

Preparation and Testing of Foamed Cement Formulations at Atmospheric Pressure

API RECOMMENDED PRACTICE 10B-4
SECOND EDITION, OCTOBER 2015

REAFFIRMED, AUGUST 2019



AMERICAN PETROLEUM INSTITUTE

Special Notes

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

Neither API nor any of API's employees, subcontractors, consultants, committees, or other assignees make any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information contained herein, or assume any liability or responsibility for any use, or the results of such use, of any information or process disclosed in this publication. Neither API nor any of API's employees, subcontractors, consultants, or other assignees represent that use of this publication would not infringe upon privately owned rights.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any authorities having jurisdiction with which this publication may conflict.

API publications are published to facilitate the broad availability of proven, sound engineering and operating practices. These publications are not intended to obviate the need for applying sound engineering judgment regarding when and where these publications should be utilized. The formulation and publication of API publications is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

Users of this recommended practice should not rely exclusively on the information contained in this standard. Sound business, scientific, engineering, and safety judgment should be used in employing the information contained herein.

All rights reserved. No part of this work may be reproduced, translated, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise, without prior written permission from the publisher. Contact the Publisher, API Publishing Services, 1220 L Street, NW, Washington, DC 20005.

Copyright © 2015 American Petroleum Institute

Foreword

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

The verbal forms used to express the provisions in this recommended practice are as follows:

- the term “shall” denotes a minimum requirement in order to conform to the recommended practice;
- the term “should” denotes a recommendation or that which is advised but not required in order to conform to the recommended practice;
- the term “may” is used to express permission or a provision that is optional; and
- the term “can” is used to express possibility or capability.

Informative elements: As used in a standard, “informative” denotes elements that: identify the standard, introduce its content, and explain its background, development, and its relationship with other standards; or provide additional information intended to assist the understanding or use of the standard.

Normative elements: As used in a standard, “normative” denotes elements that describe the scope of the standard and that set out provisions that are required to implement the standard.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this publication or comments and questions concerning the procedures under which this publication was developed should be directed in writing to the Director of Standards, American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. A one-time extension of up to two years may be added to this review cycle. Status of the publication can be ascertained from the API Standards Department, telephone (202) 682-8000. A catalog of API publications and materials is published annually by API, 1220 L Street, NW, Washington, DC 20005.

Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

Contents

Page

1	Scope	1
2	Normative References	1
3	Terms, Definitions, and Symbols	1
3.1	Terms and Definitions	1
3.2	Symbols	3
4	Sampling	4
4.1	General	4
4.2	Method	4
5	Slurry Calculations	4
5.1	Introduction	4
5.2	Calculation of Base Cement Slurry Composition With and Without Surfactant(s)	4
5.3	Determination of Slurry Volume and Mass	5
6	Base Cement Slurry Preparation and Testing	9
6.1	General	9
6.2	Conditioning Procedures	9
6.3	Density Measurement	9
6.4	Stability of Unfoamed Base Cement Slurry	9
6.5	Determination of Rheological Properties	9
6.6	Determination of Static Fluid Loss	9
6.7	Determination of Thickening Time	10
6.8	Determination of Compressive Strength	10
6.9	Compatibility	10
7	Preparation of Foamed Cement Slurry at Atmospheric Pressure	10
7.1	Unfoamed Base Cement Slurry Preparation	10
7.2	Blending Apparatus	11
7.3	Generation of a Foamed Cement Slurry	12
8	Atmospheric Testing of Foamed Cement Slurries	14
8.1	General	14
8.2	Determination of Foamed Cement Slurry Density	14
8.3	Determination of Foamed Cement Slurry Stability	14
8.4	Determination of Compressive Strength	19
	Annex A (informative) Nitrogen Density, ρ_{N_2}	21
	Annex B (informative) Nitrogen—A Real Gas	28
	Annex C (informative) Nitrogen Compressibility Factor, Z (Dimensionless)	30
	Annex D (informative) Example Calculations for the Preparation of Foamed Cement Slurry at Atmospheric Pressure	37
	Bibliography	40

Contents

Page

Figures

1	Blending Container and Multi-blade Assembly	11
2	Example of Curing Mold for Evaluation of Foamed Cement Slurry Stability	18
3	Evaluation Report Form: Foamed Cement Slurry Stability at Temperature <90 °C (194 °F)	20

Tables

A.1	Nitrogen Density (kg/m ³) from Temperature and Absolute Pressure in SI Units	22
A.2	Nitrogen Density (lbm/gal) from Temperature and Absolute Pressure in USC Units	25
C.1	Nitrogen Compressibility Factor from Temperature and Absolute Pressure in SI Units	31
C.2	Nitrogen Compressibility Factor from Temperature and Absolute Pressure in USC Units	34

Preparation and Testing of Foamed Cement Formulations at Atmospheric Pressure

1 Scope

This standard defines the test methods including the generation of unfoamed base and their corresponding foamed cement slurries at atmospheric pressure. These procedures are developed for foaming cement slurries with air, at atmospheric conditions, which could mimic a foam quality experienced with nitrogen at downhole conditions; they may be modified to accommodate other gases such as nitrogen. Slurries that are foamed with nitrogen, and their properties, will also be discussed within this standard as they are relevant to the scope of the standard.

This standard does not address testing at pressures above atmospheric conditions, nor does this standard include or consider the effects of nitrogen solubility in the nitrogen fraction calculations.

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. However, not all documents listed may apply to your specific needs. The body of the standard should be referred to for how these documents are specifically applied. For a list of other standards associated with this standard, see the Bibliography.

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

API Recommended Practice 10B-3, *Recommended Practice on Testing of Deepwater Well Cement Formulations*

3 Terms, Definitions, and Symbols

3.1 Terms and Definitions

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

3.1.1

additive

Material added to a cement slurry to modify or enhance some desired property.

3.1.2

batch mixing

Process of mixing and holding a volume of cement slurry prior to placement in the wellbore.

3.1.3

cement

Portland cement

Material formed by the grinding of clinker, generally consisting of hydraulic calcium silicates and aluminates and usually containing one or more of the forms of calcium sulfate added during grinding.

3.1.4

compatibility

Capacity to form a fluid mixture that does not undergo undesirable chemical and/or physical reactions.

3.1.5

compressive strength

Strength of a set cement sample measured by the force required to cause it to fail in compression, expressed as force per unit area.

3.1.6**consistometer**

Device used to measure the thickening time of a cement slurry at specified temperature and pressure.

NOTE An atmospheric consistometer can be used to condition fluids prior to testing and for determining the thickening time of arctic slurries.

3.1.7**foamed cement**

Cement slurry containing a stable gas fraction (typically nitrogen) well dispersed and entrained within the slurry.

3.1.8**free fluid**

Colored or colorless liquid that has separated from a cement slurry when standing in a static condition.

3.1.9**nitrogen fraction**

Volume percent nitrogen within a volume of foamed cement slurry, commonly referred to as foam quality.

NOTE In the laboratory the nitrogen fraction will typically be created with air. Nitrogen fraction is a function of temperature and pressure and thus can vary widely during job placement.

3.1.10**relative density****specific gravity**

Ratio of the mass of a substance to the mass of an equal volume of a standard substance at a reference temperature.

NOTE The standard substance is typically water; the reference temperature is typically 4 °C (39 °F) for a relative density or specific gravity of 1.00.

3.1.11**sedimentation**

Separation and settling of solids in a cement slurry.

3.1.12**slurry stability test**

Test to determine the degree of sedimentation and/or free fluid development in a cement slurry.

3.1.13**sonic strength**

Compressive strength of a cement sample obtained by measuring the velocity of sound through the cement and computing the strength using a correlation to compressive strength measurements.

3.1.14**static fluid loss test**

Test to determine filtrate lost from a cement slurry when placed against a 45 µm (325 mesh) screen at 6900 kPa (1000 psi) differential pressure.

3.1.15**thickening time**

Time elapsed from the initial application of pressure and temperature to the time at which the slurry reaches a consistency deemed sufficient to make it unpumpable (e.g. 70 Bc or 100 Bc).

NOTE The results of a thickening-time test provide an indication of the length of time a cement slurry can remain pumpable under the test conditions.

3.1.16**unfoamed base cement slurry**

Cement slurry utilized to create a foamed cement that does not contain the surfactant(s), or gas fraction of the foamed cement slurry.

3.1.17**unfoamed base cement slurry with surfactants**

Cement slurry utilized to create a foamed cement that does contain the surfactant(s), utilized to create the foamed cement slurry.

3.1.18**unstable foamed cement**

Foamed cement that fails to maintain the evenly and well dispersed nitrogen (or gas) fraction following foam generation.

NOTE In the laboratory the nitrogen fraction will typically be created with air; a foamed cement that cannot be foamed to the desired nitrogen (or gas) fraction may remain stable but may not be fit for purpose and should be redesigned.

3.2 Symbols

d_{rel}	relative density of the set cement segment
m_a	mass of additive(s) without surfactants
m_{airf}	foamed cement segment weight in air
m_{BWOS}	mass of unfoamed base cement slurry with no surfactant(s)
m_{BWS}	mass of unfoamed base cement slurry with surfactant(s) to be placed in the blending container
m_c	cement mass
m_s	mass of surfactant(s)
m_w	mix water mass
m_{waterf}	foamed cement segment weight in water
m_{wfb}	mass of water to fill blender (used to determine blender volume)
$V_{ad.abs}$	solid additive volume
V_{bc}	blending container volume
V_{BWOS}	slurry volume without surfactant(s)
V_{BWS}	unfoamed base cement slurry volume with surfactant(s)
$V_{c.abs}$	cement volume
V_w	mix water volume
$v_{ad.abs}$	solid additive absolute volume
$v_{c.abs}$	cement absolute volume
w_s	mass fraction of surfactant(s) expressed as a percentage
ϕ_{N2A}	nitrogen fraction required to achieve the design downhole density at estimated downhole conditions of pressure and temperature in the well at atmospheric conditions expressed as a percentage
ϕ_{N2L}	nitrogen fraction in the lab
ρ_{BWOS}	base cement slurry density without surfactant(s)
ρ_{BWS}	density of the unfoamed base cement slurry with surfactant(s)
ρ_{FA}	atmospheric foamed cement slurry density calculated with the required nitrogen fraction to achieve the design downhole density (at estimated downhole conditions of pressure and temperature in the well)

ρ_{FD}	targeted in situ downhole density of the foamed cement slurry
ρ_{N2D}	downhole density of nitrogen at the estimated pressure and temperature in the well (expressed in grams per centimeter or kilograms per cubic meter; can be obtained from Annex A)
ρ_{set}	density of set cement segment
ρ_{Water}	density of water

4 Sampling

4.1 General

Samples of the water, cement material or cement blend, and additives (solid or liquid) used for mixing are required to test a foamed cement slurry. These samples shall be obtained in accordance with API 10B-2. Appropriate sampling equipment and methods should be used to obtain samples. Wellsite, or representative samples, should be used to ensure the test materials match as closely as possible to those used for job execution.

4.2 Method

Applicable sampling techniques for the fluids and materials used in foamed cementing operations can be found within API 10B-2.

5 Slurry Calculations

5.1 Introduction

The maximum nitrogen fraction calculations are based on the properties of nitrogen at anticipated in situ downhole conditions. Nitrogen fraction calculations can be performed using the equations and tables contained in this standard, or by the use of a numerical foamed cement simulator. Small, but acceptable, differences in nitrogen fraction results may occur due to variations in compressibility factors (Z nitrogen) between the tables within this standard and those used by numerical simulators.

Laboratory preparation and testing are performed based on the results of these calculations using air (instead of nitrogen). At atmospheric conditions, the differences between cement foamed with nitrogen or air are not significant.

5.2 Calculation of Base Cement Slurry Composition With and Without Surfactant(s)

The base cement slurry for preparing a foamed cement slurry contains surfactant(s) that 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 as all additives added to mix the initial base cement slurry and exclude the surfactant(s) used for foaming the system.

The mass fraction of surfactant(s), w_s , expressed as a percentage, can be calculated according to Equation (1):

$$w_s = \frac{m_s}{m_c + m_a + m_s + m_w} \times 100 \quad (1)$$

where

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

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

m_c is the cement mass expressed in grams;

m_a is the additive(s) mass without surfactants expressed in grams; and

m_w is the mix water mass expressed in grams.

NOTE Mass fraction for other components of the foamed cement (such as cement and water) can be calculated by Equation (1) and replacing the numerator, mass of surfactant(s), m_s , by the mass of the foamed cement component (such as cement and water).

If desired, the base cement slurry density without surfactant(s), ρ_{BWOS} , can be calculated in grams per cubic centimeter according to Equation (2):

$$\rho_{BWOS} = \frac{m_c + m_a + m_w}{(m_c \times v_{c,abs}) + (m_a \times v_{ad,abs}) + V_w} \quad (2)$$

where

ρ_{BWOS} is the base cement slurry density without surfactant(s) expressed in grams per cubic centimeter;

m_c is the cement mass expressed in grams;

m_a is the additive(s) mass without surfactants expressed in grams;

m_w is the mix water mass expressed in grams;

$v_{c,abs}$ is the cement absolute volume expressed in cubic centimeters per gram;

$v_{ad,abs}$ is the solid additive absolute volume expressed in cubic centimeters per gram; and

V_w is the mix water volume expressed in cubic centimeters.

NOTE 1 Mass and volume calculations are described in API 10B-2.

NOTE 2 Mass fraction and density can be calculated using homogeneous metric (SI) or U.S. customary (USC) units.

5.3 Determination of Slurry Volume and Mass

5.3.1 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.

During the job design process the maximum nitrogen fraction in the annulus following cement placement (in situ) shall be determined for each foamed cement job and is typically determined with computer-aided foamed cement job design tools. The maximum nitrogen fraction should be agreed by the user and the provider of the foamed cement before testing begins. This maximum nitrogen fraction shall be utilized during testing to evaluate the stability of the foamed cement slurry as specified in 8.3.

Nitrogen is a real gas; therefore, not only does the volume of nitrogen change with pressure and temperature but also its density. Pre-calculated nitrogen densities are also provided in tables within Annex A. The nitrogen density can be calculated using the equations in Annex B, which include the compressibility factor (Z nitrogen). Nitrogen compressibility factors are provided within Annex C, Table C.1 (for SI units) and Table C.2 (for USC units).

Once the pressure and temperature are determined for laboratory testing, the appropriate atmospheric nitrogen fraction can be determined utilizing the nitrogen density tables in Annex A and the equations as specified in 5.3.

NOTE Refer to Annex D for example calculations.

5.3.2 Atmospheric Nitrogen Fraction to Achieve the Design Density Calculated with the Downhole N₂ Density at the Estimated Pressure and Temperature in the Well

Utilizing the design downhole density and the estimated pressure and temperature in the well, the laboratory nitrogen fraction ϕ_{N2A} (i.e. volume fraction of gas) is calculated according to Equation (3):

$$\phi_{N2A} = \frac{\rho_{BWS} - \rho_{FD}}{\rho_{BWS} - \rho_{N2D}} \times 100 \quad (3)$$

where

ϕ_{N2A} is the nitrogen fraction required to achieve the designed downhole density at estimated downhole conditions of pressure and temperature in the well at atmospheric conditions expressed as a percentage

ρ_{BWS} is the density of the unfoamed base cement slurry with surfactant(s), expressed in kilograms per cubic meter at downhole conditions;

ρ_{FD} is the targeted in situ (downhole) density of the foamed cement slurry, expressed in kilograms per cubic meter; and

ρ_{N2D} is the downhole density of nitrogen at the estimated pressure and temperature in the well, expressed in kilograms per cubic meter, obtained from Annex A.

Stability and compressive strength testing of the foamed cement shall be conducted at the nitrogen fraction (expressed as a percentage) required to achieve the designed downhole density at estimated downhole conditions of pressure and temperature in the well at atmospheric conditions.

NOTE 1 To facilitate the use of the tables in Annex A, the density terms according to Equation (3) can be expressed in units of kg/m³ or lbm/gal; if the density is expressed in kg/m³, to express the density in g/cm³ divide the value by 1000.

NOTE 2 The atmospheric laboratory prepared density will vary from the target in situ (downhole) density (see 5.3.7).

5.3.3 Calculation of Atmospheric Foamed Cement Slurry Density Utilizing the Nitrogen Fraction Required to Achieve the Design Downhole Density at Estimated Downhole Conditions of Pressure and Temperature in the Well

The atmospheric foamed cement slurry density (ρ_{FA}) with the required nitrogen fraction to achieve the design downhole density, at estimated downhole conditions of pressure and temperature in the well (ϕ_{N2A}) can now be calculated according to Equation (4):

$$\rho_{FA} = \frac{100 - \phi_{N2A}}{100} \times \rho_{BWS} \quad (4)$$

where

ρ_{FA} is the atmospheric foamed cement slurry density calculated with the required nitrogen fraction to achieve the design downhole density, at estimated downhole conditions of pressure and temperature in the well, expressed in grams per cubic centimeter;

ϕ_{N2A} is the nitrogen fraction required to achieve the design downhole density at estimated downhole conditions of pressure and temperature in the well at atmospheric conditions expressed as a percentage;

ρ_{BWS} is the density of the unfoamed base cement slurry with surfactant(s), expressed in grams per cubic centimeter.

5.3.4 Mass of Unfoamed Base Cement Slurry with Surfactant(s) Required for Testing

The mass of cement slurry in grams, including surfactant(s), m_{BWS} , to be placed into the blending container to prepare the foamed cement slurry can be calculated according to Equation (5):

$$m_{BWS} = V_{bc} \times \rho_{FA} \quad (5)$$

where

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

V_{bc} is the blending container volume, expressed in cubic centimeters; and

ρ_{FA} is the atmospheric foamed cement slurry density, expressed in grams per cubic centimeter and calculated with the required nitrogen fraction to achieve the design downhole density, at estimated downhole conditions of pressure and temperature in the well.

5.3.5 Surfactant(s) and Base Cement Slurry Mass Required for Testing

The masses of surfactant(s), m_s , and mass of unfoamed base cement slurry with no surfactant(s), m_{BWOS} , required for testing are found according to Equations (6) and (7).

The mass of surfactant(s) to be placed into the blending container with the unfoamed base cement slurry, m_{BWS} , can be calculated according to Equation (6):

$$m_s = m_{BWS} \times \frac{w_s}{100} \quad (6)$$

where

m_s is the mass of surfactant(s), expressed as a percentage;

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

w_s is the mass fraction of surfactant(s), expressed in grams.

The mass of unfoamed base cement slurry with no surfactants, m_{BWOS} , can be calculated according to Equation (7):

$$m_{BWOS} = m_{BWS} - m_s \quad (7)$$

where

m_{BWOS} is the mass of unfoamed base cement slurry with no surfactant(s), expressed in grams;

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

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

NOTE The percentage contribution of each material by mass was determined as specified in 5.2.

5.3.6 Volume and Mass of Unfoamed Base Cement Slurry Required for Testing

The volume of unfoamed base slurry with surfactant(s), V_{BWS} , may also be calculated utilizing the laboratory atmospheric density calculated according to Equation (4); see 5.3.3. This density is calculated utilizing the nitrogen fraction required to achieve the designed downhole density at the estimated conditions of pressure and temperature in the well according to Equation (3); see 5.3.2.

The volume of unfoamed base cement slurry, V_{BWS} , can be calculated according to Equation (8):

$$V_{BWS} = V_{bc} - \frac{V_{bc} \times \phi_{N2A}}{100} \quad (8)$$

where

V_{BWS} is the unfoamed base cement slurry volume, expressed in cubic centimeters;

V_{bc} is the blending container volume, expressed in cubic centimeters; and

ϕ_{N2A} is the nitrogen fraction required to achieve the design downhole density at estimated downhole conditions of pressure and temperature in the well at atmospheric conditions expressed as a percentage.

The mass of unfoamed base cement slurry, m_{BWS} , can be calculated according to Equation (9):

$$m_{BWS} = V_{BWS} \times \rho_{BWS} \quad (9)$$

where

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

V_{BWS} is the slurry volume of the unfoamed base cement slurry with surfactant(s), expressed in cubic centimeters; and

ρ_{BWS} is the density of the unfoamed base cement slurry with surfactant(s), expressed in grams per cubic centimeter.

5.3.7 Density of a Laboratory Atmospherically Foamed Cement

Following the generation of the foamed cement slurry, the density (ρ_{FA}) may be calculated according to Equation (10):

$$\rho_{FA} = \frac{100 - \phi_{N2L}}{100} \times \rho_{BWS} \quad (10)$$

where

ρ_{FA} is the atmospheric foamed cement slurry density calculated with the required nitrogen fraction to achieve the design downhole density, at estimated downhole conditions of pressure and temperature in the well, expressed in grams per cubic centimeter;

ϕ_{N2L} is the nitrogen fraction in the lab, expressed as a percentage; and

ρ_{BWS} is the density of the unfoamed base cement slurry with surfactant(s), expressed in grams per cubic centimeter.

NOTE An example of the use of these equations for calculations can be found in Annex D.

6 Base Cement Slurry Preparation and Testing

6.1 General

For the following tests performed on the unfoamed base cement slurry, the unfoamed base cement slurry without the surfactant(s) shall be prepared in accordance with API 10B-2. After the slurry is prepared, stop the blending container, add the surfactant(s), and stir gently with a spatula to distribute it uniformly in the slurry. It is recommended that the slurry should be poured gently from the blending container to a beaker and back three times to ensure a uniform distribution of the surfactant(s).

When testing unfoamed base slurry with surfactants, air entrainment can potentially create errors in some test results. A small amount of defoamer can be used to prevent air entrainment in the laboratory. This is not recommended when testing foam stability in the laboratory and is not recommended during field applications in oil and gas wells.

NOTE Preparation of sufficient volume of the base cement slurry may require multiple mixes using the standard mixing procedure, or use of a large laboratory blender; see preparation of large slurry volumes in API 10B-2.

6.2 Conditioning Procedures

For conditioning procedures for testing of the unfoamed base cement slurry, refer to API 10B-2 or API 10B-3. Report any conditioning procedure used in the preparation of the unfoamed base slurry.

6.3 Density Measurement

The density of the unfoamed base cement slurry with surfactants can be determined by methods found in API 10B-2. Failure to measure the atmospheric density of the base slurry, inclusive of the foaming surfactant(s), will lead to incorrect volumes in the blender and subsequent incorrect air fraction of the foamed slurry.

6.4 Stability of Unfoamed Base Cement Slurry

The unfoamed base cement slurry with surfactant(s) shall be evaluated in accordance with API 10B-2. The unfoamed base slurry with surfactant(s) shall be stable. If the unfoamed base cement slurry shows signs of instability, redesign the slurry.

Some signs of instability can include:

- a) excessive free fluid;
- b) streaking or light to dark color change from top to bottom; and/or
- c) large variations in density from sample top to bottom in the sedimentation test.

6.5 Determination of Rheological Properties

Rheological properties test on the unfoamed base cement slurry with surfactant(s) shall be performed in accordance with API 10B-2 or API 10B-3.

NOTE Use of the rotational viscometer with a foamed cement slurry may result in separation of the gas from the slurry, causing erroneous results.

6.6 Determination of Static Fluid Loss

Fluid-loss tests performed on the foamed cement slurry prepared at atmospheric pressure may not yield reliable results and should not be performed. Specialized test methods have determined that fluid-loss values obtained from a