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Oil and gas industries including lower carbon energy — Cements and materials for well cementing —

Part 5: Determination of shrinkage and expansion of well cement formulations

Industries du pétrole et du gaz, y compris les énergies à faible teneur en carbone — Ciments et matériaux pour la cimentation des puits —

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

FDIS stage

Contents

Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 67, *Oil and gas industries including lower carbon energy*, Subcommittee SC 3, *Drilling and completion fluids, well cements and treatment fluids*., in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 12, *Oil and gas industries including lower carbon energy*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 10426-5:2004), which has been technically revised.

The main changes are as follows:

— addition of the Introduction, with background information on expansion and shrinkage;

— addition of annular ring test under impermeable conditions at atmospheric pressure;

— inclusion of an informative annex describing a method to determine the stress generated by expansion under confined conditions at elevated temperature and pressure;

— inclusion of an informative annex describing the annular ring test at elevated pressure.

A list of all parts in the ISO 10426 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

When Portland cement reacts with water, there is an overall reduction in the absolute volume of components:

$$V_c + V_w > V_{ch} \quad (1)$$

Where

V_c is the volume of cement

V_w is the volume of water

V_{ch} is the volume of cement hydrates

where

- V_c is the volume of cement;
- V_w is the volume of water;
- V_{ch} is the volume of cement hydrates.

In this document the absolute volume decrease [(V_c + V_w) − V_{ch}] is referred to as hydration shrinkage, although in other documents it can also be referred to as chemical shrinkage, total chemical contraction, or hydration volume reduction.

Depending on the exposure conditions, presence of external stresses during setting, and, most importantly, access to external water, the hydration shrinkage may lead to bulk shrinkage of the set cement.

The change in the sample dimensions is referred to as bulk shrinkage or expansion. Bulk shrinkage and expansion of the cement refer to the result of the measurement of a 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. For small values of shrinkage or expansion, typically the case in well cement systems, the fractional volume dimensional change can be approximated as 3 times the fractional linear dimensional change.

Bulk shrinkage may cause:

— formation of a micro-annulus, potentially affecting cement evaluation logs;

— loss of zonal isolation leading to crossflow or sustained casing pressure;

— lack of a hydraulic seal when using cement inflatable packers;

— poor sealing of abandonment plugs.

Additives are available that can overcome the effects of hydration shrinkage and generate bulk expansion of set cement. In plug applications, bulk expansion of cement will generategenerates stress at the cement-rock or cement-formation interface. A method of measuring the stress generated by expansion in a plug-type geometry is given in Annex AAnnex A..

In this document, SI units are used; and where practical, U.S. customary units are included in brackets for information.

This document is based on API Technical Report 10TR 2.

Oil and gas industries including lower carbon energy — Cements and materials for well cementing —

Part 5: Determination of shrinkage and expansion of well cement formulations

1 Scope

This document provides the methods for the testing of well cement formulations to determine the dimension changes during the curing process (cement hydration) at atmospheric and elevated pressure and the stress generated by expansion in a confined environment under elevated temperature and pressure.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Specification 10A, *Cements and Materials for Well Cementing*

API Recommended Practice 10B-2, *Recommended Practice for Testing Well Cements*

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ~~—~~ISO Online browsing platform: available at https://www.iso.org/obp

— ~~—~~IEC Electropedia: available at https://www.electropedia.org/

3.1
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
CEA
cement expansion additive
additive used in a cement slurry formulation to provide *bulk expansion* (3.1~~(3.1),~~), or reduce *bulk shrinkage* (3.2~~(3.2)~~)

3.4
hydration shrinkage
difference in the volume between the hydration products and the volume of the dry cement, additives and water

3.5
radial interface stress
stress generated at the interface between the set cement and casing or borehole wall due to *bulk shrinkage* (3.2(3.2)) or *bulk expansion* (3.1(3.1)) of the cement

3.6
UCA
ultrasonic cement analyser
instrument used for the non-destructive sonic determination of compressive strength of cement

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

4.1 General

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 and type 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 synthetic mineral growth is strongly controlled by the state of stress and growth tends to occur relatively more in low stress locations, for example, in pore spaces within the cement matrix. Therefore, the degree of cement shrinkage and expansion is dependent on several conditions, not all of which can be uniquely defined. The test does not fully represent the annulus of a well.

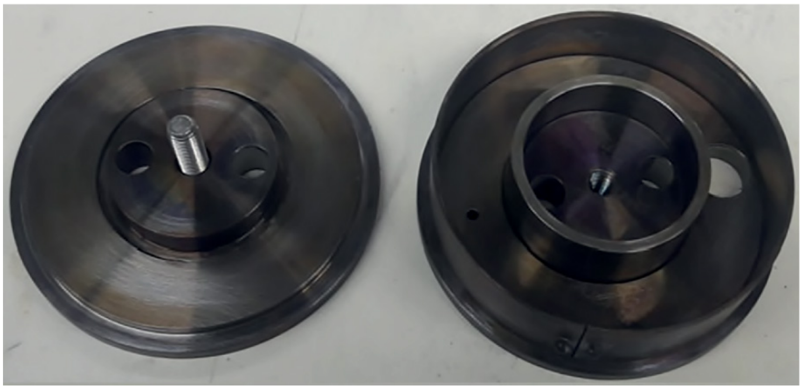
A method for determining the shrinkage or expansion at pressures above atmospheric pressure is given in Annex BAnnex B..

4.2 Apparatus

4.2.1 Mould

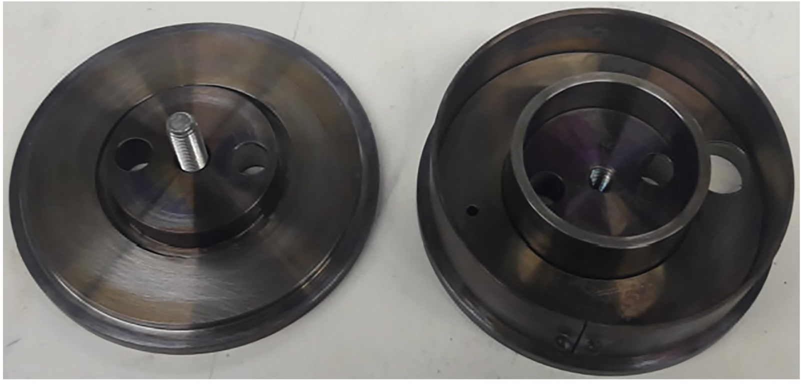
4.2.1.1 General

Use corrosion-resistant material (e.g. stainless steel). The outer diameter (OD) of the internal ring shall be 50,8 mm ± ± 0,3 mm (2,0 in ± ± 0,01 in) and the outer diameter (OD) of the external ring shall be 88,9 mm ± ± 0,3 mm (3,5 in ± ± 0,01 in). See Figures 1Figures 1,, and 22..



Left: bottom plate.

Right: Inner and outer rings placed on the top plate (step d of 4.3.1).



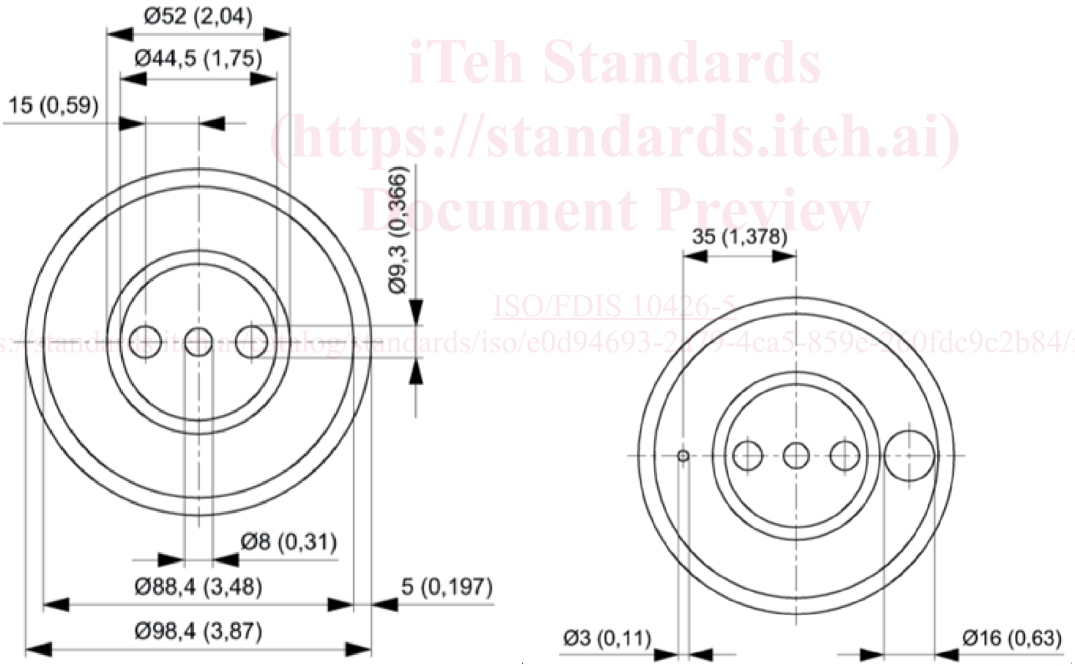
Key

1 bottom plate

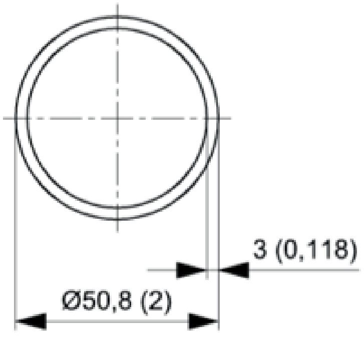
2 inner and outer rings placed on the top plate (step d of 4.3.1)

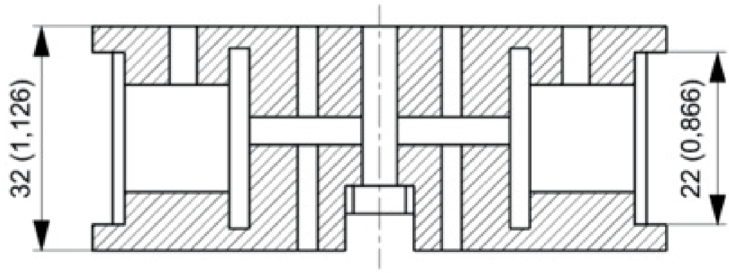
Figure 1 — Typical mould assembly

Dimensions in millimetres (inches)

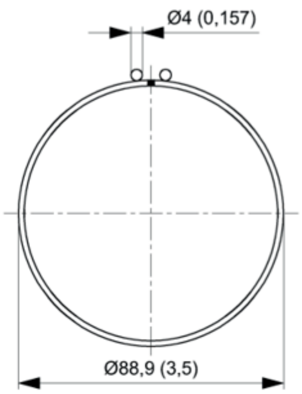


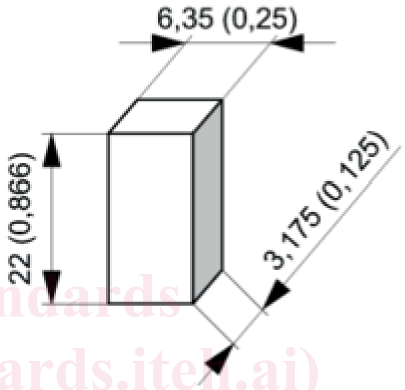
a) Base b) Lid



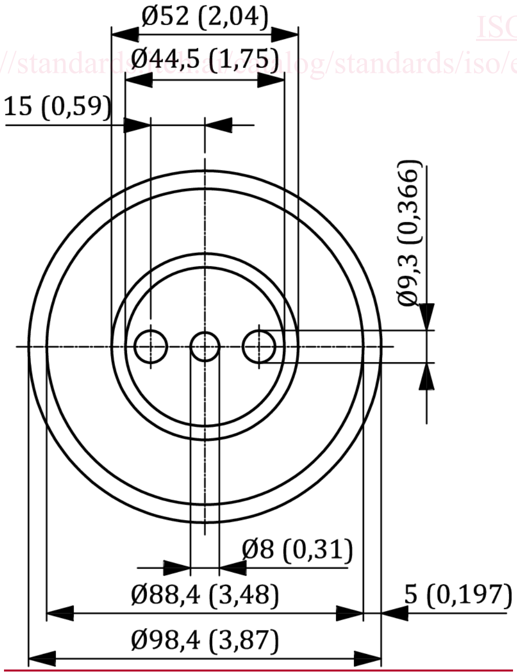


~~c) Internal ring~~ ~~d) Annular ring mould~~

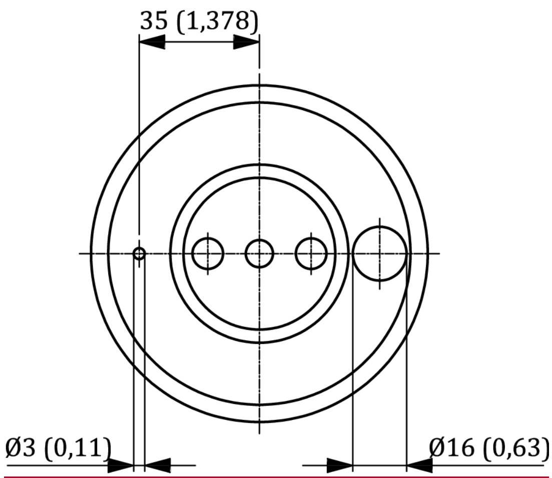




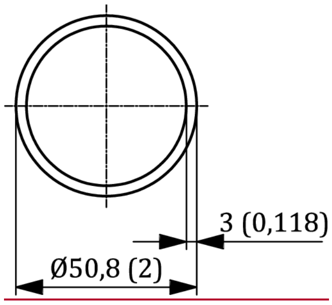
~~e) External ring~~ ~~f) Spacer block~~



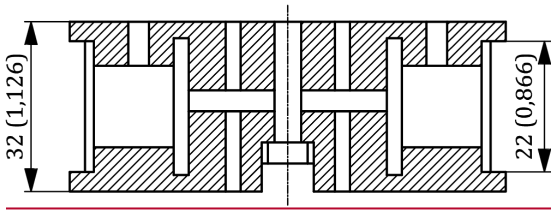
a) Base



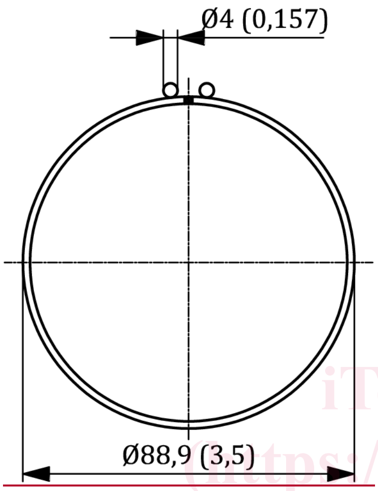
b) Lid



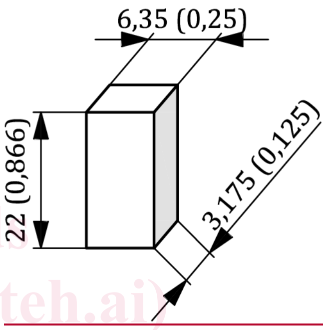
c) Internal ring



d) Annular ring mould



e) External ring



f) Spacer block

Figure 2 — Schema of typical mould assembly parts

4.2.1.2 Mould verification

The resilience of the ring of the mould shall be verified annually. If the ring is dropped or damaged during use, then the resilience shall be verified. The resilience shall be such that the mass of 1 000 g ± 1 g applied as shown in Figure 3~~Figure 3~~ shall increase the distance between the two steel measurement balls (see Figure 8~~Figure 8)~~) by 2 mm ± 0,3 mm (0,078 7 in ± 0,011 8 in) without permanent deformation. The load shall be applied perpendicular to the gap (90°). 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).