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

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

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

Partie 4: Préparation et essais en conditions ambiantes des laitiers de ciment mousse

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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.

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 documents 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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

The committee responsible for this document is 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 second edition cancels and replaces the first edition (ISO 10426-4:2004), which has been technically revised.

This document supplements API RP 10B-4, 2nd edition (2015).

The technical requirements of this document and API RP 10B-4 used to be identical. In the meantime API RP 10B-4 has been technically revised as API RP 10B-4, 2nd edition (2015). The purpose of this edition of ISO 10426-4 is to bring this document up-to-date, by referencing the current edition of API RP 10B-4 and including supplementary content.

The main changes compared to the previous edition of ISO 10426-4 are as follows:

— The lay-out of the document has been significantly reorganized.

— Clause 3 has been added.

— In the first edition, the nature of the gas used to create the foam cement is not specified. In API RP 10B-4, second edition, air is used to produce a foam cement whilst care is taken to mimic a nitrogen-based foam cement sample under downhole conditions.

— In API RP 10B-4, second edition, Formula (2) uses the product of mass and absolute volume (reciprocal density) to calculate the volumes of cement, additives and mix water. The first edition simply uses the volumes.

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

The test methods contained in this document, though generally based on ISO 10426-2, take into account the specialized sampling/testing requirements of foamed cement slurries. ISO 10426-2 contains no dedicated test methods for foamed cement slurries.

Well cements that can be used in foam cementing can include those of ISO Classes A, C, G or H (as given in ISO 10426-1), high-alumina cement, various types of ductile cement compositions, etc. In each foam cementing operation, the cement chosen needs to be fit for purpose.

In this document, where practical, United States customary (USC) units are included in parentheses for information.

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

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

1 Scope

This document provides procedures for testing of foamed cement slurries and their corresponding unfoamed base cement slurries at atmospheric pressure. These methods are developed for foamed cement slurries with air, at atmospheric conditions, which could mimic a foam quality experienced with nitrogen at downhole conditions and which can be modified to accommodate other gases such as nitrogen. This document also addresses slurries that are foamed with nitrogen including their properties.

This document does not address testing at pressures above atmospheric conditions and does not include or consider the effects of nitrogen solubility in the nitrogen fraction calculations.

This document supplements API RP 10B-4, 2nd edition (2015), the requirements of which are applicable with the exceptions specified in this document.

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 RP 10B-4, 2nd edition (2015), *Recommended Practice on Preparation and Testing of Foamed Cement Formulations at Atmospheric Pressure*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in in API RP 10B-4, 2nd edition (2015) apply.

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

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

— IEC Electropedia: available at http://www.electropedia.org/

3.2 Abbreviations

T_{BHC} bottom hole circulating temperature

T_{BHS} bottom hole static temperature

FCCC foam cement curing cell

4 Supplements to API RP 10B-4, 2nd edition (2015)

4.1 General requirements

The requirements specified in API RP 10B-4, 2nd edition (2015) shall apply, with the exceptions specified in 4.2 to 4.4.

4.2 Procedure for compressive strength determination

The requirements of API RP 10B-3, 2nd edition (2016), 7.6.2 laid out in 6.8 of API RP 10B-4, 2nd edition (2015), shall apply, with the exception of the reference to ASTM C109/109M 07 which shall be ASTM C109/109M.

4.3 Stability of set foamed cement slurry

The requirements specified in API RP 10B-4, 2nd edition (2015), 8.3.3.1 apply, with the following exception:

— For downhole temperatures above 90°C, the foamed cement shall be cured and tested in accordance with the procedures outlined in Annex A.

4.4 Determination of compressive strength

The requirements specified in API RP 10B-4, 2nd edition (2015), 8.4 apply, with the following exception:

— For downhole temperatures above 90 °C, the foamed cement shall be cured and tested in accordance with the procedures outlined in Annex A.

Annex A
(normative)

Testing of foam cement cured at BHST

A.1 Curing foam cement in an oven

The temperature increase during cement curing causes expansion of the gas phase. To prevent this expansion, a foam cement pressure test cell is required for curing foam at elevated temperature in a heating oven.

This annex describes a curing method specially designed to prevent excessive foam cement expansion at temperatures above 90 °C (194 °F).

This test method is not applicable to non-foamed cement slurries as extreme pressures will be generated in the cells. A minimum 15 % quality foam cement is recommended,

A.2 The foam cement curing cell

The FCCC should not deform and should be able to contain the pressures generated by the expansion of the foam cement and the pressure generated by the vapour pressure of water at the test temperature. The vapour pressure of water is 1,6 MPa (225 psi) at 200 °C (392 °F).

The FCCC should meet or exceed the local pressure regulations and include an over-pressure rupture disc as required.

The FCCC end caps also include two or more vent plugs in case one becomes plugged.

An example of a suitable FCCC is shown in Figure A.1. It is made from stainless steel, has a non-stick polytetrafluoroethylene (PTFE) or similar insert, and screw end caps with O-ring seals to contain the pressure. The dimensions of the cells and insert should provide set cement samples with a minimum diameter of 25 mm and a minimum length of 100 mm.

A.3 The foam cement curing method

A.3.1 General

The foam cement curing method in this clause applies to FCCCs as described in Clause A.2 and shown in Figure A.1.

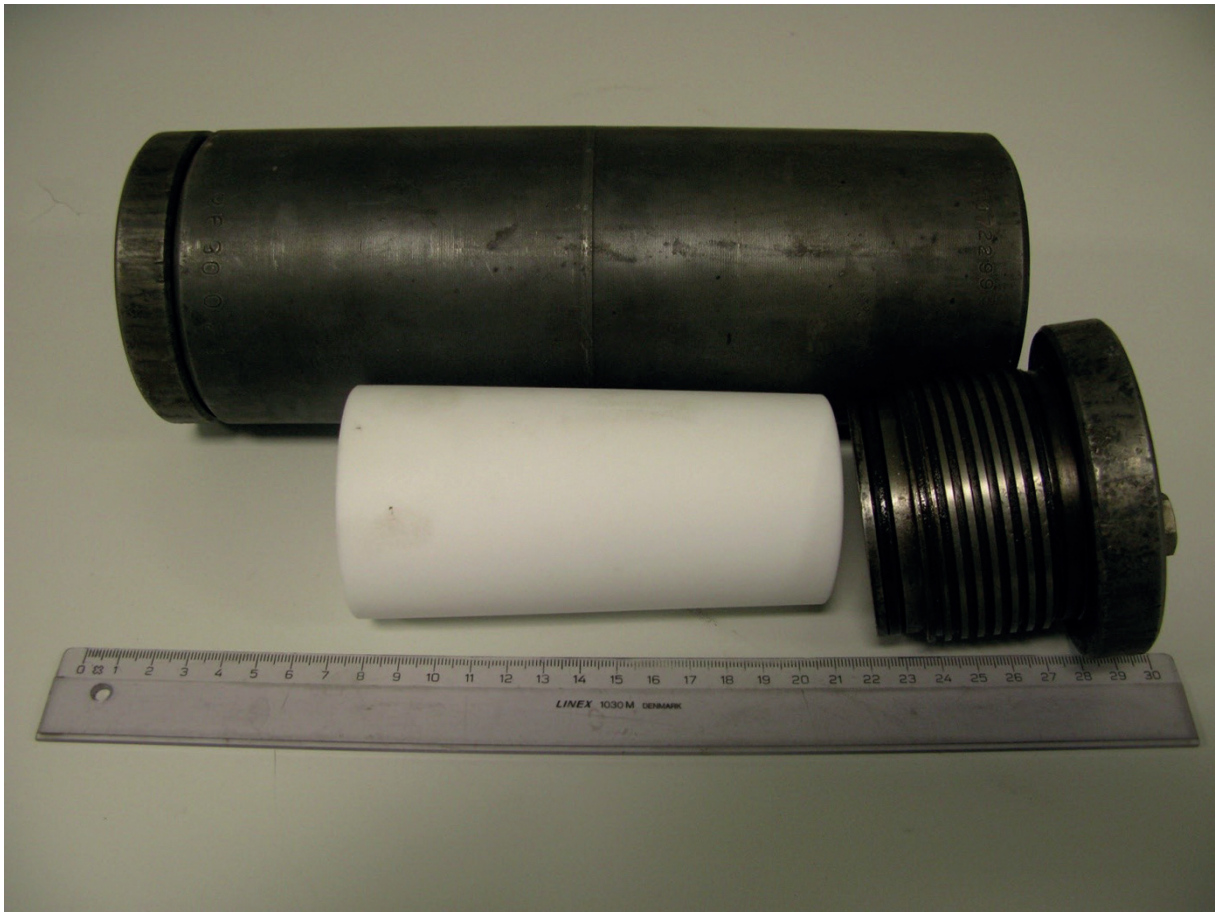

Figure A.1 — The high temperature foam cement curing cell with polytetrafluoroethylene (PTFE) sleeve

A.3.2 Preparation of the foam cement curing cell

Prepare the FCCC as follows:

a) Thoroughly clean the inside of the FCCC and the polytetrafluoroethylene (PTFE) sleeve.

b) Inspect the O-rings and replace them if necessary. (Because of the non-stick properties of the polytetrafluoroethylene (PTFE) sleeve, it is not necessary to apply grease anywhere inside the transfer cell or sleeve.)

c) Remove, separate, and thoroughly clean the vent plug.

d) Remove, separate, and thoroughly clean the rupture disk assembly. Pack it with grease and reassemble it.

e) Reattach the rupture disk assembly to the lid.

A.3.3 Preparation and curing the foam cement sample

Prepare and cure the foam cement sample as follows:

a) Prepare the foam cement slurry according to API RP 10B-4, 2nd edition (2015), Clause 7.

b) Pour a sample of the foam cement into an FCCC, until the top of the polytetrafluoroethylene (PTFE) ring.

c) Screw the lid on the cell and then screw in the vent plug to seal.

d) Set the cell vertically in the oven which has been pre-heated to T_{BHC}. The pressure will then rise inside due to thermal expansion of the gas in the foam cement and the increase in the vapour pressure of water. The contribution of the vapour pressure of water dominates above 120 °C.

e) Program a temperature ramp to the expected T_{BHS}

   — Preferably use the predicted temperature development used for sonic strength measurements based on temperature simulations.

   — Alternatively ramp according to the standard sonic strength measurement test temperature schedule.

f) Cure the cement until adequate compressive strength has been obtained, consider the sonic strength measurements for determining the required duration. A minimum of 1 000 psi should be obtained.

g) Allow the FCCC to cool in air to below 100 °C.

h) Cool the FCCC further to room temperature in a sink containing cold water. In practice, leaving the cell to cool overnight in water ensures that room temperature is reached.

i) With the FCCC submersed in water, open the vent plug slowly. No, or hardly any bubbles should be seen.

   If gas still escapes from the FCCC, meaning that insufficient cooling has taken place, start the procedure from the beginning with a much longer cooling period. Any pressure trapped within the foam cement sample can (partially) fail the sample in tensile mode as the pores in the foam cement are not connected and thus pressure cannot escape from them.

j) Remove the rupture disk assembly.

k) Remove the top and bottom end caps from the cell.

   Resistance while unscrewing the first end cap may be an indication of still trapped pressure in the cell. Ensure that all pressure is released before proceeding and check the samples integrity after freeing it from the FCCC.

l) Press the set foam cement sample and polytetrafluoroethylene (PTFE) sleeve from the FCCC with your thumbs or fingers or turn the FCCC bottom-side up and jar it downward onto the floor or a solid area.

A.4 Testing of foam cement samples cured at BHST

A.4.1 Stability of set foamed cement slurry

The stability of set foamed cement cured at temperatures above 90 °C can be determined following the method described in API RP 10B-4, 2nd edition (2015), 8.3.3.2.

A.4.2 Determination of foamed cement compressive strength

ASTM C39/C39M can be used to determine the compressive strength of the cylindrical specimens prepared in this procedure.

API TR 10TR7 provides additional information on the determination of compressive strength of cylindrical specimens.

Bibliography

[1] ISO 10426-1, *Petroleum and natural gas industries — Cements and materials for well cementing — Part 1: Specification*

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

[3] API RP 10B-3, 2nd edition (2016), *Recommended practice for testing of deepwater well cement formulations*

[4] API TR 10TR7, *Mechanical behaviour of cement*

[5] ASTM C39/C39M, *Standard test method for compressive strength of cylindrical concrete specimens*

[6] ASTM C109/C109M, *Standard test method for compressive strength of hydraulic cement mortars (using 2-in, or [50-mm] cube specimens)*

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