INTERNATIONAL STANDARD

ISO 10426-4

First edition
2004-03-01

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

Reference number
ISO 10426-4:2004(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

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 10426-4 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

Users of this part of ISO 10426 should be aware that further or differing requirements may 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 may 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.

Cements or cement blends used for foamed cement slurry preparation at atmospheric pressure should be fit for purpose. Such cements could include well cements of ISO Classes, high alumina cement, or other speciality cements. The cements and blending materials should conform to appropriate standards. Where International Standards do not exist, conformance with other appropriate standards should be made.

In this part of ISO 10426, where practical, U.S. Customary units are included in brackets 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 part of ISO 10426 defines the methods for the generation and testing of foamed cement slurries and their corresponding unfoamed base cement slurries at atmospheric pressure.

2 Normative references

The following normative document is 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 Sampling

3.1 General

Samples of the cement material or cement blend, solid and liquid additives, and water used for mixing are required to test a foamed cement slurry in accordance with this part of ISO 10426. Accordingly, the best available sampling technology should be employed to ensure the test materials match as closely as possible those found at the well site.

3.2 Method

Applicable sampling techniques for the fluids and materials used in foamed cementing operations can be found in ISO 10426-2:2003, Clause 4. If required, the temperatures of the mix water, cement or cement blends, and liquid additives may be measured with a thermocouple or thermometer capable of measuring temperature with an accuracy of ± 2 °C (± 3,5 °F). These temperatures should be recorded. Temperature-measuring devices shall be calibrated (in the case of a thermocouple) or checked for accuracy (in the case of a thermometer) annually.

4 Slurry calculations

4.1 Calculation of base cement slurry composition with and without surfactant(s)

The final base cement slurry for preparing a foamed cement slurry contains surfactant(s), which cannot be added to the base cement slurry for initial mixing. This requires calculation of the relative mass percentage (mass fraction) of the surfactant(s) in the foamed cement slurry. This is done by taking the total mass of the

surfactant(s) and dividing by the total mass of the base cement slurry. (For these calculations, additives are considered those materials added to the cement that do not result in foaming the system.)

The mass fraction (percentage) of surfactant(s) can be calculated by:

$$w_s = [m_s/(m_c + m_a + m_s + m_w)] \times 100 \quad (1)$$

where

w_s is the mass fraction of surfactant(s), expressed as a percent;

m_s is the mass of surfactant(s), expressed in grams;

m_c is the mass of cement, expressed in grams;

m_a is the mass of additive(s), expressed in grams;

m_w is the mass of water, expressed in grams.

If desired, the base cement slurry density without surfactant (ρ_{bwos}) can be calculated, in grams per cubic centimetre, by:

$$\rho_{bwos} = \frac{m_c + m_a + m_w}{V_c + V_a + V_w} \quad (2)$$

where

m_c is the mass of cement, expressed in grams;

m_a is the mass of additive(s), expressed in grams;

m_w is the mass of water, expressed in grams;

V_c is the absolute volume of cement, expressed in cubic centimetres;

V_a is the absolute volume of additive(s), expressed in cubic centimetres;

V_w is the volume of water, expressed in cubic centimetres.

4.2 Determination of slurry volume and mass

4.2.1 Slurry volume

4.2.1.1 General

Determine the volume of unfoamed base cement slurry to be used. The total volume of unfoamed base cement slurry shall include the volume of surfactant(s) to be added to the base cement slurry. The surfactant(s) is(are) added after the initial mixing of the base cement slurry. The volume of unfoamed base cement slurry with surfactants to be placed in the blending container can be calculated by one of two methods (see 4.2.1.2 and 4.2.1.3).

4.2.1.2 Known gas content

When it is desired to foam a slurry with a specific volume fraction of gas per volume of slurry (foam quality), the resultant density of the foamed cement slurry must be determined. This can be calculated by:

$$\rho_{fs} = \left(\frac{100 - \varphi_g}{100} \right) \times \rho_{ufss} \tag{3}$$

where

ρ_{fs} is the density of the foamed cement slurry, expressed in kilograms per cubic metre (pounds-mass per gallon);

φ_g is the volume fraction of gas in the final foamed cement slurry, expressed as a percent;

ρ_{ufss} is the density of the unfoamed base cement slurry with surfactant(s), expressed in kilograms per cubic metre (pounds-mass per gallon).

4.2.1.3 Known foamed cement slurry density

When the desired density of the foamed cement slurry is known [or after calculating it with Equation (3)], determine the mass, in grams, of cement slurry including surfactant(s) to be placed into the blending container to prepare the foamed cement slurry. The mass of unfoamed base cement slurry with surfactant(s) can be calculated by:

$$m_{ufss} = V_{mc} \times \rho_{fs} \tag{4}$$

where

m_{ufss} is the mass of unfoamed base cement slurry with surfactant(s) to be placed in the blending container, expressed in grams;

V_{mc} is the blending container volume, expressed in cubic centimetres;

ρ_{fs} is the desired density of the foamed cement slurry, expressed in grams per cubic centimetre.

4.2.2 Surfactant(s) and slurry mass

The masses of surfactant(s) and unfoamed base cement slurry required for testing are found using Equations (5) and (6).

The mass of surfactant(s) to be placed into the mixer with the unfoamed base cement slurry is determined as follows:

$$m_s = m_{ufss} \times \frac{w_s}{100} \tag{5}$$

where

m_s is the mass of surfactant(s), expressed in grams;

m_{ufss} is the mass of unfoamed base cement slurry with surfactant(s), expressed in grams;

w_s is the mass fraction of surfactant, expressed as a percent.

The mass of base cement slurry is determined as follows:

$$m_{ufs} = m_{ufss} - m_s \tag{6}$$

where

m_{ufs} is the mass of unfoamed base cement slurry without surfactant(s), expressed in grams;

m_{ufss} is the mass of unfoamed base cement slurry with surfactant(s), expressed in grams;

m_s is the mass of surfactant(s) to be added to the unfoamed base cement slurry, expressed in grams.

NOTE The percentage contribution of each material by mass was determined in 4.1.

4.2.3 Additional calculations

If the density of the foamed cement slurry is known, the volume fraction (percent) of gas can be calculated by:

$$\varphi_g = \frac{\rho_{ufss} - \rho_{fs}}{\rho_{ufss}} \times 100 \tag{7}$$

where

φ_g is the volume fraction of gas in final foamed cement slurry, expressed as a percent;

ρ_{ufss} is the density of the unfoamed base cement slurry with surfactant(s), expressed in kilograms per cubic metre;

ρ_{fs} is the density of the foamed cement slurry, expressed in kilograms per cubic metre.

The volume of unfoamed base cement slurry can be calculated by:

$$V_{us} = V_{mc} - \frac{V_{mc} \times \varphi_g}{100} \tag{8}$$

where

V_{us} is the unfoamed base cement slurry volume, expressed in cubic centimetres;

V_{mc} is the blending container volume, expressed in cubic centimetres;

φ_g is the volume fraction of gas in final foamed cement slurry, expressed as a percent.

The mass of unfoamed base cement slurry can be calculated by:

$$m_{ufss} = V_{us} \times \rho_{ufss} \tag{9}$$

where

m_{ufss} is the mass of unfoamed base cement slurry with surfactant(s), expressed in grams;

V_{us} is the unfoamed base cement slurry volume, expressed in cubic centimetres;

ρ_{ufss} is the density of the unfoamed base cement slurry with surfactant, expressed in grams per cubic centimetre.

NOTE The density terms contained in Equations (7) and (9) can be expressed in units of kg/m^3 or g/cm^3.

5 Apparatus

5.1 Blending container, with a lid that seals, for preparing foamed cement slurry at atmospheric pressure in the laboratory (see Figure 1).

The blending container is similar to that used for standard slurry preparation, except it has a threaded cap with an O-ring seal. The cap has a small hole [± 19 mm (± 0,75 in) diameter] in the centre fitted with a removable plug with a vent hole. A conventional blending container that does not have a seal cannot be used for these tests.

5.2 Mixing blade assembly, either a single mixing blade as supplied by the manufacturer, or a multiple stacked-blade assembly.

Testing to date has not identified a significant difference in slurries mixed with the two different blade assemblies using the sealed blending container.

5.2.1 Single blade assembly, in accordance with ISO 10426-2:2003, Clause 5.

5.2.2 Multi-blade (stacked-blade) assembly, constructed of a series of assemblies, each blade in accordance with ISO 10426-2:2003, Clause 5 (see Figure 1).

The assembly consists of five standard blades attached to a central shaft, and spaced equally along the shaft.

Figure 1 — Blending container and multi-blade assembly

6 Preparation of base cement slurry

6.1 Determination of blending container volume

This method assumes the base cement slurry as described in 4.1 is prepared in a separate mixing container and this prepared slurry weighed into the blending container with a sealed lid. Accurate determination of the volume of the blending container is critical to this procedure. The calculations for slurry volume, density and foamed cement slurry-to-gas ratio are based on determination of this container volume, as follows.

Weigh the clean, dry blending container (including mixing assembly, screw-on lid and screw-in plug for the lid). Remove the screw-on lid from the blending container and remove the screw-in plug from the lid. Fill the blending container with water and screw the lid on tightly. Pour additional water into the hole in the lid until the container is completely filled, and screw the plug into the lid. Wipe the excess water that exits from the plug's