

Cements and Materials for Well Cementing

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Introduction

It is necessary that users of this specification be aware that further or differing requirements can be required for individual applications. This specification 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, it is the responsibility of the vendor to identify any variations from this specification and provide details.

In this specification, where practical, US Customary (USC) units are included in brackets for information. The units do not necessarily represent a direct conversion of SI to USC units, or USC to SI units. Consideration has been given to the precision of the instrument making the measurement. For example, thermometers are typically marked in 1° increments, thus temperature values have been rounded to the nearest degree.

In this specification, calibrating an instrument refers to assuring the accuracy of the measurement. Accuracy is the degree of conformity of a measurement of a quantity to its actual or true value. Accuracy is related to precision, or reproducibility, of a measurement. Precision is the degree to which further measurements or calculations will show the same or similar results. Precision is characterized in terms of the standard deviation of the measurement. The results of calculations or a measurement can be accurate, but not precise, precise but not accurate, neither or both. A result is valid if it is both accurate and precise.

Cements and Materials for Well Cementing

1 Scope

1.1 General

This document specifies requirements and gives recommendations for six classes of well cements, and two classes of composite well cements including their chemical and physical requirements, and procedures for physical testing.

This specification is applicable to well cement classes A, B, C, and D, which are the products obtained by grinding Portland cement clinker and, if needed, calcium sulfate (CaSO_4) as an interground additive. Processing additives can be used in the manufacture of cement of these classes. Suitable set-modifying agents can be interground or blended during the manufacture of Class D cement. Annex B describes composite well cement classes K and L, which are the products obtained by intergrinding Portland cement clinker and one or more forms of CaSO_4 with composite constituents, or by subsequent blending of separately produced Portland cement with separately processed composite constituents. Composite constituents are also specified in Annex B.

This specification is also applicable to well cement classes G and H, which are the products obtained by grinding clinker with no additives other than one or more forms of CaSO_4 , water, or chemical additives as required for chromium (VI) reduction.

1.2 Use of Metric SI and US Customary Units

This document contains metric SI and US customary oilfield units. For the purposes of this document, the conversion between the systems is not exact and has been intentionally rounded to allow for ease of use in calibration and measurement.

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 applies (including any addenda/errata). 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.

API Specification 13A, *Specification for Drilling Fluid Materials*

ASTM¹ C109/C109M, *Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)*

ASTM C114, *Standard Test Methods for Chemical Analysis of Hydraulic Cement*

ASTM C115, *Standard Test Method for Fineness of Portland Cement by the Turbidimeter*

ASTM C183, *Standard Practice for Sampling and the Amount of Testing of Hydraulic Cement*

ASTM C204, *Standard Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus*

ASTM C465, *Standard Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements*

¹ ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, www.astm.org.

ASTM E1404, *Standard Specification for Laboratory Glass Conical Flasks*

EN² 196-2, *Methods of testing cement — Part 2: Chemical analysis of cement*

EN 196-6, *Methods of testing cement — Part 6: Determination of fineness*

EN 196-7, *Methods of testing cement — Part 7: Methods of taking and preparing samples of cement*

ISO³ 24450, *Laboratory glassware — Wide-necked boiling flasks*

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

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

3.1.1

additive

Material added to a cement slurry to modify its properties.

3.1.2

atmospheric pressure consistometer

Device used for pre-conditioning a cement slurry under temperature and at atmospheric pressure.

3.1.3

Bearden units of consistency

B_c

Measure of the consistency of a cement slurry when determined on a pressurized consistometer.

3.1.4

blending

A process in which two or more ingredients are combined into an intimate and uniform product of finely divided dry material, as by special blending equipment.

3.1.5

cement

Portland cement

Ground clinker generally consisting of hydraulic calcium silicates and aluminates, and usually containing one or more forms of CaSO_4 as an interground additive.

3.1.6

cement class

Designation for classification of well cement according to its intended use.

3.1.7

clinker

Fused materials produced in the kiln during cement manufacturing that are interground with CaSO_4 to make cement.

² European Committee for Standardization, Rue de la Science 23, B-1040 Brussels, Belgium; www.cen.eu.

³ International Organization for Standardization, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland; www.iso.org.

3.1.8**compressive strength**

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

3.1.9**free-fluid
(free-water)**

Colored or colorless liquid that separates from a cement slurry under static conditions.

3.1.10**grade**

Designation achieved under the API system for denoting the sulfate resistance of a particular cement.

3.1.11**intergrinding**

A process involving grinding Portland cement clinker with suitable other components to produce finely divided dry material.

3.1.12**load frame**

Frame to place a load on cement samples for determining compressive strength of cement.

3.1.13**pressurized consistometer**

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

3.1.14**slurry container
(slurry cup)**

Container in an atmospheric or pressurized consistometer used to hold the slurry for pre-conditioning purpose or for the thickening-time test.

3.1.15**thickening time**

Time after which the consistency of a cement slurry has become so high that the slurry is considered unpumpable.

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

3.2 Acronyms and Abbreviations

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

ASTM American Society for Testing and Materials

C₃A tricalcium aluminate

C₄AF tetracalcium aluminoferrite

CaSO₄ calcium sulfate

C₃S tricalcium silicate

EN European Committee for Standardization

HSR	high sulfate-resistant
INSP	inspection (dimension requiring verification)
ISO	International Organization for Standardization
MSR	moderate sulfate-resistant
NIST	National Institute of Standards and Technology
O	ordinary
OD	outside diameter

4 Requirements

4.1 Specification, Chemical, and Physical Requirements

4.1.1 Classes and Grades

4.1.1.1 General

Well cements shall be specified using the classes A, B, C, D, G, or H and the grades ordinary (O), moderate sulfate-resistant (MSR), and high sulfate-resistant (HSR). Composite well cements shall be specified using classes K and L, consisting of Portland cements and additional composite constituents according to Annex B.

A well cement, or composite well cement, that has been manufactured and supplied in accordance with this specification may be mixed and placed in the field using alternate water ratios and/or additives. It is not intended that manufacturing compliance with this specification be based on such field conditions.

Processing additives, set modifying agents, or chemical additives used to reduce chromium (VI) shall not prevent a well cement from performing its intended functions.

4.1.1.2 Well Cement Testing by the Manufacturer

To conform to this standard, the manufacturer shall perform testing of well cements to the following:

- at a laboratory under a Quality Management System that conforms to a nationally or internationally recognized standard, such as API Specification Q1 or ISO 9001;
- at the same place of manufacturing as the Portland cement component in the case of composite well cements;
- on unmodified samples taken in accordance with 4.2, including composite samples, defined as a sample blended in the laboratory from multiple samples that are taken from the product in accordance with 4.2.

NOTE This clause does not prohibit users of well cement from independently performing specification testing according to this standard.

4.1.1.3 Class A

This product is obtained by grinding clinker that consists of hydraulic calcium silicates and contains one or more forms of CaSO_4 as an interground additive. Processing additives used in the manufacture of Class A cement shall meet the requirements given in ASTM C465.

NOTE This product is intended for use when special properties are not required and is available only in O grade, similar to the requirements given in ASTM C150 for Type I cement.

4.1.1.4 Class B

This product is obtained by grinding clinker that consists of hydraulic calcium silicates and contains one or more forms of CaSO_4 as an interground additive. Processing additives used in the manufacture of Class B cement shall meet the requirements given in ASTM C465.

NOTE This product is intended for use when conditions require moderate or high sulfate resistance and is available in both MSR and HSR grades, similar to the requirements given in ASTM C150 for Type II cement.

4.1.1.5 Class C

This product is obtained by grinding clinker that consists of hydraulic calcium silicates and contains one or more forms of CaSO_4 as an interground additive. Processing additives used in the manufacture of Class C cement shall meet the requirements given in ASTM C465.

NOTE This product is intended for use when conditions require high early strength, and is available in O, MSR, and HSR grades, similar to the requirements given in ASTM C150 for Type III cement.

4.1.1.6 Class D

This product is obtained by grinding clinker that consists of hydraulic calcium silicates and contains one or more forms of CaSO_4 as an interground additive. Processing additives used in the manufacture of Class D cement shall meet the requirements given in ASTM C465.

Further, at the option of the manufacturer, suitable set-modifying agents may be interground or blended during manufacture.

NOTE This product is intended for use under conditions of moderately high temperatures and pressures and is available in MSR and HSR grades.

4.1.1.7 Class G

This product is obtained by grinding clinker that consists of hydraulic calcium silicates and contains one or more forms of CaSO_4 as an interground additive. No additives other than CaSO_4 , water, or chemical additives as required for chromium (VI) reduction shall be interground or blended with the clinker during manufacture of Class G well cement, provided that such additives do not prevent the well cement from performing its intended purpose.

NOTE This product is intended for use as a basic well cement and is available in MSR and HSR grades.

4.1.1.8 Class H

This product is obtained by grinding clinker that consists of hydraulic calcium silicates and contains one or more forms of CaSO_4 as an interground additive. No additives other than CaSO_4 , water, or chemical additives as required for chromium (VI) reduction shall be interground or blended with the clinker during manufacture of Class H well cement, provided that such additives do not prevent the well cement from performing its intended purpose.

NOTE This product is intended for use as a basic well cement and is available in MSR and HSR grades.

4.1.1.9 Composite Well Cements

See Annex B for the specifications of composite well cements.

4.1.2 Chemical Requirements

Well cements shall conform to the respective chemical requirements of classes and grades given in Table 1. This specification is applicable to the testing of cements that conform to the chemical requirements of classes and grades given in Table 1.

Chemical analyses of well cements shall be carried out as specified in ASTM C114.

NOTE For the purposes of this provision, EN 196-2 is equivalent to ASTM C114.

Table 1—Chemical Requirements

	Cement Class					
	A	B	C	D	G	H
Ordinary grade (O)						
Magnesium oxide (MgO), maximum, percent	6.0	NA ^a	6.0	NA	NA	NA
Sulfur trioxide (SO ₃), maximum, percent ^b	3.5	NA	4.5	NA	NA	NA
Loss on ignition, maximum, percent	3.5 ^c	NA	3.5 ^c	NA	NA	NA
Insoluble residue, maximum, percent	1.5	NA	1.5	NA	NA	NA
Tricalcium aluminate (C ₃ A), maximum, percent ^e	NR ^d	NA	15	NA	NA	NA
Moderate sulfate-resistant grade (MSR)						
Magnesium oxide (MgO), maximum, percent	NA	6.0	6.0	6.0	6.0	6.0
Sulfur trioxide (SO ₃), maximum, percent ^b	NA	3.0	3.5	3.0	3.0	3.0
Loss on ignition, maximum, percent	NA	3.0	3.5 ^c	3.0	3.0	3.0
Insoluble residue, maximum, percent	NA	0.75	1.5	0.75	0.75	0.75
Tricalcium silicate (C ₃ S), maximum, percent ^e minimum, percent ^e	NA	NR	NR	NR	58	58
	NA	NR	NR	NR	48	48
Tricalcium aluminate (C ₃ A), maximum percent ^e	NA	8	8	8	8	8
Total alkali content, expressed as sodium oxide (Na ₂ O) equivalent, maximum, percent	NA	NR	NR	NR	0.75	0.75
High sulfate-resistant grade (HSR)						
Magnesium oxide (MgO), maximum, percent	NA	6.0	6.0	6.0	6.0	6.0
Sulfur trioxide (SO ₃), maximum, percent ^b	NA	3.0	3.5	3.0	3.0	3.0
Loss on ignition, maximum, percent	NA	3.0	3.5 ^c	3.0	3.0	3.0
Insoluble residue, maximum, percent	NA	0.75	1.5	0.75	0.75	0.75
Tricalcium silicate (C ₃ S), maximum, percent ^e minimum, percent ^e	NA	NR	NR	NR	65	65
	NA	NR	NR	NR	48	48
Tricalcium aluminate (C ₃ A), maximum, percent ^e	NA	3	3	3	3	3
Tetracalcium aluminoferrite (C ₄ AF) plus twice the tricalcium aluminate (C ₃ A), maximum, percent ^e	NA	24	24	24	24	24
Total alkali content expressed as sodium oxide (Na ₂ O) equivalent, maximum, percent	NA	NR	NR	NR	0.75	0.75

^a NA indicates "not applicable."

^b When the tricalcium aluminate content (expressed as C_3A) of the cement is 8 % or less, the maximum SO_3 content shall be 3 %, or 3.5 % for Class C cement.

^c Added mineral ingredients shall have a calcium carbonate content greater or equal than 75 %.

^d NR indicates "no requirement."

^e The expressing of chemical limitations by means of calculated assumed compounds does not necessarily mean that the oxides are actually or entirely present as such compounds. The compounds (in percent) are calculated according to the ratio of the mass percentages of aluminum oxide to ferric oxide (Al_2O_3 to Fe_2O_3), where w is the percentage mass fraction of the compound indicated in the subscript:

1) When $w_{Al_2O_3}/w_{Fe_2O_3}$ is greater than 0.64, the compounds shall be calculated as follows:

$$i) \quad C_3A = 2.65 w_{Al_2O_3} - 1.69 w_{Fe_2O_3}$$

$$ii) \quad C_3S = 4.07 w_{CaO} - 7.60 w_{SiO_2} - 6.72 w_{Al_2O_3} - 1.43 w_{Fe_2O_3} - 2.85 w_{SO_3}$$

$$iii) \quad C_4AF = 3.04 w_{Fe_2O_3}$$

2) When $w_{Al_2O_3}/w_{Fe_2O_3}$ is 0.64 or less, the C_3A content is zero, and the C_3S and C_4AF shall be calculated as follows:

$$i) \quad C_3S = 4.07 w_{CaO} - 7.60 w_{SiO_2} - 4.48 w_{Al_2O_3} - 2.86 w_{Fe_2O_3} - 2.85 w_{SO_3}$$

$$ii) \quad C_4AF = 3.04 w_{Fe_2O_3}$$

^f The sodium oxide equivalent, expressed as Na_2O equivalent, shall be calculated by the formula:

$$Na_2O \text{ equivalent} = 0.658 w_{K_2O} + w_{Na_2O}$$

4.1.3 Physical and Performance Requirements

Well cement shall conform to the respective physical and performance requirements specified in Table 2 and in Sections 6 through 10.

Table 2—Summary of Physical and Performance Requirements

Well Cement Class				A	B	C	D	G	H
Mix water , % mass fraction of cement (Table 4)				46	46	56	38	44	38
Fineness tests (alternative methods) (Section 6)									
Turbidimeter (specific surface, minimum, m ² /kg)				150	160	220	NR ^a	NR	NR
Air permeability (specific surface, minimum, m ² /kg)				280	280	400	NR	NR	NR
Free-fluid content , maximum, percent (Section 8)				NR	NR	NR	NR	5.9	5.9
Compressive Strength Test Curing time: 8 hr	Schedule Number Table 7	Final Curing Temperature °C (°F)	Curing Pressure MPa (lbf/in. ²)	Minimum Compressive Strength MPa (lbf/in. ²)					
(Section 9)	NA ^b	38 (100)	atmospheric	1.7 (250)	1.4 (200)	2.1 (300)	NR	2.1 (300)	2.1 (300)
(Section 9)	NA	60 (140)	atmospheric	NR	NR	NR	NR	10.3 (1500)	10.3 (1500)
(Section 9)	6S	110 (230)	20.7 (3000)	NR	NR	NR	3.4 (500)	NR	NR
Compressive Strength Test Curing time: 24 hr	Schedule Number Table 7	Final Curing Temperature °C (°F)	Curing Pressure MPa (lbf/in. ²)	Minimum Compressive Strength MPa (lbf/in. ²)					
(Section 9)	NA	38 (100)	atmospheric	12.4 (1800)	10.3 (1500)	13.8 (2000)	NR	NR	NR
(Section 9)	4S	77 (170)	20.7 (3000)	NR	NR	NR	6.9 (1000)	NR	NR
(Section 9)	6S	110 (230)	20.7 (3000)	NR	NR	NR	13.8 (2000)	NR	NR

Well Cement Class			A	B	C	D	G	H
Thickening-time Test	Specification Test Schedule Number Tables 9 through 11	Maximum Consistency (15 min to 30 min stirring period) B_c^c	Thickening Time (minimum/maximum) minutes					
(Section 10)	4	30	90/NR	90/NR	90/NR	90/NR	NR	NR
(Section 10)	5	30	NR	NR	NR	NR	90/120	90/120
(Section 10)	6	30	NR	NR	NR	100/NR	NR	NR
^a NR indicates "no requirement." ^b NA indicates "not applicable." ^c Bearden units of consistency, B_c , obtained on a pressurized consistometer as defined in Section 10 and calibrated in accordance with Annex C.								

4.2 Sampling Frequency, Timing of Tests, and Equipment

4.2.1 Sampling Frequency

4.2.1.1 Well Cement Classes C, D, G, and H

A sample for testing shall represent the product as produced. At the discretion of the manufacturer, a sample shall be taken by either of the following methods:

- a) over an interval of 24 h; or
- b) on a 1000-ton (maximum) production run.

4.2.1.2 Well Cement Classes A and B

A sample for testing shall represent the product as produced. At the discretion of the manufacturer, a sample shall be taken by either of the following methods:

- a) over a 14-day continuous production interval; or
- b) on a 25,000 ton (maximum) production run.

4.2.2 Time from Sampling to Testing

Each sample shall be tested for conformance to this specification. All tests shall be completed within seven working days after sampling.

4.2.3 Specified Equipment

Equipment used for testing well cements shall comply with Table 3. Dimensions shown in Figures 5 through 7 and Figures 10 through 14 are for the purposes of manufacturing the cement-specification test equipment. Dimensional recertification is not required, with the exception of key dimensions tagged "INSP," which shall be verified to judge wear (see Annex C).

Table 3—Specification Test Equipment for Well-Cement Manufacturers

Test or preparation	Well cement Classes	Section Reference	Required Equipment
Sampling	All	5	Apparatus as specified in ASTM C183 NOTE For the purposes of this provision, EN 196-7 is equivalent to ASTM C183.
Fineness	A, B, C	6	Turbidimeter and auxiliary equipment as specified in ASTM C115 or air permeability apparatus and auxiliary equipment as specified in ASTM C 204. NOTE For the purposes of this provision, EN 196-6 is equivalent to ASTM C204.
Slurry preparation	All	7	Apparatus as specified in 7.1
Free-fluid	G, H	8	Apparatus as specified in 8.1
Atmospheric pressure compressive strength	A, B, C, G, H	9	Apparatus as specified in 9.1
Pressure cured compressive strength	D	9	Apparatus as specified in 9.1
Thickening time	All	10	Pressurized consistometer specified in 10.1

4.2.4 Calibration

Equipment shall be calibrated in accordance with the requirements in Annex C.

5 Sampling Procedure

One or more of the procedures in accordance with ASTM C183 shall be used to secure a sample of well cement for specification testing purposes.

NOTE For the purposes of this provision, EN 196-7 is equivalent to ASTM C183.

6 Fineness Tests

6.1 Procedure

Tests for fineness of well cement shall be in accordance with either the procedure in ASTM C115 for the turbidimeter test or the procedure in ASTM C204 for the air permeability test that is at the discretion of the manufacturer.

NOTE For the purposes of this provision, EN 196-6 is equivalent to ASTM C204.

6.2 Requirements

Acceptance requirements for the fineness test are a minimum specific surface area (expressed in square meters per kilogram) as given in Table 2. Classes D, G, and H cements have no fineness requirement.

7 Preparation of Slurry for Free-fluid, Compressive Strength and Thickening-time Tests

7.1 Apparatus

7.1.1 General

Unless otherwise noted, all apparatuses shall be calibrated according to Annex C.

7.1.2 Electronic or Mechanical Balances

Balances shall have, at a minimum, a two-decimal-place precision reading and conform to requirements specified in Annex C.

7.1.3 Weight Sets

Weight sets include sets used daily for routine weighing and reference weight sets used for calibration. Weight sets shall conform to requirements specified in Annex C.

7.1.4 Sieves

An 850 μm wire cloth sieve (US sieve No. 20), shall be used for sieving cement prior to slurry preparation.

NOTE The sieve does not require verification.

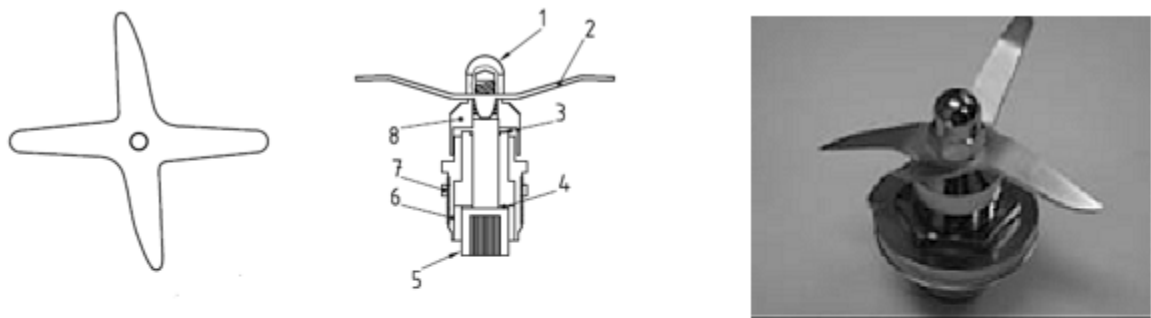
7.1.5 Mixing Devices

The mixing device for the preparation of well cement slurries shall be a 1 L (1 qt) size, bottom-drive, blade-type mixer, with a timing device able to measure both 15 s and 35 s. The mixing device shall be able to mix cement slurry at 4000 r/min $\pm$ 250 r/min rotational speed, and at 12,000 r/min $\pm$ 500 r/min rotational speed (see Annex C).

An example of a mixing device in common use is shown in Figure 1. The mixing-blade assembly and mixing container shall be constructed of durable, corrosion-resistant material. The mixing-blade assembly (see Figure 2) shall be constructed in such a manner that the blade can be removed for weighing and changing. The blade shall be mounted with its sharp edge on the leading-edge rotation. If the mixing device leaks at any time during the mixing procedure, the contents shall be discarded, the leak shall be repaired, and the procedure shall be restarted. According to Annex C, the mixing blade shall be weighed initially and replaced with an unused blade if observed blade deformation has occurred or after a blade has lost 10 % of its mass.



Figure 1—Example of a Typical Cement-Mixing Device



- Key**
- | | |
|--|---------------------|
| 1 cap nut | 5 socket head shaft |
| 2 blade (installed with tapered edge down) | 6 bearing holder |
| 3 O-ring | 7 hexagonal nut |
| 4 thrust washer | 8 bearing cap |

Figure 2—Common Blade Assembly

7.2 Procedure

7.2.1 Sieving

Prior to mixing, the cement shall be sieved using the method described according to ASTM C183 using a sieve defined in 7.1.4.

NOTE For the purposes of this provision, EN 196-7 is equivalent to ASTM C183.

7.2.2 Temperature of Water and Cement

The temperature of the mix water in the container within 60 s prior to mixing shall be $23\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ ($73\text{ }^{\circ}\text{F} \pm 2\text{ }^{\circ}\text{F}$), and the temperature of the cement within 60 s prior to mixing shall be $23\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ ($73\text{ }^{\circ}\text{F} \pm 2\text{ }^{\circ}\text{F}$).

7.2.3 Mix Water

Distilled or deionized water shall be used for testing. The mix water shall be weighed directly into a clean, dry mixing container. No water shall be added to compensate for evaporation, wetting, or other losses.

7.2.4 Mixing Quantities

The quantities of slurry component shown in Table 4 shall be used for testing. The use of the quantities of components shown in Table 4 results in mix-water percentages (based on the mass of dry cement) consistent with the water percentages shown in Table 2.

Table 4—Slurry Requirements

Components	Class A and B g	Class C g	Class D and H g	Class G g
Mix water	355 $\pm$ 0.5	383 $\pm$ 0.5	327 $\pm$ 0.5	349 $\pm$ 0.5
Cement	772 $\pm$ 0.5	684 $\pm$ 0.5	860 $\pm$ 0.5	792 $\pm$ 0.5

For composite well cement classes without specified mix-water percentages (see Annex B), the quantities of composite well cement and mix water shall be measured at $\pm 0.5\text{ g}$ based on a calculated slurry volume of 600 mL.

7.2.5 Mixing Cement and Water

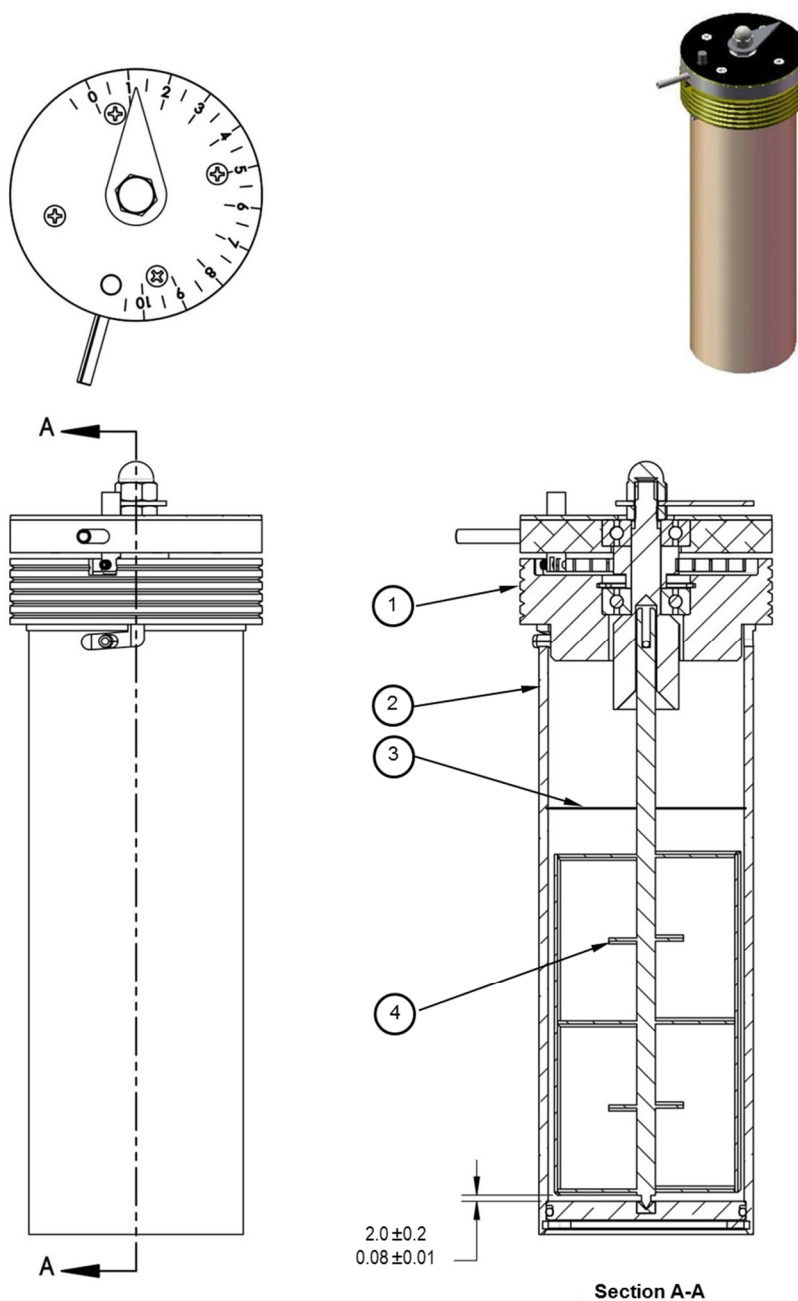
The mixing container with the required mass of mix water, as specified in Table 4, shall be placed on the mixer base, with the motor turned on and maintained at $4000\text{ r/min} \pm 250\text{ r/min}$ while the cement sample is added at a uniform rate for no more than 15 s. After 15 s at $4000\text{ r/min} \pm 250\text{ r/min}$, place the cover on the mixing container and continue mixing at $12,000\text{ r/min} \pm 500\text{ r/min}$ for $35\text{ s} \pm 1\text{ s}$.

8 Free-fluid Test (free-water)

8.1 Apparatus

8.1.1 Atmospheric Pressure Consistometer

The atmospheric pressure consistometer (see Figures 3 through 6) or the pressurized consistometer described in 10.1 (run at atmospheric pressure) shall be used for stirring and conditioning the cement slurry for the determination of free-fluid content. The atmospheric pressure consistometer consists of a rotating cylindrical slurry container, equipped with a fixed paddle assembly, in a temperature-controlled liquid bath. It shall be capable of maintaining the temperature of the bath and the slurry container rotating speed requirements as specified in Annex C. The paddle and all parts of the slurry container exposed to the slurry shall be constructed of corrosion-resistant materials.

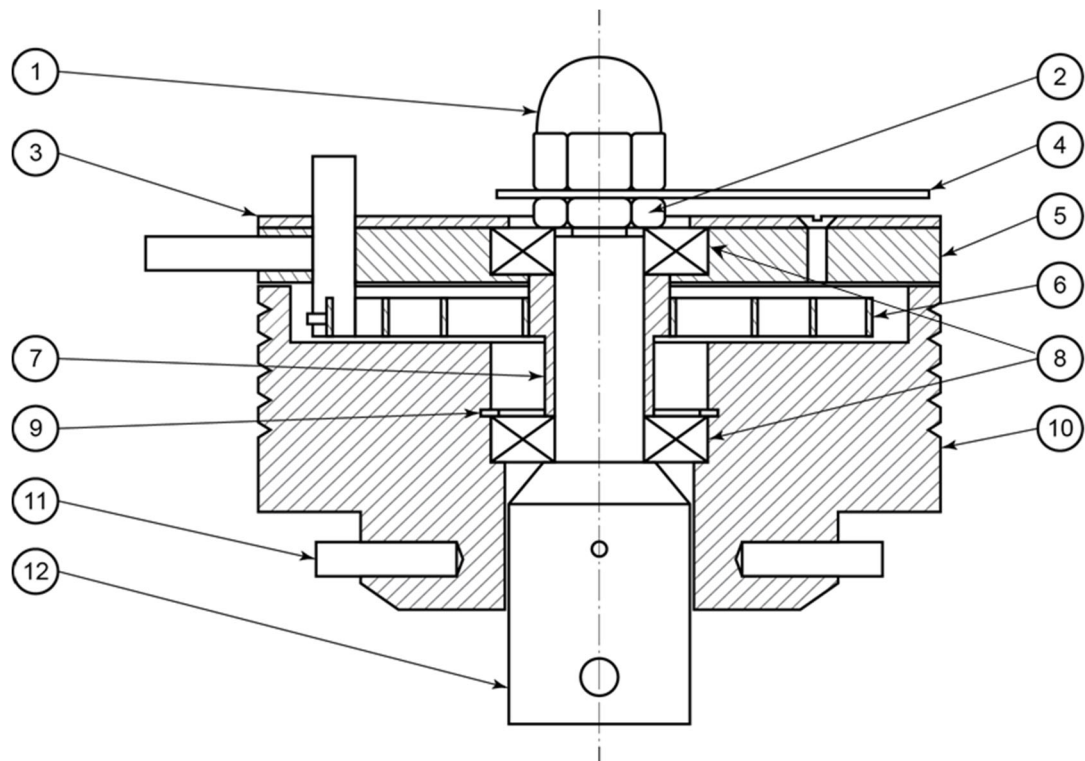


Key

- | | | | |
|---|---------------------------------|---|-----------------------------|
| 1 | lid (see Figure 4) | 3 | fill-level indicator groove |
| 2 | slurry container (see Figure 5) | 4 | paddle (see Figure 6) |

NOTE Dimensions are provided for manufacturing reference only and are in mm (in.) unless otherwise indicated.

Figure 3—Container Assembly for an Atmospheric Pressure Consistometer

**Key**

1	cap lock nut	7	collar
2	center lock reverse jam nut	8	bearing
3	dial	9	retaining ring
4	pointer	10	lid
5	dial and base assembly	11	roll pin
6	spring	12	shaft

Figure 4—Typical Lid and Mechanism for an Atmospheric Pressure Consistometer (see Figure 3)