INTERNATIONAL STANDARD

ISO 10427-2

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Petroleum and natural gas industries — Equipment for well cementing —

Part 2:
Centralizer placement and stop-collar testing

Industries du pétrole et du gaz naturel — Équipement de cimentation de puits —

Partie 2: Mise en place des centreurs et essai des colliers d'arrêt

Reference number
ISO 10427-2:2004(E)

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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.

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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 10427-2 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 3, *Drilling and completion fluids, and well cements*.

This first edition of ISO 10427-2, together with ISO 10427-1 and ISO 10427-3, cancels and replaces ISO 10427:1993, which has been technically revised.

ISO 10427 consists of the following parts, under the general title *Petroleum and natural gas industries — Equipment for well cementing*:

— *Part 1: Casing bow-spring centralizers*

— *Part 2: Centralizer placement and stop-collar testing*

— *Part 3: Performance testing of cementing float equipment*

Introduction

This part of ISO 10427 is based on API Specification 10D, 5th edition, January 1995 [1].

In this part of ISO 10427, where practical, U.S. Customary units are included in brackets for information.

INTERNATIONAL STANDARD ISO 10427-2:2004(E)

Petroleum and natural gas industries — Equipment for well cementing —

Part 2:
Centralizer placement and stop-collar testing

1 Scope

This part of ISO 10427 provides calculations for determining centralizer spacing, based on centralizer performance and desired standoff, in deviated and dogleg holes in wells for the petroleum and natural gas industries. It also provides a procedure for testing stop collars and reporting test results.

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 11960, *Petroleum and natural gas industries — Steel pipes for use as casing or tubing for wells*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply:

3.1
annular clearance for perfectly centred casing
wellbore diameter minus casing outside diameter divided by two

3.2
centralizer permanent set
change in centralizer bow height after repeated flexing

NOTE A bow-spring centralizer is considered to have reached permanent set after being flexed 12 times.

3.3
flexed
condition of a bow-spring when a force three times the specified minimum restoring force (± 5 %) has been applied to it

[ISO 10427-1:2001, 3.1]

NOTE Specified minimum restoring force values are found in Table 1 of ISO 10427-1:2001.

3.4
holding device
device employed to fix the stop collar or centralizer to the casing

EXAMPLE Set screws, nails, mechanical dogs and epoxy resins.

[ISO 10427-1:2001, 3.2]

3.5
holding force
maximum force required to initiate slippage of a stop collar on the casing

[ISO 10427-1:2001, 3.3]

3.6
hole size
diameter of the wellbore

[ISO 10427-1:2001]

3.7
limit clamp
equivalent term for a stop collar

3.8
restoring force
force exerted by a centralizer against the casing to keep it away from the wellbore wall

NOTE Restoring-force values can vary based on the installation methods.

[ISO 10427-1:2001, 3.5]

3.9
rigid centralizer
centralizer manufactured with bows, blades or bars that do not flex

NOTE Adapted from ISO 10427-1:2001, 3.6.

3.10
running force
maximum force required to move a centralizer through a specified wellbore diameter

NOTE Running-force values can vary based on the installation methods.

[ISO 10427-1:2001]

3.11
sag point
point where the casing deflection is at a maximum

NOTE Casing that is supported at two points will tend to sag between the support points, this sag is called the casing sag or casing deflection.

3.12
slippage force range
range of forces required to continue to move a stop collar after the holding force has been overcome

3.13
solid centralizer
centralizer manufactured in such a manner as to be a solid device with nonflexible fins or bands

NOTE These centralizers have solid bodies and solid blades.

3.14
standoff
smallest distance between the outside diameter of the casing and the wellbore

[ISO 10427-1:2001, 3.8]

3.15
standoff ratio
R_s
ratio of standoff to annular clearance for perfectly centred casing

NOTE 1 It is expressed as a percentage.

NOTE 2 Adapted from ISO 10427-1:2001, 3.9.

3.16
starting force
maximum force required to insert a centralizer into a specified wellbore diameter

NOTE Starting-force values can vary based on the installation methods.

[ISO 10427-1:2001, 3.10]

3.17
stop collar
device attached to the casing to prevent movement of a casing centralizer

NOTE A stop collar can be either an independent piece of equipment or integral with the centralizer.

[ISO 10427-1:2001, 3.11]

4 Methods for estimating centralizer placement

4.1 General

The equations presented below are based on certain assumptions and are considered sufficiently accurate for general use. More specific calculations based on complete wellbore data may be available but are beyond the scope of this document.

There is no recommendation or requirement for a specific standoff ratio for casing centralization. The standoff ratio of 67 % is used in the specification for the purpose of setting a minimum standard for performance of casing bow-spring centralizers only. This number is used only in the specifications for bow-spring type centralizers and deals with the minimum force for each size of centralizer at that standoff. The 67 % standoff ratio is not intended to represent the minimum acceptable amount of standoff required to obtain successful centralization of the casing. The user is encouraged to apply the standoff ratio required for specific well conditions based on well requirements and sound engineering judgement.

Even a minor change in inclination and/or azimuth, with the string of casing hanging below it, materially affects the standoff and the requirements for centralizer placement.

The lateral load (force) on a centralizer is composed of two components. The first is the weight component of the section of pipe supported by the centralizer, and the second is the tension component exerted by the pipe hanging below the centralizer.

4.2 Standoff ratio calculation

Annular clearance (l_a) for perfectly centred casing can be calculated as follows (see Figure 1):

$$l_a = \frac{D_w - D_p}{2} \tag{1}$$

where

l_a is the annular clearance for perfectly centred casing, expressed in metres (inches);

D_w is the wellbore diameter, expressed in metres (inches);

D_p is the casing outside diameter, expressed in metres (inches).

The standoff at the centralizer in a given hole size is represented by the symbol S_c (see Figure 1). The standoff at a bow-spring centralizer is taken from the load deflection curve of the centralizer, tested in that hole size, based upon the lateral load applied (see ISO 10427-1:2001, A.1 [2]).

NOTE Differences in hole size alter the load-deflection curve of a centralizer.

Since the bows or blades of a solid or rigid centralizer do not deflect, the standoff at the centralizer is determined using the rigid or solid blade diameter as follows:

$$S_c = \frac{D_c - D_p}{2} \tag{2}$$

where

S_c is the standoff at the centralizer, expressed in metres (inches);

D_c is the outside diameter of the centralizer solid or rigid blades, expressed in metres (inches).

Standoff at the sag point may be determined by Equation (3), which considers the deflection of the casing string and compression of the centralizers due to lateral load (Figure 1).

$$S_s = S_c - \delta \tag{3}$$

where

S_s is the standoff at the sag point, expressed in metres (inches);

δ is the maximum deflection of the casing between centralizers, expressed in metres (inches).

The minimum standoff may occur at the location between centralizers where the deflection (δ) of the casing is at its maximum or at the centralizers. Therefore, standoff (S) of a section of casing is the minimum value of standoff at the centralizers (S_c) or standoff at the sag point (S_s).

The standoff ratio (R_s) may be calculated as follows:

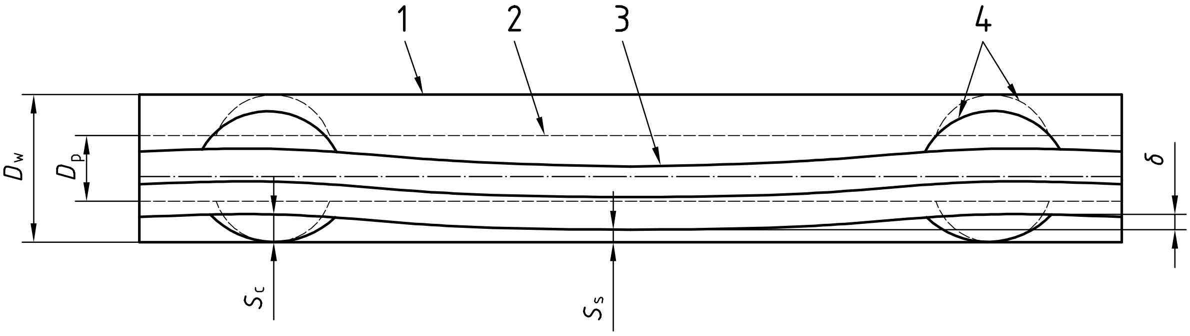
$$R_s = \frac{S}{l_a} \times 100 \tag{4}$$

where

R_s is the standoff ratio, expressed as a percentage;

S is the standoff, expressed in metres (inches);

l_a is the annular clearance for perfectly centred casing, expressed in metres (inches).



Key

1	wellbore	δ	maximum casing deflection
2	casing (perfectly centred)	D_p	casing outside diameter
3	casing (deflected)	D_w	wellbore diameter
4	centralizer	S_c	standoff at the centralizer
		S_s	standoff at the sag point

Figure 1 — Calculation of casing standoff in a wellbore

4.3 Buoyed weight of casing

4.3.1 General

The buoyed weight of casing is the effective weight of the casing in the well. Consideration is given to the densities of the fluids inside and outside the casing, and the weight of the casing in air.

4.3.2 Generalized equation

The following is a generalization of the treatment of effective weight of casing to accommodate different internal and external fluids, based upon a model developed by Juvkam-Wold and Baxter [3].

$$W_b = W \cdot f_b \tag{5}$$

$$f_b = \frac{\left(1-\dfrac{\rho_e}{\rho_s}\right)-\left(\dfrac{D_i}{D_p}\right)^2\left(1-\dfrac{\rho_i}{\rho_s}\right)}{\left(1-\dfrac{D_i^2}{D_p^2}\right)} \tag{6}$$

where

W_b is the unit buoyed weight of the casing, expressed in newtons per metre (pound-force per inch);

W is the unit weight of casing in air, expressed in newtons per metre (pound-force per inch);

f_b is the buoyancy factor;

D_i is the inside diameter of the casing, expressed in metres (inches);

D_p is the casing outside diameter, expressed in metres (inches);

ρ_i is the density of the fluid inside the casing, expressed in kilograms per cubic metre (pound-mass per gallon);

ρ_s is the density of the casing, expressed in kilograms per cubic metre (pound-mass per gallon);

ρ_e is the density of the fluid outside the casing, expressed in kilograms per cubic metre (pound-mass per gallon).

4.3.3 Discussion

The buoyed weight of the casing being cemented changes during a cementing operation. As the densities of the fluids inside the casing and the annulus change, the relative buoyed weight tends to reach a maximum when the highest density fluid is inside the casing, and a minimum when the highest density fluid is in the annulus. In the calculation of buoyed weight for centralizer spacing, the densities of the fluids both inside the casing and in the annulus should be considered. The calculated centralizer spacing can vary depending on the selection of fluid densities present during the cement job. The standoff ratio will change as the fluid densities change, and the user should note at what point during the cement job the required centralization standoff ratio needs to be met, and the appropriate buoyed weight for use in the calculations.

4.4 Calculations for centralizer spacing

4.4.1 General

The equations are valid only for casing strings with axial tension and do not apply for casing strings under compression. The equations do not consider end effects, for example at the shoe, the wellhead, or the liner hanger. The equations are valid only for calculating the casing deflection between two identical centralizers. The lateral load calculations are based upon a “soft string model” and do not take into effect casing stiffness. Additional models have been developed that consider the effects of compression on the casing standoff and lateral loads [4].

4.4.2 Casing deflection in a one-dimensional (1-D) straight, inclined wellbore without axial tension

In an inclined wellbore with no doglegs and negligible axial tension or compression in the casing, the casing deflection at the sag point between two centralizers can be calculated as follows:

$$\delta = \frac{(W_b \cdot \sin\theta) l_c^4}{384 E \cdot I} \qquad (7)$$

where

δ is the maximum deflection of the casing between centralizers, expressed in metres (inches);

W_b is the unit buoyed weight of the casing, expressed in newtons per metre (pound-force per inch);

θ is the wellbore inclination angle, expressed in degrees;

l_c is the distance between centralizers, expressed in metres (inches);

E is the modulus of elasticity of the casing, expressed in newtons per square metre (or pascals) (pound-force per square inch);

I is the moment of inertia of the casing, expressed in m^4 (in^4).

The lateral load of a length (l_c) of casing can be calculated as follows:

$$F_l = W_b \cdot l_c \cdot \sin\theta \tag{8}$$

where F_l is the lateral load, expressed in newtons (pound-force).

4.4.3 Casing deflection in a 1-D straight, inclined wellbore with axial tension

Equation (9) incorporates the effects of tension and can be used to determine the maximum casing deflection in a wellbore that is inclined, but has no doglegs or changes in direction.

$$\delta = \left(\frac{(W_b \cdot \sin\theta) l_c{}^4}{384 E \cdot I}\right)\left(\frac{24}{\mu^4}\right)\left(\frac{\mu^2}{2} - \frac{\mu \cdot \cosh\mu - \mu}{\sinh\mu}\right) \tag{9}$$

$$\mu = \sqrt{\frac{F_t \cdot l_c{}^2}{4E \cdot I}} \tag{10}$$

where F_t is the effective tension below the centralizer, expressed in newtons (pound-force).

4.4.4 Casing deflection in a 2-D wellbore

Casing deflection in a two-dimensional wellbore section that has a constant curvature in a vertical plane can be calculated by the following expressions:

$$\delta = \left[\frac{\left(W_b \cdot \sin\bar{\theta} + \frac{F_t}{r}\right) l_c{}^4}{384\, E \cdot I}\right]\left(\frac{24}{\mu^4}\right)\left(\frac{\mu^2}{2} - \frac{\mu \cdot \cosh\mu - \mu}{\sinh\mu}\right) \tag{11}$$

where

$\bar{\theta}$ is the average wellbore inclination between two centralizers, expressed in degrees;

r is the radius of curvature of the wellbore path, expressed in metres (inches).

or

$$\delta = \left(\frac{F_\mathrm{l} \cdot l_\mathrm{c}^3}{384 E \cdot I} \right) \left(\frac{24}{\mu^4} \right) \left(\frac{\mu^2}{2} - \frac{\mu \cdot \cosh \mu - \mu}{\sinh \mu} \right) \tag{12}$$

In a 2-D wellbore with decreasing inclination, the lateral load can be expressed as:

$$F_\mathrm{l} = W_\mathrm{b} \cdot l_\mathrm{c} \cdot \sin \overline{\theta} + 2 F_\mathrm{t} \cdot \sin \frac{\beta}{2} \tag{13}$$

where β is the total angle change between centralizers, expressed in degrees.

In a 2-D wellbore with increasing inclination, the lateral load can be expressed as:

$$F_\mathrm{l} = W_\mathrm{b} \cdot l_\mathrm{c} \cdot \sin \overline{\theta} - 2 F_\mathrm{t} \cdot \sin \frac{\beta}{2} \tag{14}$$

4.4.5 Casing deflection in a 3-D wellbore

Casing deflection in wellbores with changes in inclination and azimuth can be calculated using the following formulae derived by Juvkam-Wold and Wu [5]. Equation (15) is used to calculate the lateral load of a length of casing (l_c) in the dogleg plane for a drop-off wellbore where the inclination decreases with increasing measured depth. Equation (16) is used to calculate the lateral load of a length of casing (l_c) in a build-up wellbore where the inclination increases with increasing measured depth.

$$F_\mathrm{l,dp} = W_\mathrm{b} \cdot l_\mathrm{c} \cdot \cos \gamma_\mathrm{n} + 2 F_\mathrm{t} \cdot \sin \frac{\beta}{2}, \text{ or} \tag{15}$$

$$F_\mathrm{l,dp} = W_\mathrm{b} \cdot l_\mathrm{c} \cdot \cos \gamma_\mathrm{n} - 2 F_\mathrm{t} \cdot \sin \frac{\beta}{2} \tag{16}$$

$$\cos \gamma_\mathrm{n} = \frac{\sin \left[(\theta_1 - \theta_2)/2 \right]}{\sin (\beta / 2)} \sin \left(\frac{\theta_1 + \theta_2}{2} \right) \tag{17}$$

$$\beta = \cos^{-1} \left[\cos \theta_1 \cos \theta_2 + \sin \theta_1 \sin \theta_2 \cos (\phi_2 - \phi_1) \right] \tag{18}$$

$$F_\mathrm{l,p} = W_\mathrm{b} \cdot l_\mathrm{c} \cdot \cos \gamma_0 \tag{19}$$

$$\cos \gamma_0 = \frac{\sin \theta_1 \sin \theta_2 \sin (\phi_2 - \phi_1)}{\sin \beta} \tag{20}$$

$$\delta = \left(\frac{F_\mathrm{l} \cdot l_\mathrm{c}^3}{384 E \cdot I} \right) \left(\frac{24}{\mu^4} \right) \left(\frac{\mu^2}{2} - \frac{\mu \cdot \cosh \mu - \mu}{\sinh \mu} \right) \tag{21}$$

$$F_\mathrm{l} = \sqrt{F_\mathrm{l,dp}^{\;2} + F_\mathrm{l,p}^{\;2}} \tag{22}$$

where

γ_n is the angle between the gravity vector and the principal normal of the wellbore, expressed in degrees;

γ_0 is the angle between the gravity vector and the binormal of the wellbore, expressed in degrees;

ϕ is the azimuth angle, expressed in degrees;

$F_{l,dp}$ is the total lateral load in the dogleg plane, expressed in newtons (pounds-force);

$F_{l,p}$ is the total lateral load perpendicular to the dogleg plane, expressed in newtons (pounds-force).

When there is no azimuth change, $\phi_1 = \phi_2 = \phi$, the above equations reduce to those of the 2-D wellbore.

5 Procedure for testing stop collars

5.1 General

For the purposes of this procedure, the term “stop collar” is used to indicate any type of device employed to prevent or limit movement of a centralizer on the casing. This includes stop collars that are independent of the centralizer and holding devices that are built into the centralizer, as in the case of solid or rigid centralizers. In this clause, the principles described for centralizers apply to other casing hardware that incorporate the use of a stop collar. Examples of these include cement baskets, scratchers, etc.

The holding device used to prevent the slippage of a centralizer can be an independent piece of equipment, as in the case of a stop collar, or can be integral within the centralizer itself. Several types are available that include the use of screws, nails and mechanical dogs. Some manufacturers also recommend the use of resins in conjunction with their particular holding device.

Regardless of the mechanism used to hold the centralizer in place, the holding device shall be capable of preventing slippage. While the holding force of the stop collar should be greater than the starting force of the centralizer, some multiplier should be applied depending on the particular well conditions.

In the case of either solid or rigid centralizers, it is recognized that these types of centralizer do not have a starting force, as they have a constant outside diameter. The minimum holding force applied to these centralizers should follow the same guidelines as a bow-type centralizer that would be used in the same hole configuration. This same recommendation also applies to other casing hardware incorporating a stop collar.

It should be noted that the data obtained for centralizer starting, running and restoring forces can vary depending on how the centralizer is installed on the casing. The use of a stop collar either as an integral part of the centralizer or with the centralizer placed over the stop collar can provide different results for some centralizers.

Further information indicates that the casing grade, mass, and surface finish can affect the results obtained from stop-collar tests. Changes in the hardness of the casing, as well as the casing wall thickness, have been shown to cause variations in the results by as much as a factor of four. It is therefore recommended that in a critical situation, the testing be performed using the same casing grade and mass as are to be used for the well.

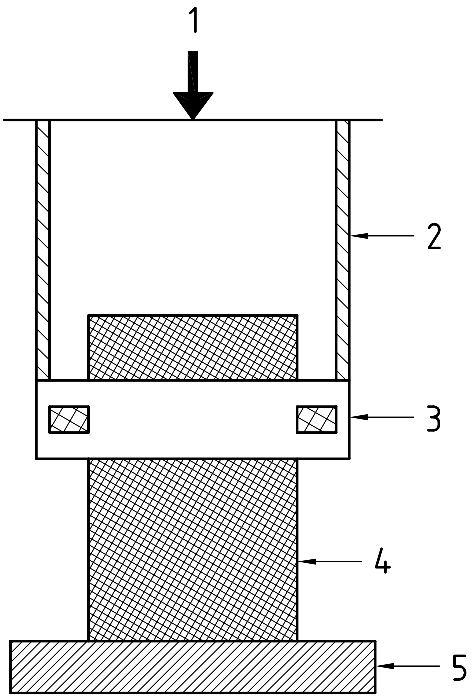
The rate at which the load is applied during the test can have a minor effect on the results. While small changes in the loading rate should have minimal effects, shock loading can alter the results. In some instances it may be desirable to equate the loading rate to the anticipated casing running speed, and adjust the rate accordingly. There are insufficient data currently available to make a firm conclusion or recommendation on loading rates. Associated with the loading rate is the manner in which the load is applied. This test procedure incorporates a concentric loading pattern, which may not match precisely the type of loading that can occur during actual field use. The purpose of this procedure is to provide a consistent method for performing routine tests. If the actual field conditions warrant, individual customized testing may be appropriate. Note that this is a destructive test, and may require replacement of the test casing and the stop collar following each test.

5.2 Apparatus

The test equipment used in this test shall be capable of the application of vertical loads and capable of measuring those loads and vertical displacement.

5.2.1 Test assembly, which should consist of an inner test casing and an outer sleeve (see Figure 2).

The test casing shall be within the tolerances as indicated in ISO 11960 for non-upset pipe. Burrs or similar defects should be removed prior to testing. The outer sleeve should provide a load surface on which to distribute the load to the stop device. Minor notching of the outer sleeve to allow for concentric loading is acceptable.



Key

1 applied force

2 outer sleeve

3 stop collar

4 test casing

5 rigid surface

Figure 2 — Typical test assembly

5.2.2 Instrumentation

The instrumentation should be capable of recording or otherwise indicating the application of vertical loads, including the maximum load applied during the test as well as the load at initiation of slippage (the holding force) and the slippage force range. The accuracy of load measurements should be within 5 % of the measured value.

The test stand should be instrumented to allow displacement readings of 1,6 mm (1/16 in) or less of displacement, with an accuracy of ± 0,8 mm (± 1/32 in) within the range of measurement.

Measuring equipment shall be calibrated at least annually.

5.3 Test procedure

5.3.1 The stop collar should be installed on the test casing per manufacturer's recommendations. Installation position should allow for at least 102 mm (4 in) of travel during the test.

5.3.2 The outer sleeve should be placed over the test casing. This should apply a concentric load to the stop collar.

5.3.3 The outer sleeve should be continuously and slowly loaded. The applied load, plus the mass of the outer sleeve, should be recorded.

5.3.4 The test should be continued until the stop collar has been displaced at least 102 mm (4 in) or completely fails (breaks).

5.4 Reporting of test results

The following information should be reported. A typical form for test results is given in Annex A:

a) size, mass, grade and type of surface finish of the test casing;

b) measured inner diameter (ID) and outer diameter (OD) of the test casing, outer sleeve, and stop collar;

c) loading rate and loading technique;

d) holding force;

e) slippage force range;

f) condition of the inner test casing following the test, noting any scarring of the casing and the depth, length, and width of the scarring;

g) orientation of the stop collar where appropriate (to be reported with stop collars that are to be installed in a particular direction);

h) identification of any minor modifications made to the end of the outer sleeve to allow for concentric loading;

i) stop-collar manufacturer, model number, nominal sizes, number and type of attachments, installation torque on attachment device, if applicable.

Annex A
(informative)

Documentation of stop-collar test results

Date of test:________________

A.1 Stop-collar information

Part Number: ________________________ Manufacturer: __________________________________

Model Number: ________________________

Casing size: ___________________ mm (in) Installation torque (if applicable): _________________

A.2 Test Specimen Number: ____________

A.3 Dimensional data

A.3.1 Test assembly characteristics (see Figure 2)

Part	OD mm (in)	ID mm (in)	Mass kg (lb)
Test casing			—
Outer sleeve			
Stop collar			—

A.3.2 Test casing

A.3.2.1 Diameter: __________ mm (in)

A.3.2.2 Linear mass: __________ kg/m (lbm/ft)

A.3.2.3 Grade: __________

A.3.2.4 Surface finish: __________

A.4 Test parameters

A.4.1 Holding force (maximum load prior to slippage): __________ N (lbf)

A.4.2 Time to maximum load: __________ s

A.4.3 Load rate: __________ / _________ = ______________ N/s (lbf/s)

A.4.4 Slippage force range: Max. load: __________ N (lbf); Min. load: _________ N (lbf)

A.5 Test casing inspection (post-test)

A.5.1 Scarring: __________

A.5.2 Scar depth: __________ mm (in)

A.5.3 Scar length: __________ mm (in)

A.5.4 Scar width: __________ mm (in)

A.6 Comments

Tests performed by: ____

Tests witnessed by: ____

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