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Petroleum and natural gas industries — Cements and materials for well cementing —

Part 5: Determination of shrinkage and expansion of well cement formulations at atmospheric pressure

Industries du pétrole et du gaz naturel — Ciments et matériaux pour la cimentation des puits —

Partie 5: Détermination du retrait et de l'expansion à la pression atmosphérique des formulations de ciments pour puits

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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 10426-5 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*.

ISO 10426 consists of the following parts, under the general title *Petroleum and natural gas industries — Cements and materials for well cementing*:

— *Part 1: Specification*

— *Part 2: Testing of well cements*

— *Part 3: Testing of deepwater well cement formulations*

— *Part 4: Preparation and testing of foamed cement slurries at atmospheric pressure*

— *Part 5: Determination of shrinkage and expansion of well cement formulations at atmospheric pressure*

Introduction

Dimensional changes in oil- and gas-well cements after placement, phenomena often referred to as shrinkage, (when the dimensional change corresponds to a decrease in cement volume) have often been used to explain various wellbore phenomena including

— a microannulus, leading to a bad bond as demonstrated by the bond log;

— interzonal communication, resulting in costly remedial operations;

— lack of a hydraulic seal when utilizing cement inflatable packers.

Attempts have been made to find additives that decrease cement shrinkage (shrinkage being a fundamental characteristic of Portland cement) The best solution for shrinkage thus far has been the identification of additives that favour the expansion of the cement. However, even if cement expands dimensionally, it will still shrink internally. In this case, the bulk expansion of the cement sample is simply superimposed on an inner shrinkage that will affect the porosity of the sample.

Shrinkage and expansion in cement result from the formation of hydration products having a density different from the compounded density of the reaction components. This can result in the following:

— change in pore volume;

— change in pore pressure;

— change in sample dimensions;

— change in internal stress.

In a closed cell with a non-deformable boundary, the volume of hydrates produced during the chemical reaction is less than the volume of dry compounds plus water. The change in volume of hydrates will be referred to as inner hydration shrinkage. The change in the sample dimensions will be referred to as bulk shrinkage or expansion. Bulk shrinkage and expansion of cement refer to the result of the measurement of linear dimensional change or volume change. The volume to which all volume changes are related is the volume of the slurry immediately after mixing and emplacement in the experimental equipment.

In this part of ISO 10426, units are given as SI, and where practical, U.S. Customary units are included in brackets for information.

Users of this part of ISO 10426 should be aware that further or differing requirements might be needed for individual applications. This part of ISO 10426 is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This can be particularly applicable where there is innovative or developing technology. Where an alternative is offered, the vendor should identify any variations from this International Standard and provide details.

This part of ISO 10426 is based on API Technical Report 10TR 2 [1].

Petroleum and natural gas industries — Cements and materials for well cementing —

Part 5: Determination of shrinkage and expansion of well cement formulations at atmospheric pressure

1 Scope

This part of ISO 10426 provides the methods for the testing of well cement formulations to determine the dimension changes during the curing process (cement hydration) at atmospheric pressure only. This is a base document, because under real well cementing conditions shrinkage and expansion take place under pressure and different boundary conditions.

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 10426-2:2003, *Petroleum and natural gas industries — Cements and materials for well cementing — Part 2: Testing of well cements*

3 Terms and definitions

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

3.1
bulk expansion
increase in the external volume or dimensions of a cement sample

3.2
bulk shrinkage
decrease in the external volume or dimensions of a cement sample

3.3
hydration shrinkage
difference in the volume between the hydration products and the volume of the dry cement, additives and water

4 Sampling

4.1 General

Samples of the neat cement or cement blend, solid and liquid additives, and mixing water are required to test a slurry according to this part of ISO 10426. Accordingly, the best available sampling technology should be employed to ensure the laboratory test conditions and materials match as closely as possible those found at the wellsite. Some commonly used sampling devices are shown in ISO 10426-2:2003, Figure 1.

4.2 Method

Applicable sampling techniques for the fluids and materials used are specified in ISO 10426-2:2003, Clause 4.

5 Determination of shrinkage or expansion under conditions of free access of water at atmospheric pressure — Annular ring test

5.1 General information

The annular expansion mould is a device suitable for measuring only the linear bulk shrinkage or expansion properties of a cement formulation. The magnitude of expansion depends on the amount of expanding agent, cement powder, slurry design and curing condition (pressure, temperature, time, fluid access). It should be noted that expansion is strongly affected by boundary conditions. The chemical process of mineral growth is strongly controlled by the state of stress and mineral growth will tend to occur where the stress value is the lowest, i.e. in pore space or empty spaces. Therefore, the degree of cement shrinkage and expansion is dependent on a number of conditions, not all of which can be uniquely defined. The test does not represent fully the annulus of a well.

5.2 Apparatus

5.2.1 Mould

5.2.1.1 General

Use corrosion-resistant material (e.g. stainless steel). The outer diameter (OD) of the inner ring shall be 50,8 mm (2 in) and the inner diameter (ID) of the outer expansion ring shall be 88,9 mm (3,5 in). See Figures 1, 2 and 3.

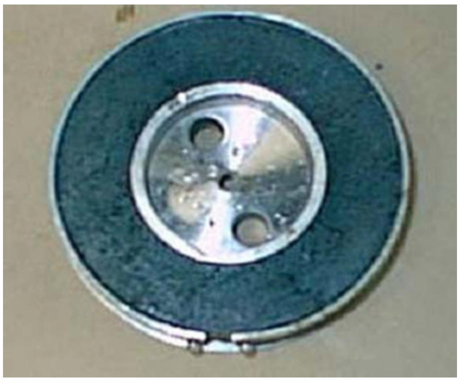


Figure 1 — Typical mould assembly (top view)

Figure 2 — Typical mould assembly (side view)

Dimensions in millimetres (inches)

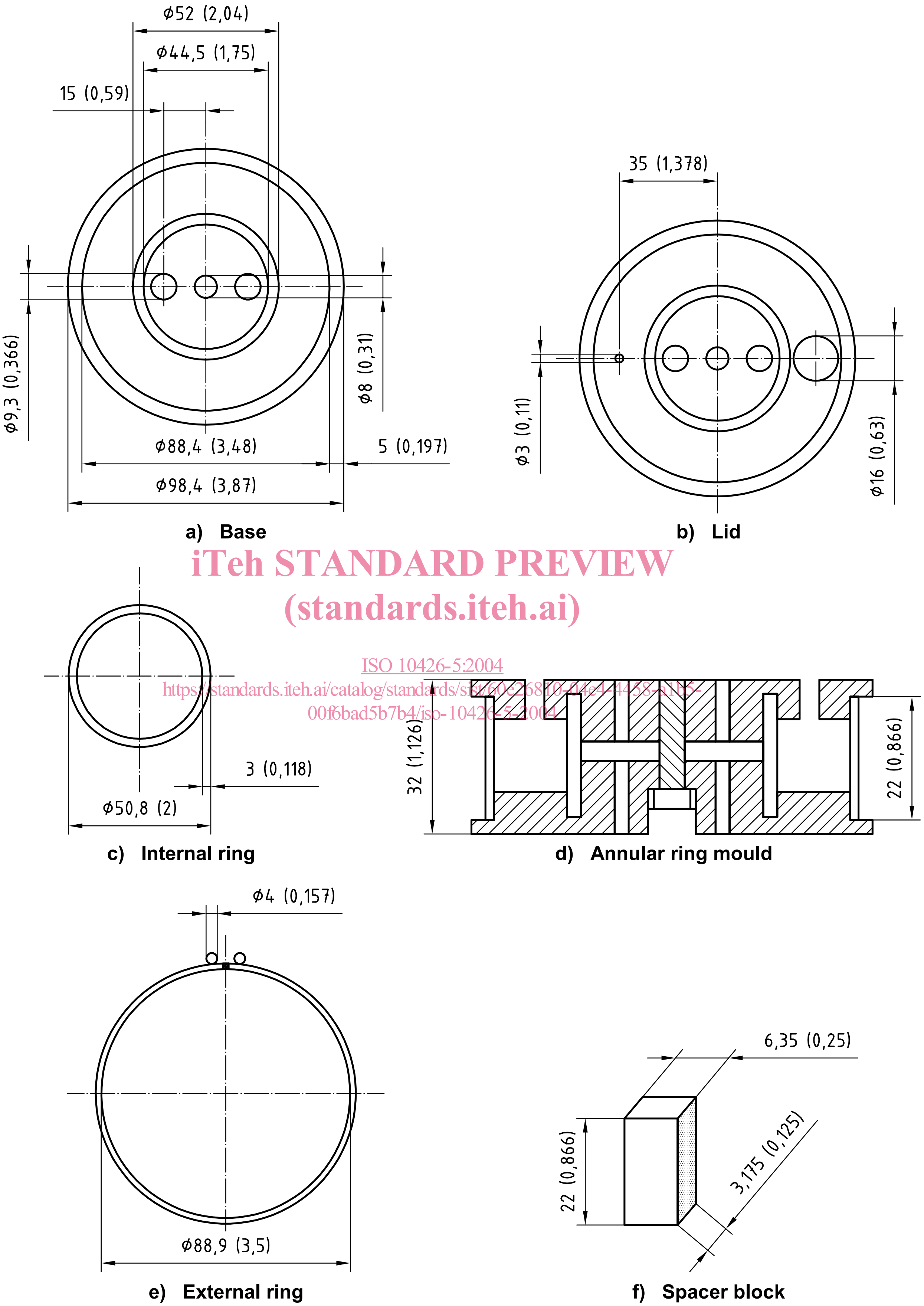


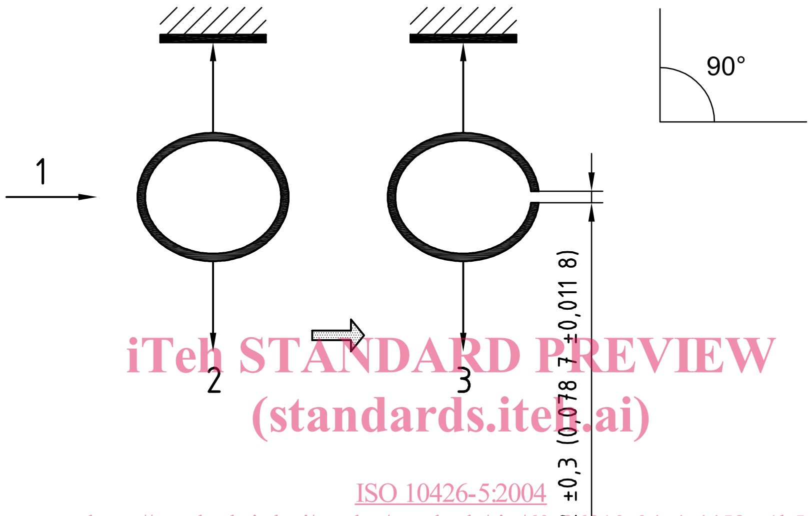
Figure 3 — Schema of typical mould assembly parts

5.2.1.2 Mould calibration

The resilience of the ring of the mould shall be calibrated annually. The resilience shall be such that the mass of 1 000 g ± 1 g (2,204 6 lb ± 0,002 lb) applied as shown in Figure 4 shall increase the distance between the two steel measurement balls (see Figure 9) by 2 mm ± 0,3 mm (0,078 7 in ± 0,011 8 in) without permanent deformation.

Attention must be paid to ensure that the load is applied perpendicular to the gap (90°) in order to avoid errors, which might be easily made. The readings shall be repeated at least three times to obtain an average value with a standard deviation of 0,05 mm (0,002 in).

Dimensions in millimetres



Key

1 ring

2 mass, 0 g

3 mass, 1 000 g ± 1 g (2,204 6 lb ± 0,002 lb)

Figure 4 — Schema of a calibration measurement of the ring — Resilience test

5.2.1.3 Spacer block

The spacer block shall be used only in the case of shrinkage measurement. It is used to slightly increase the diameter of the outer ring prior to slurry-pouring and to measure shrinkage by removing it once the cement starts to set. The dimensions of the block shall be 3,175 mm × 3,175 mm to 6,35 mm × 6,35 mm (0,125 in × 0,125 in to 0,25 in × 0,25 in) and 22,0 mm (0,866 in) tall; see Figure 3. To ensure that the spacer block's thermal expansion properties are the same as those of the expandable outer ring, the block shall be made of the same material as the mould (e.g. stainless steel).

5.2.2 Water curing bath

A curing bath or tank having dimensions suitable for the complete immersion of a mould(s) in water and which can be maintained within ± 2 °C (± 3 °F) of the prescribed test temperature shall be employed. The curing bath is an atmospheric-pressure apparatus (bath) for curing specimens at a temperature of up to 88 °C (190 °F). It shall have an agitator or circulating system.

5.2.3 Cooling bath

The cooling-bath dimensions shall be such that the specimen to be cooled from the curing temperature can be completely submerged in water maintained at 27 °C ± 3 °C (80 °F ± 5 °F).

5.2.4 Temperature measuring system

The temperature-measuring system shall be calibrated to an accuracy of ± 1 °C (± 2 °F). Calibration shall be no less frequent than monthly. The procedure described in ISO 10426-2:2003, Annex A, is commonly used.

5.2.4.1 Thermometer

A thermometer with a range including 21 °C to 100 °C (70 °F to 212 °F) with minimum scale divisions not exceeding 1 °C (2 °F) should be used.

5.2.4.2 Thermocouple

A thermocouple system with the appropriate range should be used.

5.2.5 Consistometer

The atmospheric-pressure consistometer shall be used for stirring and conditioning the cement slurry. The consistometer consists of a rotating cylindrical slurry container, equipped with an essentially stationary paddle assembly, in a temperature-controlled liquid bath. The consistometer shall be capable of maintaining the temperature of the bath within ± 2 °C (± 3 °F) of the test temperature and of rotating the slurry container at a speed of 2,5 r/s ± 0,25 r/s (150 rpm ± 15 rpm) during the stirring and conditioning period for the slurry. The paddle and all parts of the slurry container exposed to the slurry shall be constructed of corrosion-resistant materials (see ISO 10426-1:2000).

5.3 Procedure

5.3.1 Preparation of the mould

The assembled moulds shall be watertight to avoid leakage. The interior faces of the moulds and contact surfaces of the plates may be lightly coated with a release agent. Alternatively, the interior faces of the moulds and contact surfaces of the plates may be left clean and dry. In the case of a shrinkage test, place the spacer block inside the split of the outer ring. Prepare the mould as follows.

a) Clean the mould thoroughly.

b) Place a bead of grease on the upper and lower plates where the inner stationary ring and the outer expandable ring touch.

c) If desired, apply a very thin film of light mineral oil to the inner and outer rings and to the surface of the top and bottom covers that will contact the cement.

d) With the top cover inverted, place the inner and outer rings on the top cover.

e) Place the bottom cover over the inner and outer rings.

f) Insert the bolt into the centre hole and tighten the bolt to hold the mould together.

g) Verify that the expandable outer ring rotates freely and place the big hole adjacent to the split (Figure 9).

h) Place a small amount of high-temperature grease between the split in the outer ring; the grease will seal the split and prevent the slurry from leaking before it sets.

i) To test for shrinkage, coat a spacer block with grease and place the block with the small side between the split in the outer expandable ring; see Figures 5 and 6.