Specification for Casing Bow-spring Centralizers

API SPECIFICATION 10D
SEVENTH EDITION, XXXXX 20XX

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Introduction

This edition is based on API Specification 10D, 6th edition, March 2002.

Users of this standard should be aware that further or differing requirements may be needed for individual applications. This standard is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. 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 standard and provide details.

In this standard, quantities expressed are expressed in international System of Units (SI) and/or in U.S. customary units (USC). The values associated with the different units do not necessarily represent a direct conversion of SI units to USC units, or USC units to SI units. Consideration has been given to the precision of the instrument making the measurement.

Calibrating an instrument refers to ensuring the accuracy of the measurement. Accuracy is the degree of conformity of a measurement of a quantity to its actual or true value. Accuracy is related to precision, or reproducibility, of a measurement. Precision is the degree to which further measurements or calculations will show the same or similar results. Precision is characterized in terms of the standard deviation of the measurement. The results of calculations or a measurement can be accurate but not precise, precise but not accurate, neither accurate nor precise, or both accurate and precise. A result is valid if it is both accurate and precise.

This document uses a format for numbers which follows the examples given in API Document Format and Style Manual, First Edition, June 2007 (Editorial Revision, January 2009). This numbering format is different than that used in API 10D, Sixth Edition. In this document the decimal mark is a period and separates the whole part from the fractional part of a number. No spaces are used in the numbering format. The thousands separator is a comma and is only used for numbers greater than 10,000 (i.e. 5000 items, 12,500 bags).

API Specification 10D — Casing Bow-spring Centralizers

1 Scope

This specification provides testing, performance and marking requirements for casing bow-spring centralizers to be used in oil and natural gas well construction. The procedures provide verification testing for the manufacturer's design, materials and process specifications, and periodic testing to confirm the consistency of product performance. This specification is not applicable to other devices, such as rigid centralizers and cement baskets, or bow-spring centralizers used for other purposes (e.g. wireline tools, gravel pack, inner string).

2 Normative Reference

The following normative document contains provisions which, through reference in this text, constitute provisions of this specification. For dated references only the edition cited applies, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this specification are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

API Specification 5CT, Specification for Casing and Tubing.

3 Terms and Definitions, Symbols and Abbreviations

3.1 Terms and Definitions

For the purposes of this specification, the following terms and definitions apply.

3.1.1

annular clearance
Radial clearance between the outside diameter of the casing and the wellbore.

3.1.2
API test load

Specified normal force applied to a bow-spring centralizer to evaluate standoff performance.

3.1.3
bow-spring centralizer
An apparatus comprised of a plurality of bow-shaped springs biased outwardly from a tubular body, the outside diameter of which can vary under a change in applied load, and connected by two end collars, which is placed on the outside of a tubular (e.g. casing or tubing), and used to centralize the tubular in a wellbore.

3.1.4
bow-spring centralizer sub
A bow-spring centralizer installed on a tubular body having an integral holding method where the tubular body becomes its own section of the casing string.

3.1.5
casing nominal diameter
Theoretical outside diameter of the casing.

3.1.6
conventional application
An application where the smallest wellbore diameter that the bow-spring centralizer will pass through is at the centralizer setting depth (see Figure 1).

3.1.7
holding device
Device employed to limit the axial movement of the stop collar or bow-spring centralizer on the casing.

EXAMPLE Set screws, nails, machined tubular, mechanical dogs, epoxy resins, or machined features (integral).

3.1.8
hole size
Diameter of the wellbore at the intended centralizer setting depth.

NOTE This includes setting depth in cased hole, open hole, or restriction(s).

3.1.9
open hole
The portion of the wellbore that is not cased.

3.1.10
restarting force
Maximum force required to restart movement of a bow-spring centralizer inside a specific wellbore diameter in given conditions and installation methods.

3.1.11
restoring force
Normal force exerted by a bow-spring centralizer against the casing to keep it away from the wellbore wall, and equal to the load force required to provide the deflection of the bow in given conditions and installation methods.

3.1.12
restriction
The smallest diameter through which the bow-spring centralizer is passed in testing.

3.1.13
running force
Average force required to move a bow-spring centralizer through a specified wellbore diameter in given conditions and installation methods.

3.1.14
standoff
Smallest distance between the outside diameter of the casing and the wellbore.

3.1.15
standoff ratio
Ratio of standoff to annular clearance, expressed as a percentage (see Figure 7).

NOTE In the field standoff ratio is commonly named "standoff".

3.1.16
starting force
Maximum force required to insert a bow-spring centralizer into a specified wellbore diameter in given conditions and installation methods.

3.1.17
stop collar
Device attached to the casing to limit axial movement of a casing bow-spring centralizer.

NOTE Can be either an independent piece of equipment or integral with the bow-spring centralizer.

3.1.18
under-reamed application
An application where the bow-spring centralizer passes through a smaller inside diameter in the wellbore prior to reaching the centralizer setting depth (see Figure 1).

3.1.19
wellbore
A wellbore is the actual hole that forms the well. A wellbore can be encased by materials such as steel and cement, or it may be uncased.

NOTE This includes cased hole, open hole, or restriction(s).

3.2 Symbols and Abbreviations

3.2.1 Symbols

For the purposes of this specification, the following symbols are used:

C_{v} coefficient of variation, expressed as a percentage;

D_{C} casing nominal (outer) diameter, expressed in millimeters (inches);

$D_{\mathrm{C,x}}$ casing nominal diameter "x" considered for interpolation, expressed in millimeters (inches);

D_{H} open hole diameter (or outer casing inside diameter), expressed in millimeters (inches);

F_{API} API test load, expressed in newtons (pounds-force);

$F_{\mathrm{API,x}}$ API test load for casing diameter "x", expressed in newtons (pounds-force);

$F_{\mathrm{S,max}}$ maximum starting force, expressed in newtons (pounds-force);

$F_{\mathrm{S,max,x}}$ maximum starting force for casing diameter "x", expressed in newtons (pounds-force);

$D_{C,1}$ casing nominal diameter (Table 1) larger than "x", expressed in millimeters (inches);

$D_{C,2}$ casing nominal diameter (Table 1) smaller than "x", expressed in millimeters (inches);

F_1 API test load (Table 1) for casing diameter larger than "x", expressed in newtons (pounds-force);

F_2 API test load (Table 1) for casing diameter smaller than "x", expressed in newtons (pounds-force);

N number of data samples;

SOR standoff ratio, expressed in percent;

W weight of a 12.2 m (40ft) of a medium linear-mass casing expressed in kilograms (pounds-mass);

X value of data sample;

e standoff (minimum annular clearance), expressed in millimeters (inches);

g_n standard gravity constant, 9.80665 m/s^2;

δ bow deflection and casing eccentricity, expressed in millimeters (inches);

μ non-zero mean, average of data samples;

σ standard deviation for data samples.

3.2.2 Abbreviations

ID inside diameter

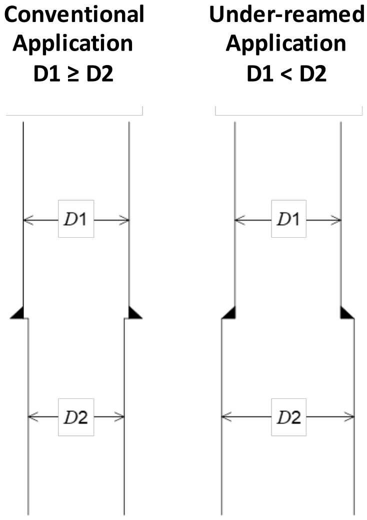
OD outside diameter

SOR standoff ratio

4 Requirements

4.1 Functions of a Centralizer

The main objective of casing centralizers is to facilitate the placement of cement slurry in the annulus by centralizing the casing in the wellbore. Centralizers may also facilitate the running of casing. The two types of applications defined in this document are shown in Figure 1.



Key

$D1$ minimum ID above setting depth.

$D2$ ID at setting depth.

Figure 1—Conventional and Under-reamed Bow-spring Centralizer Applications

4.2 Starting Force

The maximum starting force for conventional applications shall be less than the weight of 12 m (40 ft) of casing of medium linear mass as defined in Table 1. The maximum starting force shall be determined for a bow-spring centralizer in new, fully assembled condition being run in an outer pipe internal diameter (ID) equal to the hole size. Starting force values for under-reamed applications may be higher.

4.3 Standoff Ratio at API Test Load

The minimum standoff ratio (SOR) shall not be less than 67% when the bow-spring centralizer is subjected to the API test load values given in Table 1. API test load values are a function of the casing nominal diameter and medium linear masses. See Annex A for the derivation of the requirements.

Table 1—Casing Bow-spring Centralizers Specification
API Test Load and Maximum Starting Force

Casing Nominal Diameter D_C		Medium Linear Mass Casing		API Test Load F_{API}		Maximum Starting Force $F_{S,max}$	
mm	in.	kg/m	lbm/ft	N	lbf	N	lbf
88.9	(3 ½) [a]	14.7	9.91 [a]	1760	400	1760	400
101.6	(4) [a]	16.9	11.34 [a]	2020	450	2020	450
114.3	(4 ½)	17.3	11.6	2060	460	2060	460
127.0	(5)	19.3	13.0	2310	520	2310	520
139.7	(5 ½)	23.1	15.5	2760	620	2760	620
168.3	(6 5/8)	35.7	24.0	4270	960	4270	960
177.8	(7)	38.7	26.0	4630	1040	4630	1040
193.7	(7 5/8)	39.3	26.4	4700	1060	4700	1060
219.1	(8 5/8)	53.6	36.0	6410	1440	6400	1440
244.5	(9 5/8)	59.5	40.0	7120	1600	7120	1600
273.1	(10 ¾)	75.9	51.0	4540	1020	9070	2040
298.5	(11 ¾)	80.4	54.0	4800	1080	9610	2160
339.7	(13 3/8)	90.8	61.0	5430	1220	10,850	2440
406.4	(16)	96.7	65.0	5780	1300	11,570	2600
473.1	(18 5/8)	130.2	87.5	7780	1750	15,570	3500
508.0	(20)	139.9	94.0	8360	1880	16,730	3760

NOTE 1 The test procedure of Sections 6 & 7 measures a maximum (worst-case) starting force and does not consider pre-compression that may occur due to prior restrictions.

NOTE 2 Sizes not shown in the table can be considered API compliant if criterion derived from 4.3.1 are met.

NOTE 3 API test load (F_{API}) and maximum starting force ($F_{S,max}$) values rounded from calculations using equations in A.2.

[a] Liner sizes and plain-end weight.

4.3.1 Methodology for interpolation between casing nominal diameters in Table 1.

4.3.1.1 Casing nominal diameters smaller than 244.5 mm (9 5/8 in.) or larger than 273.1 mm (10 ¾ in.)

Interpolation methodology between casing nominal diameters shall apply for the following casing nominal diameters:

— Larger than 88.9 mm (3 1/2 in.) and smaller than 244.5 mm (9 5/8 in.), or

— Larger than 273.1 mm (10 ¾ in.) and smaller than 508 mm (20 in.).

In that case for the casing nominal diameter considered ($D_{C,x}$), API test load, $F_{API,x}$, and maximum starting force, $F_{S,max,x}$, expressed in newtons (pound-forces) are identical and given by Equation (1).

$$F_{API,x} = F_{S,max,x} = F_1 + \frac{F_2 - F_1}{D_{C2} - D_{C1}} \times \left(D_{Cx} - D_{C1}\right) \quad (1)$$

where

$D_{C,1}$ is the largest casing nominal diameter in Table 1 that is smaller than $D_{C,x}$, expressed in millimetres (inches);

$D_{C,2}$ is the smallest casing nominal diameter in Table 1 that is larger than $D_{C,x}$, expressed in millimetres (inches);

F_1 is the API test load or the maximum starting force for casing nominal diameter $D_{C,1}$, expressed in newtons (pound-forces);

F_2 is the API test load or the maximum starting force for casing nominal diameter $D_{C,2}$, expressed in newtons (pound-forces).

4.3.1.2 Casing nominal diameters larger than 244.5 mm (9 5/8 in.) and smaller than 273.1 mm (10 ¾ in.)

In that case for the casing nominal diameter considered ($D_{C,x}$), API test load, $F_{API,x}$, is given by Equation (2) and maximum starting force, $F_{S,max,x}$, is given by Equation (3).

$$F_{API,x} = F_1 + \frac{2F_2 - F_1}{D_{C2} - D_{C1}} \times (D_{Cx} - D_{C1}) \qquad (2)$$

$$F_{S,max,x} = F_1 + \frac{F_2 - F_1}{D_{C2} - D_{C1}} \times (D_{Cx} - D_{C1}) \qquad (3)$$

where

$D_{C,1}$ is the largest casing nominal diameter in Table 1 that is smaller than $D_{C,x}$, expressed in millimetres (inches);

$D_{C,2}$ is the smallest casing nominal diameter in Table 1 that is larger than $D_{C,x}$, expressed in millimetres (inches);

F_1 is the API test load for casing nominal diameter $D_{C,1}$, expressed in newtons (pound-forces);

F_2 is the API test load for casing nominal diameter $D_{C,2}$, expressed in newtons (pound-forces).

EXAMPLE 1: Determining the API test load or maximum starting force for casing nominal diameter 346 mm:

As per 4.3.1.1:

$D_{C,1}$ = 339.7 mm F_1 = 5430 N

$D_{C,2}$ = 406.4 mm F_2= 5780 N

and Equation (1)

$$F_{API,346} = F_{S,max,346} = 5430 + \frac{5780 - 5430}{406.4 - 339.7} \times (346 - 339.7)$$

$$F_{API,346} = F_{S,max,346} = 5463 \text{ N}$$

EXAMPLE 2: Determining the API test load for casing nominal diameter 9 $^7/_8$ in.

As per 4.3.1.2:

$D_{C,1}$ = 9.625 in.	F_1 = 1600 lbf
$D_{C,2}$ = 10.75 in.	F_2 = 1020 lbf

and Equation (2)

$$F_{\text{API},9.875} = 1600 + \frac{(2 \times 1020) - 1600}{10.75 - 9.625} \times (9.875 - 9.625)$$

$$F_{\text{API},9.875} = 1698 \text{ lbf}$$

4.4 Establishing Initial Centralizer Performance Values

4.4.1 General

Tests for design and process verification shall be performed for a minimum of three bow-spring centralizers of a given design. All bow-spring centralizers shall conform to the performance requirements of Table 1.

The standoff at API test load for all bow-spring centralizers shall have a coefficient of variation of 15% or less. See Annex A. for explanations and formulas for coefficient of variation, standard deviation, and non-zero mean.

4.4.2 Procedure for analysing data and establishing Standoff at API test load

To analyse and establish standoff at API test load the following procedure shall be applied.

a) Perform starting, running, and standoff tests for a minimum of three bow-spring centralizers of a given design, manufactured within the past 12 months, as outlined in Section 6 for conventional applications or Section 7 for under-reamed applications.

b) Record the standoff at API test load of each bow-spring centralizer as required in 6.3.8 (conventional applications) or 7.2.3.8 (under-reamed applications).

c) Calculate the mean (μ) of the recorded standoff values at API test load (see Annex A).

d) Calculate the standard deviation (σ) of the recorded standoff values at API lest load (see Annex A).

e) Using the standard deviation and mean of the recorded standoff values at API test load, calculate the coefficient of variation (C_v) (see Annex A):

1. If the coefficient of variation for the recorded standoff values at API test load is 15% or less, the bow-spring centralizer design is acceptable. The average of the recorded standoff values at API test load shall be ~~considered~~used as the initial performance of the bow-spring centralizer, and shall be the benchmark against which all future tests are compared, unless a new benchmark is established.

2. If the coefficient of variation for the initial bow-spring centralizer tests is greater than 15%, two additional bow-spring centralizers shall be tested for starting and running forces, and standoff at API test load as outlined in Section 6 for conventional applications or Section 7 for under-reamed applications.

   Calculate the coefficient of variation of the standoff at API test load data for all bow-spring centralizers (the initial number of centralizers tested plus the two additional centralizers).

   i. If the coefficient of variation is 15% or less, the bow-spring centralizer is acceptable. The average of the five standoff values at API test load shall be considered as the initial performance of the bow-spring centralizer, and shall be the benchmark against which all future tests are compared.

   ii. If the coefficient of variation for all bow-spring centralizer tests is greater than 15%, the bow-spring centralizer of the given design does not conform to this specification.

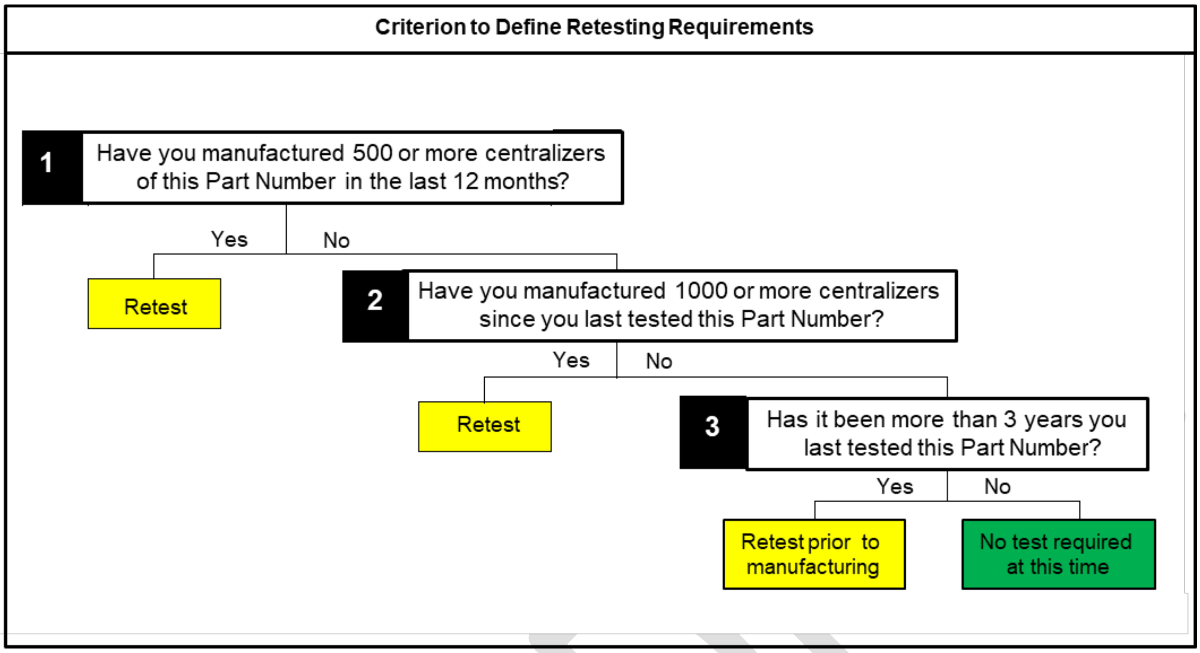
4.4.3 Frequency of testing

The criterion defined in Table 2 shall be evaluated for a production period less than or equal to 12 months from the end of the prior evaluated production period. Bow-spring centralizers shall be tested within three months of the end of the evaluated production period.

4.4.4 Retesting—Bow-spring centralizer

Retesting shall consist of testing one bow-spring centralizer of a given design manufactured within the past 12 months of the test, according to the requirements outlined in Table 2. If the testing yields results within 15% of the current standoff at API test load benchmark, the reported value shall stay the same. If the testing yields results outside 15% of the current standoff at API test load benchmark, bow-spring centralizers shall be tested according to the procedure outlined in 4.4.2 to re-establish the bow-spring centralizer performance benchmark.

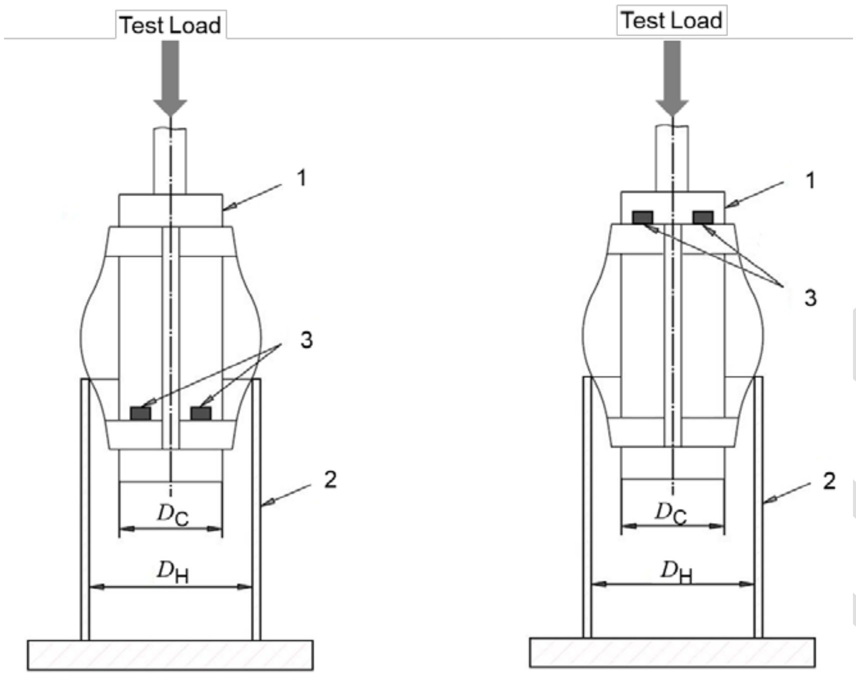
Table 2—Bow-spring Centralizers—Criterion to Define Retesting Requirements



5 Testing equipment

5.1 Test Stand

The test stand allows application of vertical loads and measures these loads and vertical displacements. Examples of typical equipment are shown in Figure 2 and Figure 3.

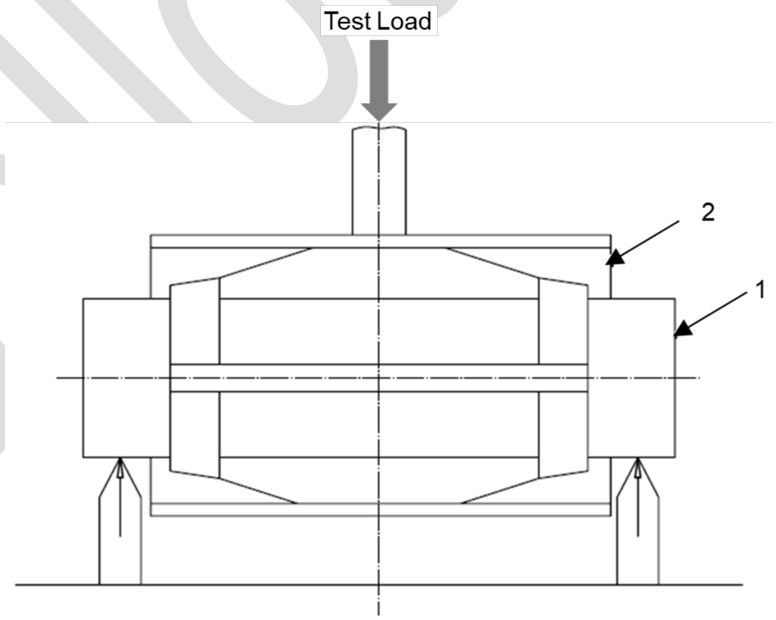


a) Pull-in Configuration **b) Push-in Configuration**

Key

1 Inner pipe
2 Outer pipe
3 Equally spaced lugs
D_C Casing nominal diameter
D_H Hole inside diameter

Figure 2—Typical Bow-spring Centralizer Starting Force Test Equipment



Key

1 Inner pipe
2 Outer pipe

Figure 3—Typical Test Equipment for Bow-spring Centralizer Standoff at Test Load

5.2 Instrumentation

Instrumentation of the test stand shall allow displacement readings of 1.6 mm (0.0625 in.) or smaller.

5.3 Accuracy

5.3.1 Accuracy of load measurements shall be within 5% of the measured value.

5.3.2 Accuracy of displacement measurements shall be within 0.8 mm (0.03 in.).

5.3.3 Calibration of all measuring equipment shall be performed at least annually.

5.4 Test Pipe

5.4.1 Inner pipe

The inner pipe shall be longer than the length of the bow-spring centralizer when subjected to a minimum of three times the API Test Load and longer than the outer pipe. Outer surface defects that can affect test results shall be removed.

For bow-spring centralizers designed to be installed on casing, the outside diameter (OD) of the inner pipe shall be within the tolerances shown in API Specification 5CT for non-upset pipe.

For a bow-spring centralizer sub, the inner pipe shall be manufactured to the same OD dimensional requirements as the specific area of the bow-spring centralizer sub body that the bow-spring centralizer will be installed on for production. Surfaces on the ends of the inner pipe, outside the length to be covered by the bow-spring centralizer and other test components, are exempt from the above requirement.

5.4.2 Outer pipe

The outer pipe shall be longer than the length of bow-spring centralizer when subjected to a minimum of three times the API test load. Inner surface defects that can affect test results shall be removed.

To conduct starting, restarting and running force test (see 6.1) the outer pipe length shall allow a travel distance of at least 102 mm (4 in.) with the apexes of all bow-springs (or any other part of the centralizer that may come into contact with the outer pipe) are completely inside the outer pipe.

The ID of the outer pipe shall equal the hole size for which the bow-spring centralizer is to be used. Tolerances shall be within +0.76 mm/-0.00 mm (+0.030 in./ -0.000 in.). The ends of the outer pipe used for the starting-force test should be bevelled on the inside edges between 30° to 35° from the center line of the pipe, with a maximum bevel of +3.2 mm (+0.125 in.) at the face of the pipe (see Figure 4).

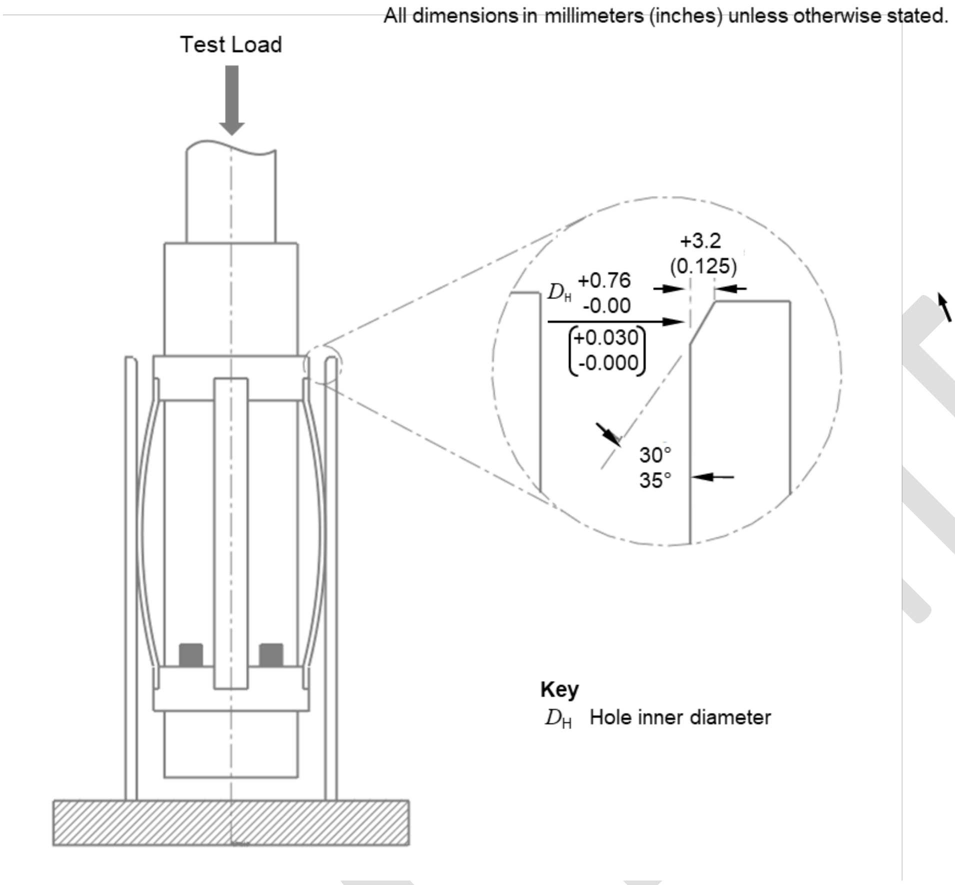


Figure 4–Outer Pipe Inner Edge Bevel

6 Testing Bow-Spring Centralizers to be used in Conventional Applications

6.1 Starting, Restarting and Running Force Test

6.1.1 General

This test determines the starting, restarting, and running forces of a bow-spring centralizer after compensating for the mass of the travelling pipe and attachments.

6.1.2 Procedure

To be used in conventional applications for testing bow-spring centralizers, the following procedure shall be applicable:

a) Install a bow-spring centralizer in new, fully assembled condition on inner pipe according to manufacturer's installation procedures and, or recommendations.

   1. For bow-spring centralizers that are designed to be primarily pulled into the outer pipe using multiple holding methods, install a bow-spring centralizer as shown in Figure 2a on the inner pipe over three (3) or more equally spaced lugs, with each lug protruding radially not more than 6.4 mm (0.25 in.) beyond the outer surface of the inner pipe.

2. For bow-spring centralizers that are designed to be primarily pushed into the outer pipe using multiple holding methods install a bow-spring centralizer as shown in Figure 2b on the inner pipe below three (3) or more equally spaced lugs, with each lug protruding radially not more than 6.4 mm (0.25 in.) beyond the outer surface of the inner pipe.

3. For bow-spring centralizers provided with one specific integral holding method the bow-spring centralizer shall be installed on the inner pipe and tested using that specific holding method.

   EXAMPLE A latch-on or slip-on bow-spring centralizer provided by the manufacturer with set screws integral to one end collar, designed to be primarily run in the wellbore with the set screws down (i.e., pulled into the hole).

NOTE Under field conditions, there are many different methods of attaching a bow-spring centralizer to the casing. The starting force, running force, restarting force, and standoff at API test load for all types of holding devices may not be the same as the test results obtained using this procedure.

b) Record whether the bow-spring centralizer will be pulled or pushed into the outer pipe.

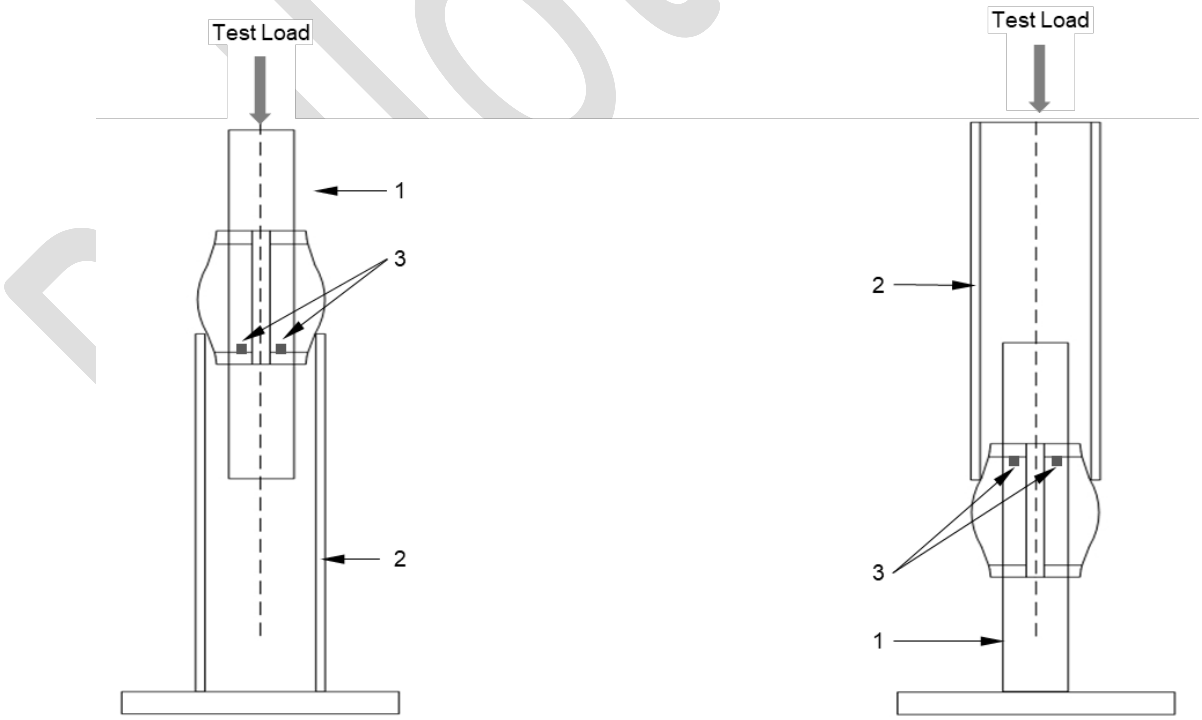
c) Record the holding device used to conduct the starting force test.

d) Record if the centralizer was coated and provide a description of the coating.

e) The test assembly shall be within 5° of vertical.

f) Lubricate the contacting surfaces with a petroleum-based grease before running the test.

g) With the bow-spring centralizer contacting the edge of the outer pipe, apply a load to insert the bow-spring centralizer into the outer pipe, see Figure 5.



a) Inner Pipe Pushed into Static Outer Pipe **b) Outer Pipe Pushed over Static Inner Pipe.**

Key

1 Inner pipe *2* Outer pipe
3 Equally spaced lugs, 3 or more, radial protruding on inner pipe: < 6.4 mm (0.25 in.)

Figure 5—Bow-spring Centralizer Conventional Application: Starting Force Test.

h) Take readings of load and travel distance from the time the load is first applied until the apexes of all bow-springs (or any other part of the centralizer that may come into contact with the outer pipe) are completely inside the outer pipe. Stop movement and release the applied load. Report the maximum load as the starting force after compensating for the mass of the travelling pipe and attachments.

i) Reapply load and record load and travel distance for a minimum of 102 mm (4 in.).

j) Report the maximum load as the restarting force after compensating for the mass of the travelling pipe and attachments.

k) Report the mean value of load measurements recorded in at least the last 51 mm (2 in.) of travel, prior to terminating travel or before any of the bow-spring apexes (or any other part of the centralizer that may come into contact with the outer pipe) exit the outer pipe, as the running force after compensating for the mass of the travelling pipe and attachments.

The result of the restarting and running force is not required to conform to a maximum value. However, the test shall be performed, and the results recorded.

6.2 Measuring Standoff at API Test Load — Procedure

For bow-spring centralizers to be used in conventional applications, the following procedure shall be applied using the same bow-spring centralizer used in 6.1.

a) Start the test with the inner pipe and the outer pipe within 5° of horizontal, (see Figures 3 and 6).

b) Ensure that an external vertical force can be applied to the outer pipe at or between the point(s) of contact of each bow-spring. See Figure 6.

c) Prior to recording the data for the test, apply a load, equal to a minimum of three times the API test load as per Table 1, to the outer pipe over each individual bow-spring 3 times. See Figure 6, Position 1.

d) Apply load and record the measurement of load-deflection readings at increments which do not exceed 1.6 mm (0.0625 in.) until a minimum of three times the API test load has been obtained, see Table 1.

e) The outer pipe shall not contact the inner pipe during the test.

f) Repeat step 6.2.d until each bow-spring and each set of bow-springs has been tested in Position 1 and Position 2 as shown in Figure 6.

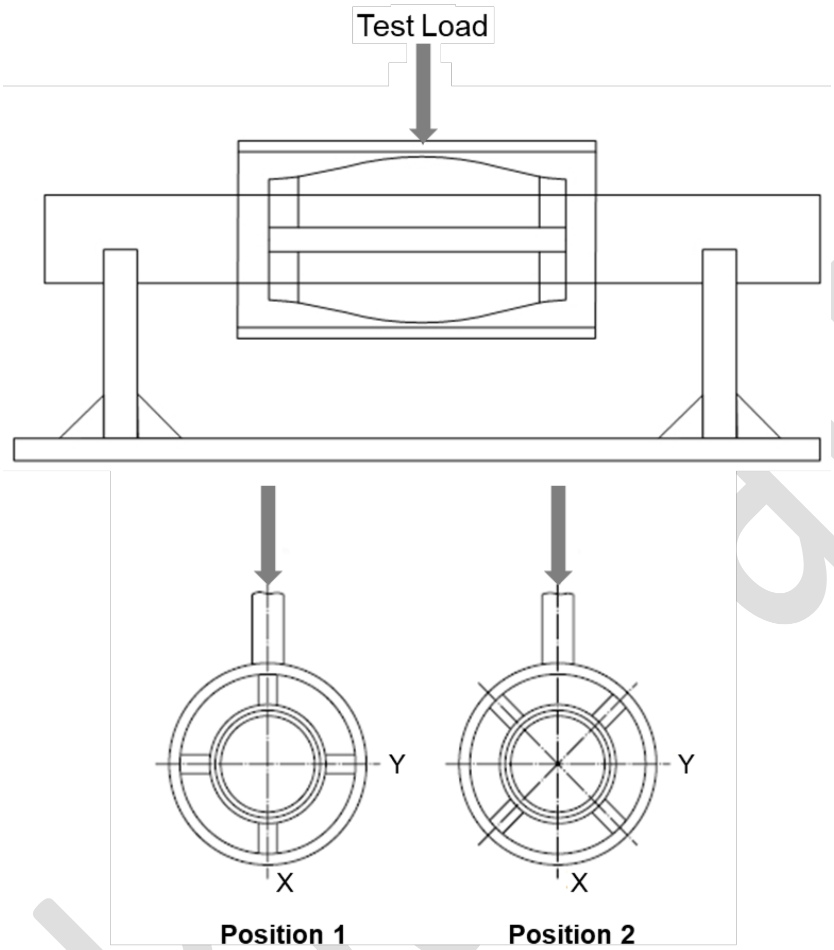


Figure 6—Standoff Test & Bow-Spring Casing Centralizer Test positions

g) Calculate the load at each deflection and bow-spring position by compensating for the mass of the travelling pipe and attachments.

h) Calculate and report the mean of the standoff values, e, at each of the following percentages of API test load: 50%, 100%, 150%, 200%, 250%, and 300%.

A standoff versus load curve may be prepared and/or reported as described in Annex A.

NOTE A standoff versus load curve will provide operators with specific information on the performance of a bow-spring centralizer in a given hole diameter. This information is useful for determining bow-spring centralizer spacing in deviated wells. However, the load curve is sometimes considered to be proprietary information by the centralizer manufacturer.

6.2.1 Calculate SOR

Standoff values shall be converted into SORs (see Figure 7), expressed in percent as given Equation (4).

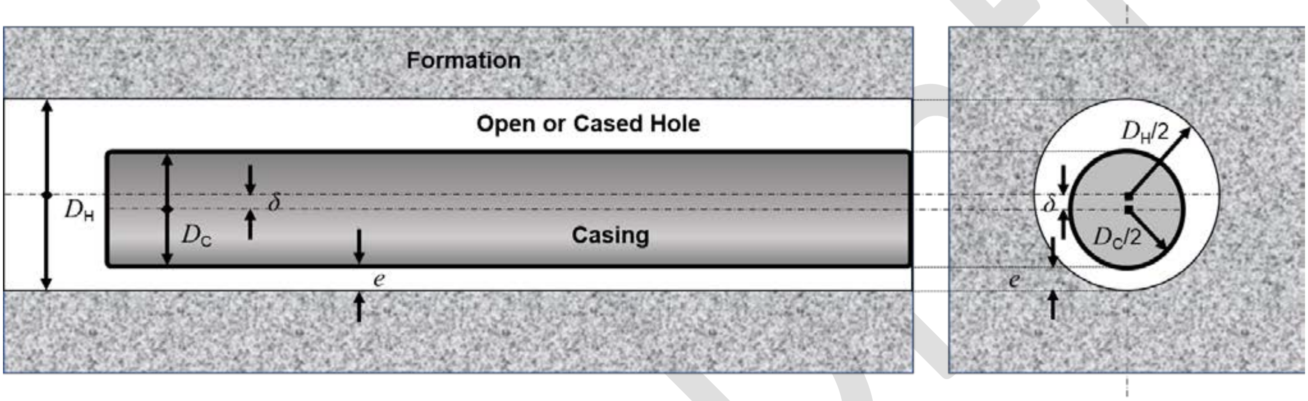
$$SOR = 100 \times \frac{2 \times e}{\left(D_{\text{H}} - D_{\text{C}}\right)} \quad (4)$$

where

e is the standoff, expressed in millimetres (inches);

D_{H} is the diameter of the open hole or outer casing inside diameter, expressed in millimetres (inches);

D_{C} is the casing nominal diameter expressed in millimetres (inches).



Key

D_{C}	Casing nominal diameter	δ	Bow deflection and casing eccentricity
D_{H}	Open hole diameter (or outer casing inside diameter)	e	Standoff

Figure 7—Casing Standoff

6.3 Pass or Fail Criteria

To pass, the bow-spring centralizer shall demonstrate the following:

a) the starting force is less than or equal to the value shown in Table 1; and,

b) the mean SOR at API test load (see Table 1), is equal to or greater that 67%.

7 Testing Bow-spring Centralizers to be used in Under-reamed Applications

7.1 General

In this case, the bow-spring centralizers are run in cased hole where previous casing ID is smaller than the open hole ID where centralizers are intended to be set (see Figure 1).

7.2 Testing Sequence for Under-reamed Applications

Bow-spring casing centralizer for under-reamed applications shall follow testing procedure as following.

a) Install a bow-spring centralizer in new, fully assembled condition on inner pipe. The same centralizer shall be used throughout the entire testing sequence.

b) Perform starting, restarting and running force tests in the outer pipe with an ID equal to the restriction according to 6.1.

c) Remove the bow-spring centralizer from the outer pipe equal to the restriction.

d) Perform the starting, restarting and running force tests in the outer pipe equal to the open hole according to 6.1.

   If performing multiple open hole size tests, the test sequence shall progress from largest open hole size to smallest open hole size.

   NOTE The starting, restarting and running forces may be zero if the centralizer OD is less than the outer pipe ID.

e) Perform the standoff at API test load test in the outer pipe equal to the open hole size according to the procedure given under 6.2. Procedure item 6.2.c) shall be performed for the first open hole test. This is not required for any subsequent open hole size tests.

7.3 Pass or Fail Criteria

To pass, the bow-spring centralizer shall demonstrate the mean SOR at API test load (see Table 1) is equal to or greater that 67% for each open hole diameter.

8 Marking

8.1 General

Casing bow-spring centralizers falling within the range of casing diameters in Table 1 and performing in conformance with this specification shall be marked by the manufacturer as specified in this section prior to shipment to the end user.

Additional markings as desired by the manufacturer or as required by the purchaser are not prohibited. The marking shall be die-stamped, paint-stencilled, etched, or adhesive-labelled on the collars or the bow-springs.

A bow-spring centralizer may be performing in conformance with this specification for a hole size range provided the bow-spring centralizer meets the requirements for both the maximum and minimum diameters of the hole size range.

The following marking requirements shall be made in sequential order on the bow-spring centralizer:

a) name or mark of the manufacturer;

b) part number or equivalent;

c) “API Specification 10D”, or “API Spec 10D”, or “API 10D”;

d) size in inches.

   U.S. Customary Units shall be used, but metric units may be used in addition, according to the following convention:

   1. Conventional applications:

The casing bow-spring centralizers shall be marked with the casing diameter on which to run the bow-spring centralizers, followed by the hole size or hole size range for which the bow-spring centralizers were tested to this specification.

2. Under-reamed applications:
   The casing bow-spring centralizers shall be marked with the casing diameter on which to run the bow-spring centralizers, followed by the restriction size, followed by the hole size or hole size range for which the bow-spring centralizers were tested to this specification.

Other markings or information may also be used as agreed between the purchaser and manufacturer.

EXAMPLE 1 Conventional application:

A 5 $^1/_2$ in. bow-spring centralizer meeting the requirements of this specification in a 7 $^7/_8$ in. hole size shall be marked as follows:

manufacturer
manufacturer part number
API 10D
5 ½ in. x 7 $^7/_8$ in.

EXAMPLE 2 Conventional application:

A 244 mm (9 $^5/_8$ in.) bow-spring centralizer meeting the requirements of this specification in a 305 mm (12 in.) hole size and 311 mm (12 ¼ in.) hole size may be marked as follows:

manufacturer
manufacturer part number
API 10D
9 $^5/_8$ in. x 12 in. – 12 $^1/_4$ in.
(244 mm x 305 mm – 311 mm)

EXAMPLE 3 Under-reamed application:

A 9 $^5/_8$ in. bow-spring centralizer passed through 10 $^5/_8$ in. restriction and meeting the requirements of this specification in a 12 in. hole size and a 12 ¼ in. hole size may be marked as follows:

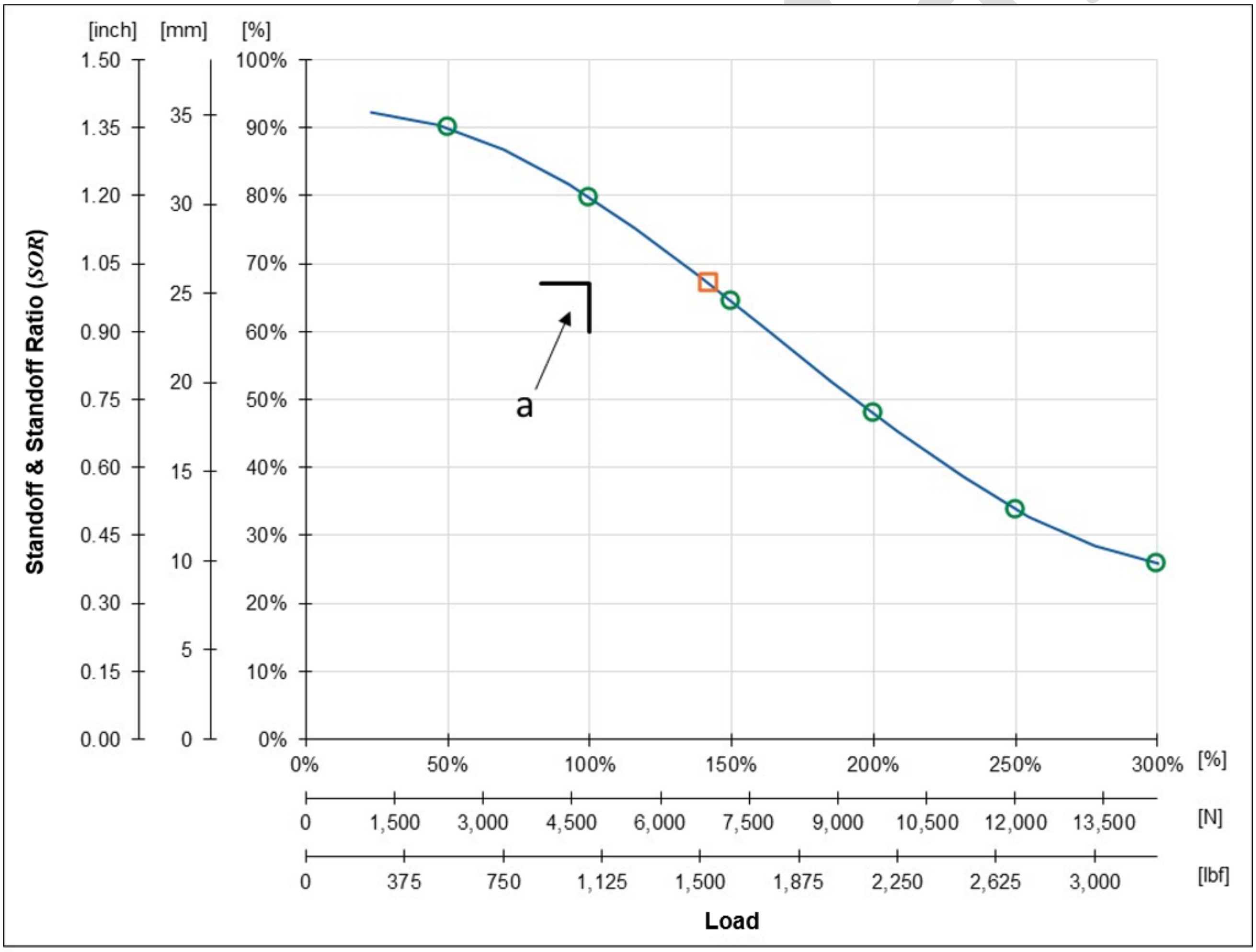
manufacturer
manufacturer part number
API 10D
9 $^5/_8$ in. x 10 $^5/_8$ in. x 12 in. – 12 $^1/_4$ in.

Annex A
(informative)

Miscellaneous information

A.1 Load-deflection Information

A typical load-deflection curve is shown in Figure A.1. The curve is prepared using the methods described in Sections 6 & 7. The purpose of the curve is to provide operators with specific information on the performance of a bow-spring centralizer in a given hole diameter. This information is useful for determining bow-spring centralizer spacing in deviated wells.



Key

o Standoff at API test load percentages

□ Load (historical restoring force) at 67% SOR

a Pass or fail criteria marker (intersection of 67% SOR and API test load)Figure A.1 — SOR vs. Load Curve Example
(298.5 mm (11 ¾ in.) bow-spring centralizer in 374.7 mm (14 ¾ in.) hole)

A.2 Determination of API Test Load Requirements

Historically, field observations indicate hole inclination on an average varies from zero to approximately 60°. Therefore, an average hole inclination of 30° is used to calculate typical normal forces acting on the centralizers.

A.2.1 Casing Strings Placed in relatively Vertical Hole Sections

For casing diameters 273.1 mm (10 ¾ in.) through 508 mm (20 in.), where casing strings are generally placed in relatively vertical hole sections, the API test load defined in Table 1 is calculated as the load provided by the weight, W, of 12.2 m (40 ft) of a medium linear-mass casing, given by Equation (A.1) :

$$F_{API} = g_n \times W \times \sin 30$$
(A.1)

where g_n is the standard gravity constant 9.80665 m/s².

In SI units, $F_{API,}$ expressed in newtons is given ‘Equation (A.2).

$$F_{API} = 4.9\ W$$

where W is the weight of 12.2 m of medium linear-mass casing, expressed in kilograms. (A.2)

In USC units, F_{API}, expressed in pounds-force, is given Equation (A.3).

$$F_{API} = 0.5\ W \qquad \text{(A.3)}$$

where W is the weight of 40 ft of medium linear-mass casing, expressed in pounds-mass.

A.2.2 Casing Strings Placed in Deviated Hole Sections

For casing diameters 114 mm (4 $^1/_2$ in.) through 244 mm (9 $^5/_8$ in.), where casing strings are generally placed in the deviated hole sections, the API test load defined in Table 1 is calculated as the load provided by the weight, W, of 12.2 m (40 ft) of a medium linear-mass casing, given by Equation (A.4) .

$$F_{API} = 2\ g_n \times W \times \sin 30 = g_n \times W \qquad \text{(A.4)}$$

where g_n is the standard gravity constant, 9.80665 m/s².

In SI units, F_{API}, expressed in newtons is given Equation (A.5).

$$F_{API} = 9.81\ W \qquad \text{(A.5)}$$

where W is the weight of 12.2 m of medium linear-mass casing, expressed in kilograms

In USC units, F_{API}, expressed in pounds-force, is given Equation (A.6) (one pound-force value is equivalent to one pound-mass).

$$F_{API} = W \qquad \text{(A.6)}$$

where W is the weight of 40 ft of medium linear-mass casing, expressed in pounds-mass.

A.3 67 % SOR for Field Applications

The 67 % SOR may or may not give adequate centralization of casing in field applications. The 67 % SOR is used merely for the purpose of specifying minimum performance requirements that bow-spring centralizers shall meet. For cementing and zonal isolation, a higher SOR may be required (see API Standard 65-2).

A.4 Coefficient of Variation *(C_v)*

A.4.1 General

Coefficient of variation, C_v, is a standardized measure of dispersion of a probability distribution or frequency distribution. Another common term is relative standard deviation (RSD). C_v is derived from the ratio of the standard deviation (σ) to the non-zero mean (μ), and the absolute value is taken for the mean to ensure it is always positive. C_v is expressed as a percentage as given Equation (A.7).

$$C_v = 100 \times \frac{\sigma}{|\mu|} \qquad \text{(A.7)}$$

The coefficient of variation is a dimensionless number. It should only be computed for data measured on a ration scale, as these measurements can only be taken as non-negative values.

A.4.2 Standard Deviation *(σ)*

Standard deviation is a measure that is used to quantify the amount of variation or dispersion of a set of data values. Standard deviation (σ) is defined by Equation (A.8).

$$\sigma = \sqrt{\frac{\sum (X-\mu)^2}{N-1}} \qquad \text{(A.8)}$$

where:

X is the value of each data sample;

μ is the non-zero mean of the N data samples;

N is the number of data samples.

A.4.3 Non-zero Mean *(μ)*

Non-zero mean, μ, is the average of a sample size. It is defined by Equation (A.9).

$$\mu = \frac{\sum X}{N} \qquad \text{(A.9)}$$

where:

X is the value of each data sample;

N is the number of data sample.

A.5 Recommended Reporting of Data

Bow-spring centralizer performance data may be provided by the manufacturer at the request of the end user. The following information is the recommended data to be provided to the end user, including the information required by this specification. The format in which the data is provided may change from manufacturer to manufacturer.

a) For bow-spring centralizers designed for conventional applications:

1) Centralizer description:

- General description of the centralizer.
- Centralizer part number.
- Centralizer inside diameter.
- Casing nominal diameter.
- Centralizer number of bows (blades).
- Centralizer maximum diameter (as manufactured and before any tests).
- Centralizer rigid OD.
- Centralizer length.
- Centralizer weight.
- Material grade.

2) Centralizer performance:

- Open hole diameter (ID).
- Centralizer installation method (e.g., over stop collar, over coupling, integral holding device, lugs).
- Centralizer starting force test orientation (see Figure 2; pull-in or push-in configuration.
- Description of centralizer coating, if present.
- Starting force of centralizer in open hole.
- Restarting force of centralizer in open hole.
- Running force of centralizer in open hole.

— Restoring force of centralizer in open hole at 67% SOR (if available).

— Standoff at the following percentages of API test load:

  o 50%, 100%, 150%, 200%, 250%, and 300%.

— Average restoring force curve.

— Centralizer maximum diameter after open hole test(s).

b) For bow-spring centralizers designed for under-reamed applications:

1) Centralizer description:

— General description of the centralizer.

— Centralizer part number.

— Centralizer inside diameter.

— Casing nominal diameter.

— Open hole diameter (ID), or open hole diameter (ID) range.

— Centralizer number of bows (blades).

— Centralizer maximum diameter (as manufactured and before any tests).

— Centralizer rigid OD.

— Centralizer length.

— Centralizer weight.

— Material grade.

2) Centralizer performance through restriction:

— Restriction diameter (ID).

— Starting force of new centralizer in restriction.

— Restarting force of new centralizer in restriction.

— Running force of new centralizer in restriction.

— Centralizer maximum diameter after restriction test.

3) Centralizer performance through open hole:

- Open hole diameter (ID), or open hole diameter (ID) range.
- Centralizer installation method (e.g., over stop collar, over coupling, integral holding device, lugs).
- Centralizer starting force test orientation (see Figure 2; pull-in or push-in configuration).
- Description of centralizer coating, if present.
- Starting force of centralizer in open hole after running through restriction.
- Running force of centralizer in open hole after running through restriction.
- Restarting force of centralizer in open hole after running through restriction.
- Restoring force at 67% SOR (if available) of centralizer in open hole after running through restriction.
- Standoff at the following percentages of API test load:
    - 50%, 100%, 150%, 200%, 250%, and 300%.
- Average restoring force curve.
- Centralizer maximum diameter after open hole test(s).

Bibliography

API Standard 65-2; *Isolating Potential Flow Zones during Well Construction*

ISO 11960, Petroleum and natural gas industries – Steel Pipes for Use as Casing or Tubing for Wells