineer competent in this scope of practice.

## D.10 Operational and safety concerns

Any additional operational or safety concerns not addressed above should be defined and detailed in such a way to cover all operator and local requirements by the user/purchaser.

## Annex E (informative)

### Equipment selection guidelines

#### E.1 General

The selection of an appropriate surface-drive system and auxiliary equipment requires that the structural, power transmission and backspin-speed control capabilities be considered and evaluated to ensure safe and durable operation of the system. The following issues are offered as a preliminary listing of major points to consider. This is not intended to be a comprehensive list as there are likely other topics of consideration for the specifying authority. However, it is strongly suggested that the products and equipment selected be rated by their supplier/manufacturer at or above the defined loading requirements of the specific application.

#### E.2 Surface-drive system

It is recommended that the user/purchaser ensure that the expected axial load, torque, speed, surface-drive system temperature and power during operation do not exceed the surface-drive ratings. The user/purchaser should also ensure that the brake system is adequate for the intended application. The maximum operating torque and the maximum dynamic fluid level are a function of the ability of the brake system to dissipate the energy stored in the production system after a shutdown, and may be determined by using the data provided with the surface-drive technical specifications in an analytical backspin model, such as the one described in Annex B. Alternatively, no brake system can be required if it is demonstrated that the backspin speed does not exceed the maximum operating speed of the surface-drive system without a brake, under normal operating conditions.

#### E.3 Torque-limiting devices

It is recommended that torque-limiting devices be installed with the surface-drive system to avoid exceeding the maximum operating torque and/or the input torque rating of the drive string. Similarly, it is recommended that the maximum hydraulic pressure on a hydraulically driven surface drive be controlled to prevent the maximum operating torque from being exceeded.

#### E.4 Sheaves

It is recommended that the smallest possible driven sheave diameter be selected as per belt and sheave supplier/manufacturer specifications. With any speed reduction drive, the rotating speed of the driver sheave is always higher than the polished rod speed by a factor of the ratio of the drive. In most cases, sheaves are cast iron and have a maximum rated rim speed of approximately 1 900 m/min (the maximum speed for most sheaves is usually either cast or stamped onto the sheave).

## Annex F (informative)

### User/purchaser functional specification form

#### Purpose

The following form may be used by the user/purchaser to help specify the functional requirements of the surface-drive system to be purchased, the requirements for these specifications are included as Clause 5, this form is offered to provide a convenient method of collecting that data, it is not fully inclusive of all requirements.

#### Company

Prepared by:	Company:
Date:	Date of delivery:

#### Surface-drive system type selection

Gear reduction drive		Direct drive		Hydraulic drive	
----------------------	--	--------------	--	-----------------	--

#### Prime mover type

Electric		Hydraulic		Internal combustion		Other	
----------	--	-----------	--	---------------------	--	-------	--

#### Surface-drive system functional characteristics

Anticipated PCP operating speed (r/min)	
Anticipated surface-drive system operating power requirements (kW/hp)	
Anticipated polished rod clamp operating torque requirements (Nm/ft-lb)	
Anticipated maximum axial load (N/lbf)	

#### Application parameters (include units of measure)

Anticipated flow rate				
Anticipated Headtubing head pressure, casing head pressure and pump intake pressure				
Produced fluid composition (S.G., viscosity, % CO <sub>2</sub> , % N <sub>2</sub> , % H <sub>2</sub> S, etc.)				
Anticipated PCP to be used (make, model):				
PCP setting depth (MD, TVD):				
Tubing (OD, ID, mass, grade)				
Drive string (OD, type, grade)				

**Environmental compatibility (check all that apply)**

Ambient temperature > 33 °C (90 °F)		Start-up temperature < - 40 °C (- 40 °F)	
High ultraviolet exposure		High relative humidity (high dew point)	
Dusty or sandy environment		Offset from vertical orientation	
Areas with unique environmental or safety concerns		Areas with salt spray	
Hazardous location classification		Noise considerations	

**Compatibility with related well equipment**

End user shall specify: size, type, material, configuration and interface dimensions of the connection between the surface drive and other well equipment such as:
Stuffing box:
Polished rod:
Wellhead:
Other:
Size, type and configuration of other products to be passed through or over the product such as polished rod, sucker rod, etc.
Size, type and configuration of other products to be used with or in conjunction with this product, (note: supporting frame rating is an interface issue)
Proximity of unrelated equipment that may impact the delivery, installation, operation, servicing or removal of the product:
Wellhead angle from the vertical to the installed position:
Prime mover interface requirements:

**Selection of quality control documentation grades (circle one)**

<p><b>Q1</b></p> <p>Enhanced quality control documentation requirements</p>
---

<p><b>Q2</b></p> <p>Standard quality control documentation requirements</p>
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## Annex G (informative)

### Brake system test methods

#### G.1 Purpose

This annex describes recommended test procedures to determine brake system performance characteristics for surface-drive systems used in PCP applications.

#### G.2 Scope

The test procedures are intended to determine the following characteristics of a surface-drive brake system:

- a) heat capacity;
- b) heat dissipation rate;
- c) backspin resisting torque versus speed.

#### G.3 Test setup

- G.3.1** The surface-drive system should be solidly mounted in a vertical operating orientation.
- G.3.2** Airflow around the surface-drive system should be restricted to simulate a “still air” environment.
- G.3.3** Ambient air temperature should be between 15 °C and 25 °C.
- G.3.4** All barriers and other heat traps (i.e. walls and ceilings) should be at least 0,5 m from the surface-drive system.
- G.3.5** All insulation and/or cooling jackets should be at least 0,5 m from the surface-drive system.
- G.3.6** A hydraulic or electric motor should be configured to rotate the power train in the reverse direction.
- G.3.7** The simulated backspin speed should be controlled to within 5 % of the target test speed.

#### G.4 Measurements

- G.4.1** Ambient air temperature should be measured at approximately mid-height of the drive and approximately 0,5 m from the nearest part of the surface-drive system.
- G.4.2** Critical component temperature (the component with the lower allowable temperature or the hottest component of the drive exposed to the atmosphere) should be monitored continuously throughout each test.
- G.4.3** Input torque should be calculated based on current measurements and a motor curve for an electric motor or the applied differential hydraulic pressure of a hydraulic motor.
- G.4.4** Rotating speed of the main shaft should be monitored using the output from a variable frequency drive or from direct measurement using electronic sensors or encoders.

## **G.5 Test procedure — Speed versus backspin resisting torque at ambient temperature**

**G.5.1** Rotate the surface-drive system in the reverse direction at a constant speed within the range of normal backspin operation.

**G.5.2** Record the speed at which the brake engages.

**G.5.3** Wait until the backspin resisting torque stabilizes (typically 10 s to 30 s), then record the speed, applied torque of the brake system and critical component temperature at that time.

**G.5.4** Increase rotating speed quickly to the next test speed.

**G.5.5** Test a total of five speeds including representative operating speeds with the highest speed equal to the maximum operating speed.

**G.5.6** Repeat steps G.5.1 to G.5.5 for at least three different initial temperatures of the critical surface-drive component.

**G.5.7** Plot the relationship between rotating speed in revolutions per minute and resisting torque in newton metres (foot-pounds) for the tested range of temperatures.

## **G.6 Test procedure — Heat dissipation rate**

**G.6.1** Rotate the drive in the reverse direction at a constant speed with the brake engaged.

**G.6.2** Monitor applied torque, rotating speed, critical component temperature and ambient temperature continuously and record data approximately every 5 min.

**G.6.3** Continue to rotate the drive until the change in the critical component temperature is less than 1 °C in 5 min.

**G.6.4** Calculate the input power under the stabilized conditions and record the ambient air temperature and the stabilized temperature of the critical component.

**G.6.5** Repeat steps G.6.1 through G.6.4 for a total of three representative operating speeds.

**G.6.6** Plot the relationship between differential drive temperature (critical component temperature minus ambient temperature) in degrees Celsius and heat dissipation rate (input power) in Watt (horsepower).

## **G.7 Test procedure — Heat capacity**

**G.7.1** Rotate the drive in the reverse direction with the brake engaged at a constant input power sufficient to raise the critical component temperature to its maximum operating temperature in less than 15 min.

**G.7.2** Record applied torque, rotating speed, critical component temperature and ambient temperature continuously.

**G.7.3** Calculate the net power absorption rate of the drive by subtracting the estimated dissipation rate (determined using the preceding test procedure) from the power input.

**G.7.4** Plot the net power absorption rate against time to calculate the total energy absorbed by the surface-drive system based on the area under this curve.

**G.7.5** Calculate the heat capacity of the surface-drive system as the total energy absorbed divided by the change in drive temperature in kilojoules per degree Celsius.



## G.8 Reporting

The results of the physical tests will include:

- a) mathematical expression or graphical representation of heat dissipation rate versus differential temperature;
- b) mathematical expression or graphical representation of backspin resisting torque versus speed;
- c) brake engagement speed;
- d) heat capacity of the surface-drive system.

## Annex H (informative)

### Selection and use of sucker rods in PCP rotary pumping applications

#### H.1 General

This annex describes the considerations related to the application of conventional sucker rods in rotary pumping applications that typically include surface-driven PCP systems.

#### H.2 Background

Progressing cavity (PC) pumping systems typically use a string of sucker rods to transmit power (torque) from the surface-drive system to the downhole pump. This application subjects the sucker rods to a combination of torsion and axial load that introduces the following unique issues related to sucker rod performance not seen in reciprocating pumping applications:

- a) rod loading is more complex due to the combined effect of torsion and axial load;
- b) rod bending due to wellbore curvatures can impose millions of strain cycles on the rods in a matter of days, making fatigue a common failure mode;
- c) rod make-up is critical, since the applied torsional load can lead to incremental make-up that can damage the sucker rod connections;

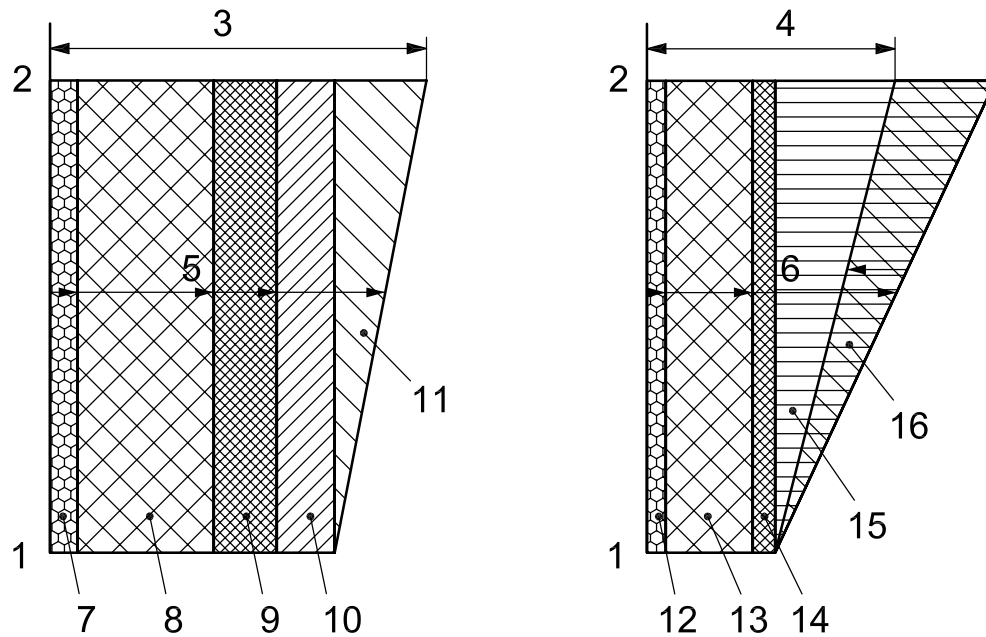
These issues are discussed in H.3 to H.7.

#### H.3 Rod loading

##### H.3.1 General

In a PCP system, the drive string shall be capable of carrying the imposed axial load and transmitting torque to the downhole pump. If the combined axial load and torque produce a combined stress that exceeds the yield capacity for the size and grade of the drive string, failure can occur.

The axial load and torque at any location along a drive string is made up of several different components as shown in Figure H.1. Several major load components are applied to the drive string at the pump (e.g., pump hydraulic torque and pump axial load) while others are developed in a distributed manner along the length of the drive string (e.g., resistive torque and rod weight). In almost all cases, the drive string axial load and torque are largest at the polished rod connection at surface.

**Key**

1 pump	7 pump hydraulic (tubing head pressure)	13 pump axial (hydrostatic pressure)
2 surface	8 pump hydraulic (hydrostatic pressure)	14 pump axial (flow losses)
3 polish rod torque	9 pump hydraulic (flow losses)	15 rod weight
4 polish rod axial load	10 pump friction	16 uplift forces
5 rod string torque	11 resistance	
6 rod string axial load	12 pump axial (tubing head pressure)	

**Figure H.1 — Components that contribute to drive string torque and axial load**

### H.3.2 Pump hydraulic torque

The hydraulic torque is a function of the pump geometry and is proportional to the differential pressure across the PCP. The differential pressure is the difference between the pressure at the pump intake (i.e., sum of the casing head pressure and the hydrostatic pressure in the casing due to the fluid level) and the pressure at the pump discharge (i.e., sum of the tubing head pressure, hydrostatic pressure in the tubing above the pump and pressure losses in the production tubing).

### H.3.3 Pump friction torque

Pump friction is due to the interference fit between the rotor and the stator. Pump friction is typically measured during a pump bench test. However, pump friction can increase downhole if the stator elastomer swells due to thermal or chemical effects. When pumping high viscosity fluids at high rates a viscous torque can also add to the torsional resistance in the pump. Pump friction is typically highest at start-up due to the effect of static friction between the rotor and the stator.

### H.3.4 Resistive drive string torque

As the drive string spins within the fluid in the production tubing, surface shear forces develop between the fluid and drive string that resist the rotation of the drive string.

### H.3.5 Pump axial load

Like the pump hydraulic torque, the pump axial load is a function of the pump geometry and is proportional to the differential pressure across the pump.

### H.3.6 Rod weight

The weight of the drive string, including the pump rotor, also adds to the axial load acting on the rod.

### H.3.7 Drive string uplift forces

Flow losses produce forces that act on the drive string in the direction of flow causing a reduction in rod tension. These forces are applied to the couplings and rod body in the form of area uplift forces and surface uplift forces, respectively.

## H.4 Rod stress limits

The rod stress limit shall be based on the effective stress (i.e., Von Mises stress), which considers the combination of axial load and torque. In PCP applications, the effective stress is primarily a function of torque, with axial load having a lesser effect.

In contrast to the cyclic rod stresses that occur in beam pumping, the rod stresses in PCP applications are relatively constant. As a result, effective rod stresses can approach the yield stress of the rod material without causing failures in PCP applications, although fatigue induced by bending can be an issue in directional and horizontal well applications.

## H.5 Rod fatigue

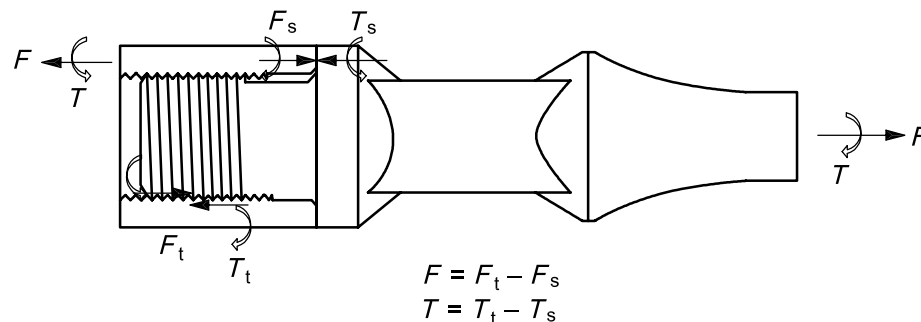
It is well established that mechanical components subjected to alternating loads are susceptible to metal fatigue. Fatigue failures can occur even if the peak stress level in the material is well below the material's yield strength. Fatigue analyses typically attempt to estimate the *operating life* of a component in an alternating stress environment. The fatigue life of a component is affected by: the average (mean) stress; the magnitude of fluctuations in the applied stress; and the number of stress fluctuations. Load fluctuations coupled with a high mean stress result in a more severe fatigue situation than in a load case with fluctuations of a similar magnitude but with negligible mean stress. This can be important in the context of PCP applications, which often involve a high mean stress in the drive string. Most steels exhibit an endurance limit, the maximum alternating stress that results in an "infinite" fatigue life. Designing drive strings for alternating stress levels below the endurance limit is an effective design criterion. However, corrosion mechanisms can act in conjunction with alternating loads to reduce the fatigue resistance of the sucker rod material, so that in some corrosive applications an "infinite" fatigue life cannot be achieved.

The operating conditions in many PCP applications expose the drive strings to severe loading fluctuations. Variations in pump discharge pressure caused by gas in the production tubing or increases in pump friction due to sand or fluid slugs can cause significant fluctuations in pump torque and axial load. In deviated wells, the rods are subjected to cyclic bending stresses at the rotational speed of the pump. Given the typical operating speeds of PCPs, the number of loading cycles can reach several million in just a few days. Therefore, it is essential to consider fatigue analyses when these loading conditions are expected to occur. In calculating fatigue life, both the high-frequency (i.e., bending effects in deviated wells) and low-frequency (e.g., gas slugging effects) are recommended for consideration.

## H.6 Connection make-up

Connection make-up is critical in PCP applications since the applied torsional load during pumping can cause incremental make-up of the connections where the applied torque exceeds the torsional resistance in the connection. The torsional resistance in the connection is a function of the pre-load on the threads and torque

shoulder created during make-up, as shown in Figure H.2. Incomplete make-up results in lower pre-loads in the connection, and therefore, a lower torsional resistance. A high tensile load in the rods can also reduce the pre-load on the torque shoulder, thereby causing a reduction in the torsional resistance of the rod string.



### Key

- $F_t$  axial force on threads
- $T_t$  torsion on threads
- $F_s$  axial force on torque shoulder
- $T_s$  torsion on torque shoulder
- $F$  total axial force
- $T$  total torsion

**Figure H.2 — Loading at connection**

The torsional resistance of a made-up connection is determined by the static coefficient of friction on the threads and torque shoulder. However, if the torsional resistance is exceeded, the frictional characteristics are determined by the kinetic coefficient of friction, which can be significantly lower than the static coefficient. In addition, rapid movement between contacting surfaces (i.e., torque shoulder and coupling face) can lead to dynamic lubrication that further reduces the friction effect. This causes the torsional resistance in the connection to decrease dramatically, allowing the connection to make-up further. This can impose loads that can damage the connection.

Signs that incremental make-up has occurred in a connection can include any or all of the following:

- a) stripped threads;
- b) belled coupling or yielding of the coupling face;
- c) tensile failure of the pin undercut.

Incremental make-up can be particularly severe in the well since the drive string acts as a large torsion spring that stores energy in the form of elastic twists of the rod. When the torsional resistance in a connection is exceeded, the stored energy maintains the applied torque, which causes the incremental make-up to occur very rapidly. This is referred to as dynamic make-up and usually results in damage to the connection.

Ensuring that the sucker rod connections are made up to the manufacturers specification can minimize the effects of incremental make-up. These specifications may specify a certain fraction of a turn past the hand-tight position, which should require a make-up torque in excess of the applied torque during pump start-up and operation. As long as the start-up and operating torques do not exceed the make-up torque, incremental make-up is not likely to occur.

## H.7 Drive string and tubing wear

Drive string and tubing wear in PCP systems differs from beam pumping systems in that the rod coupling rotates in one position on the tubing, causing the wear to be localized. In addition, PCPs are often used in applications where formation solids are produced which can substantially increase wear rates. Wear rates can

be reduced by either using couplings coated with soft, expendable material (e.g., urethane or elastomer) or by distributing the rod contact load among several rod guides placed along the rod body between couplings as shown in Figure H.3. Caution should be exercised when using these wear-mitigation devices, because they typically increase pressure losses in the production tubing, which can increase tension in the drive string, resulting in even higher contact loads between the rods and tubing.

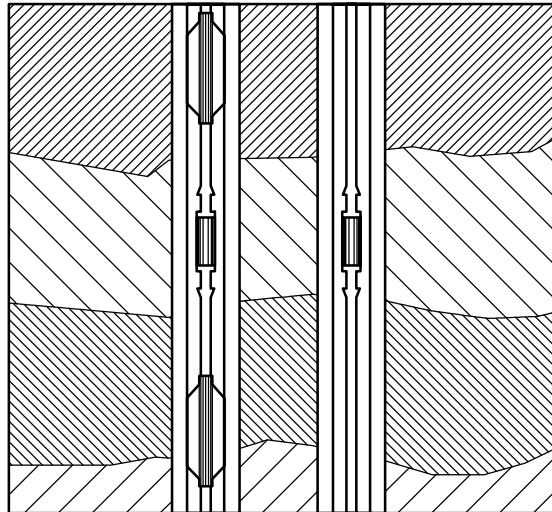


Figure H.3 — Examples of typical rod guides used in PCP applications

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