Addendum 1
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Specification for Cements and Materials for Well Cementing

API SPECIFICATION 10A
TWENTY-SECOND EDITION, JANUARY 1, 1995

American Petroleum Institute

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Replace Section 6.1.4 with the following:

6.1.4 Mixing Devices

The mixing device for preparation of well cement slurries shall be a one quart size, bottom drive, blade type mixer.

Examples of mixing devices in common use are shown in Figure 1. The mixing blade and mixing container are to be constructed of durable corrosion-resistant material. The mixing assembly shall be constructed in such a manner that the blade can be removed for weighing and changing. The mixing blade shall be weighed prior to use and replaced with an unused blade when 10% weight loss has occurred. If water leakage occurs around the bearings, the entire blender blade assembly should be replaced.

Replace Section 7 with the following:

SECTION 7
FREE FLUID TEST (FREE WATER)

7.1 APPARATUS

7.1.1 Consistometer

The atmospheric pressure consistometer or the pressurized consistometer (run at atmospheric pressure) shall be used for stirring and conditioning the cement slurry for determination of free fluid content. The consistometer consists of a rotating cylindrical slurry container, equipped with an essentially stationary paddle assembly (see Note), in a temperature controlled liquid bath. The consistometer shall be capable of maintaining the temperature of the bath at 80°F, ± 3°F (27°C, ± 1.7°C) and of rotating the slurry container at a speed of 150 rpm, ± 15 rpm (2.5 rev/sec, ± 0.25 rev/sec) during the stirring and conditioning period for the slurry. The paddle and all parts of the slurry container exposed to the slurry shall be constructed of corrosion-resistant materials. See Figures 2, 3, 4, and 5.

Note: The paddle may be used to drive a "potentiometer" (see Figures 2 and 3) to measure slurry viscosity.

7.1.2 Scales

Scales shall meet the requirements of Section 6.1.1.

7.1.3 Test Flask

A 500 ml conical flask, such as Kimax® #26650-500, which conforms to ASTM E 1404 *1994 Standard Specification for Laboratory Glass Conical Flasks Type I, Class 2* or DIN 12385 shall be used (see Figure 12).

7.2 CALIBRATION

7.2.1 Temperature Measuring System

The temperature of the bath shall be measured by thermometer (glass or digital) and/or thermocouple with digital indicator which are accurate to ± 3°F (±1.7°C). Thermocouples shall be ASTM Classification "special" Type J. Thermocouples with digital indicators and thermometers shall be checked for accuracy against a certified thermometer, traceable to the reference of the national body responsible for standards of temperature measurement, no less frequent than monthly. Thermocouples with digital indicators and thermometers found outside the acceptable ± 3°F (1.7°C) range shall be corrected or replaced. See Appendix A, Calibration Procedures for Thermocouples, Temperature Measuring Systems, and Controllers.

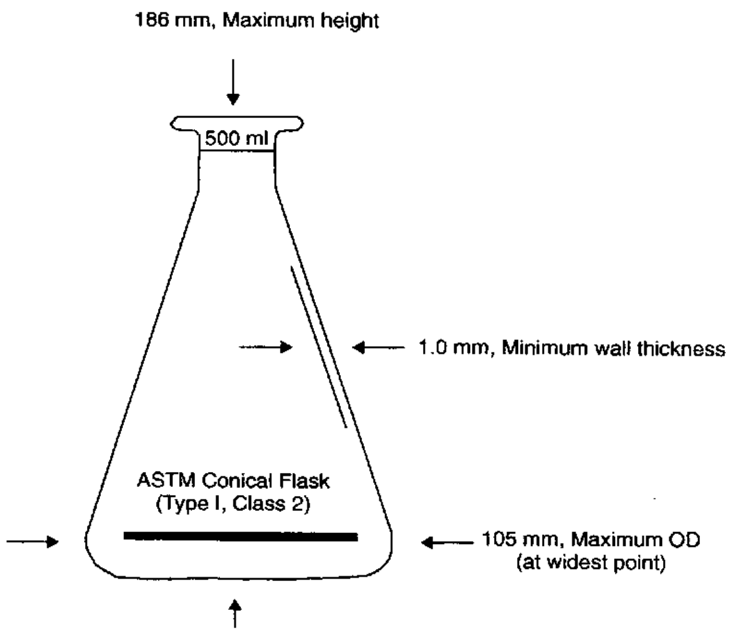

Figure 12—Test Flask

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7.2.2 Slurry Container Speed

The rotational speed shall be 150 rpm, ± 15 rpm (2.5 rev/sec, ± 0.25 rev/sec). The rotational speed of the slurry container shall be checked no less frequently than quarterly and corrected if found to be inaccurate.

7.2.3 Timer

The timer shall be accurate to within ± 30 sec/hr. It shall be checked for accuracy no less frequently than semi-annually and it shall be corrected or replaced if found to be inaccurate.

7.3 PROCEDURE

7.3.1 Prepare the slurry according to the procedure in Section 6.

7.3.2 Fill a clean and dry consistometer slurry container to the proper level.

7.3.3 Assemble the slurry container and associated parts, place them in the consistometer and start the motor according to the operating instructions of the manufacturer. The interval between the completion of mixing and the starting of the consistometer shall not exceed 1 minute.

7.3.4 Stir the slurry in the consistometer for a period of 20 minutes, ± 30 seconds. The bath temperature shall be maintained at 80°F, ± 3°F (27°C, ± 1.7°C) throughout the stirring period.

7.3.5 Transfer 790 grams, ± 5 grams of Class H slurry, or 760 grams, ± 5 grams of Class G slurry directly into the clean, dry 500 ml conical flask within 1 minute. Record the actual mass transferred. Seal the flask with a self-sealing film, such as Parafilm® or Saran Wrap®, to prevent evaporation.

7.3.6 Set the slurry-filled flask on a surface that is nominally level and vibration free. The air temperature to which the slurry-filled flask is exposed shall be 73°F ± 5°F (22.8°C ± 2.8°C). The temperature sensor for measuring air temperature shall meet the requirements of Section 7.2.1. The slurry-filled flask shall remain undisturbed for a period of 2 hours ± 5 minutes.

7.3.7 At the end of two hours, remove the supernatant fluid that has developed with a pipet or syringe. Measure the volume of supernatant fluid to an accuracy of ±0.1 ml and record it as ml Free Fluid.

7.3.8 Convert the ml Free Fluid to a percentage of starting slurry volume (~ 400 ml dependent on recorded initial mass) and express that value as % Free Fluid.

7.4 CALCULATION OF % FREE FLUID

Free Fluid shall be calculated with the following formula:

$$\%FF = (\text{ml } FF) \times (sg) \times \frac{(100)}{S_m}$$

where

$\% FF$ = free fluid content of slurry in percent,

ml FF = ml of free fluid (supernatant fluid) collected,

sg = specific gravity (g/cc) of slurry; 1.98 for Class H at 38% water; 1.90 for Class G at 44% water (if sg of base cement is other than 3.14, actual sg of slurry should be calculated and used),

S_m = initially recorded (starting) mass of slurry in grams.

7.4.1 Example Calculation of % Free Fluid

Initial recorded (starting) mass of Class H slurry = 791.7 g

Volume of free fluid (supernatant fluid) collected = 15.1 ml

sg = 1.98 g/cc (Class H)

% Free Fluid = 15.1 ml x (1.98 g/cc) x 100 / 791.7 g

% Free Fluid = 3.78

Note: cc and ml assumed to be equal for purposes of calculation; 1 ml = 1.000027 cc.

7.5 ACCEPTANCE REQUIREMENTS

The % Free Fluid for Class G and H cement shall not exceed 5.50%. Other cement classes have no free fluid requirements.

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FOREWORD

The bar notations identify parts of this standard that have been changed from the previous API edition.

This standard is under the jurisdiction of the API Committee on Standardization of Well Cements.

This standard shall become effective on the date printed on the cover but may be used voluntarily from the date of distribution.

Specification for Cements and Materials for Well Cementing

1 Scope

1.1 COVERAGE

This specification covers requirements for manufacturing eight classes of well cements. This includes chemical and physical requirements and physical testing procedures.

A well cement which has been manufactured and supplied according to this specification may be mixed and placed in the field using water ratios or additives at the user's discretion. It is not intended that manufacturing compliance with this specification be based on such field conditions.

1.2 CLASSES AND GRADES

Well cement shall be specified in the following Classes (A, B, C, D, E, F, G and H) and Grades (O, MSR and HSR).

Class A: The product obtained by grinding Portland cement clinker, consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulfate as an interground addition. At the option of the manufacturer, processing additions[1] may be used in the manufacture of the cement, provided such materials in the amounts used have been shown to meet the requirements of ASTM C 465. This product is intended for use when special properties are not required. Available only in ordinary (O) Grade (similar to ASTM C 150, Type I).

Class B: The product obtained by grinding Portland cement clinker, consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulfate as an interground addition. At the option of the manufacturer, processing additions[1] may be used in the manufacture of the cement, provided such materials in the amounts used have been shown to meet the requirements of ASTM C 465. This product is intended for use when conditions require moderate or high sulfate-resistance. Available in both moderate sulfate-resistant (MSR) and high sulfate-resistant (HSR) Grades (similar to ASTM C 150, Type II).

Class C: The product obtained by grinding Portland cement clinker, consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulfate as an interground addition. At the option of the manufacturer, processing additions[1] may be used in the manufacture of the cement, provided such materials in the amounts used have been shown to meet the requirements of ASTM C 465. This product is intended for use when conditions require high early strength. Available in ordinary (O), moderate sulfate-resistant (MSR) and high sulfate-resistant (HSR) Grades (similar to ASTM C 150, Type III).

Class D: The product obtained by grinding Portland cement clinker, consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulfate as an interground addition. At the option of the manufacturer, processing additions[1] may be used in the manufacture of the cement, provided such materials in the amounts used have been shown to meet the requirements of ASTM C 465. Further, at the option of the manufacturer, suitable set-modifying agents[1] may be interground or blended during manufacture. This product is intended for use under conditions of moderately high temperatures and pressures. Available in moderate sulfate-resistant (MSR) and high sulfate-resistant (HSR) Grades.

Class E: The product obtained by grinding Portland cement clinker, consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulfate as an interground addition. At the option of the manufacturer, processing additions[1] may be used in the manufacture of the cement, provided such materials in the amounts used have been shown to meet the requirements of ASTM C 465. Further, at the option of the manufacturer, suitable set-modifying agents[1] may be interground or blended during manufacture. This product is intended for use under conditions of high temperatures and pressures. Available in moderate sulfate-resistant (MSR) and high sulfate-resistant (HSR) Grades.

Class F: The product obtained by grinding Portland cement clinker, consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulfate as an interground addition. At the option of the manufacturer, processing additions[1] may be used in the manufacture of the cement, provided such materials in the amounts used have been shown to meet the requirements of ASTM C 465. Further, at the option of the manufacturer, suitable set-modifying agents[1] may be interground or blended during manufacture. This product is intended for use under conditions of extremely high temperatures and pressures. Available in moderate sulfate-resistant (MSR) and high sulfate-resistant (HSR) Grades.

Class G: The product obtained by grinding Portland cement clinker, consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulfate as an interground addition. No additions other than calcium sulfate or water, or both, shall be interground or blended with clinker during manufacture of Class G well cement. This product is intended for use as a basic well cement. Available in moderate sulfate-resistant (MSR) and high sulfate-resistant (HSR) Grades.

[1]A suitable processing addition or set-modifying agent shall not prevent a well cement from performing its intended functions.

Class H: The product obtained by grinding Portland cement clinker, consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulfate as an interground addition. No additions other than calcium sulfate or water, or both, shall be interground or blended with the clinker during manufacture of Class H well cement. This product is intended for use as a basic well cement. Available in moderate sulfate-resistant (MSR) and high sulfate-resistant (HSR) Grades.

2 Referenced Standards

This specification references other API and industry standards which are listed in Table 1. If a conflict arises between this specification and any of the referenced standards, the specification shall supersede.

3 Requirements

3.1 GENERAL REQUIREMENTS

Classes A, B, C, D, E and F covered by this specification are the products obtained by grinding Portland cement clinker and, if needed, calcium sulfate as an interground addition. When processing additions are used in the manufacture of the cement, such materials shall meet the requirements of ASTM C 465. Suitable set-modifying agents may be interground or blended during manufacture of Classes D, E and F.

Classes G and H are the products obtained by grinding Portland cement clinker, to which no additions other than calcium sulfate or water, or both, shall be interground or blended with clinker during manufacture.

Grades include ordinary (O), moderate sulfate resistant (MSR) and high sulfate-resistant (HSR).

3.1.1 Chemical Requirements

Well cements shall conform to the respective chemical requirements of classes and grades referenced in Table 2.

3.1.2 Physical and Performance Requirements

Well cement shall conform to the respective physical and performance requirements referenced in Table 3 and specified in Sections 5, 6, 7, 8 and 9.

3.1.3 Calibration

Equipment calibrated to the requirements contained in this specification are considered to be accurate if calibration is within the specified limits.

3.2 SAMPLING, TIMING OF TESTS AND EQUIPMENT

Well cement manufacturing under this specification shall comply with the following requirements.

3.2.1 Sampling Frequency

A sample (Classes C, D, E, F, G, H) for testing shall be taken, either method (1) on a 24-hour interval, or method (2) on a 1000 ton maximum production run. A sample (Classes A, B) for testing shall be taken, either method (1) on a 14-day interval, or method (2) on a 25,000 ton maximum production run. These samples shall represent the product as produced. At the choice of the manufacturer, either method (1) or method (2) may be used.

3.2.2 Time From Sampling to Testing

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

3.2.3 Specified Equipment

Equipment used for testing well cements shall comply with Table 4. Dimensions shown in Figures 4, 5, 9 and 10 are for cement specification test equipment manufacturing purposes. Dimensional recertification shall not be required.

4 Sampling

One or more of the procedures outlined in ASTM C 183 shall be used to secure a sample of well cement for specification testing purposes.

5 Fineness Tests

5.1 METHOD

Tests for fineness of well cement shall be made in accordance with either the testing procedure in ASTM C 115: *Standard Test Method for Fineness of Portland Cement by the Turbidimeter* for the turbidimeter test or the testing procedure in ASTM C204: *Standard Test Method for Fineness of Portland Cement* by Air Permeability Apparatus for the Air Permeability Test.

5.2 REQUIREMENTS

Acceptance requirements for the fineness test are a minimum specific surface area (m^2/kg) and are as follows:

Fineness Acceptance Requirements

Alternate Fineness Test Methods	Class A	Class B	Class C	Class D	Class E	Class F	Class G	Class H
Turbidimeter Test (m^2/kg, Minimum)	150	160	220	NR	NR	NR	NR	NR
Air Permeability Test (m^2/kg, Minimum)	280	280	400	NR	NR	NR	NR	NR

NR = No Requirement

Table 1—Referenced Standards

ASTM C 109, Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (1992)
ASTM C 114, Standard Test Methods for Chemical Analysis of Hydraulic Cement (1988)
ASTM C 115, Standard Test Methods for Fineness of Portland Cement by the Turbidimeter (1993)
ASTM C 150, Standard Specification for Portland Cement (1992)
ASTM C 177, Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus (1985)
ASTM C 183, Standard Practice for Sampling and the Amount of Testing of Hydraulic Cement (1988)
ASTM C 204, Standard Test Methods for Fineness of Portland Cement by Air Permeability (1992)
ASTM C 465, Standard Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements (1992)
ASTM C 670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials (1991)
API Manual of Petroleum Measurement Standards, Chapter 15 (Dec. 1980)
ASTM C 802, Standard Practice for Conducting an Inter-laboratory Test Program to Determine the Precision of Test Methods for Construction Materials (1987)
ASTM E 11, Standard Specification for Wire-Cloth Sieves for Testing Purposes (1987)
ASTM E 220, Standard Method for Calibration of Thermocouples by Comparison Techniques (1986)

Table 2—Chemical Requirements[1]

	Cement Class					
	A	B	C	D,E,F,	G	H
ORDINARY GRADE (O)						
Magnesium oxide (MgO), maximum, percent	6.0	NA	6.0	NA	NA	NA
Sulfur trioxide (SO_3), maximum, percent	3.5[2]	NA	4.5	NA	NA	NA
Loss on ignition, maximum, percent	3.0	NA	3.0	NA	NA	NA
Insoluble residue, maximum, percent	0.75	NA	0.75	NA	NA	NA
Tricalcium aluminate (C_3A), maximum, percent	NR	NA	15	NA	NA	NA
MODERATE SULFATE-RESIST GRADE (MSR)						
Magnesium oxide (MgO), maximum, percent	NA	6.0	6.0	6.0	6.0	6.0
Sulfur trioxide (SO_3), maximum, percent	NA	3.0	3.5	3.0	3.0	3.0
Loss on ignition, maximum, percent	NA	3.0	3.0	3.0	3.0	3.0
Insoluble residue, maximum, percent	NA	0.75	0.75	0.75	0.75	0.75
Tricalcium silicate (C_3S), maximum, percent	NA	NR	NR	NR	58[3]	58[3]
minimum, percent	NA	NR	NR	NR	48[3]	48[3]
Tricalcium aluminate (C_3A), maximum percent[3]	NA	8	8	8	8	8
Total alkali content expressed as sodium oxide (Na_2O) equivalent, maximum, percent	NA	NR	NR	NR	0.75[4]	0.75[4]
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	NA	3.0	3.5	3.0	3.0	3.0
Loss on ignition, maximum, percent	NA	3.0	3.0	3.0	3.0	3.0
Insoluble residue, maximum, percent	NA	0.75	0.75	0.75	0.75	0.75
Tricalcium silicate (C_3S) maximum, percent	NA	NR	NR	NR	65[3]	65[3]
minimum, percent	NA	NR	NR	NR	48[3]	48[3]
Tricalcium aluminate (C_3A), maximum, percent	NA	3[3]	3[3]	3[3]	3[3]	3[3]
Tetracalcium aluminoferrite (C_4AF) plus twice the tricalcium aluminate (C_3A), maximum, percent	NA	24[3]	24[3]	24[3]	24[3]	24[3]
Total alkali content expressed as sodium oxide (Na_2O) equivalent, maximum, percent	NA	NR	NR	NR	0.75[4]	0.75[4]

[1]Methods covering the chemical analyses of hydraulic cements are described in ASTM C114: *Standard Methods for Chemical Analysis of Hydraulic Cement.*
[2]When the tricalcium aluminate content (expressed as C_3A) of the cement is 8% or less, the maximum SO_3 content shall be 3%.
[3]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. When the ratio of the percentages of Al_2O_3 to Fe_2O_3 is 0.64 or less, the C_3A content is zero. When the Al_2O_3 to Fe_2O_3 ratio is greater than 0.64, the compounds shall be calculated as follows:

$C_3A = (2.65 \times \% Al_2O_3) - (1.69 \times \% Fe_2O_3)$

$C_4AF = 3.04 \times \% Fe_2O_3$

$C_3S = (4.07 \times \% CaO) - (7.60 \times \% SiO_2) - (6.72 \times \% Al_2O_3) - (1.43 \times \% Fe_2O_3) (2.85 \times \% SO_3)$

When the ratio of Al_2O_3 to Fe_2O_3 is less than 0.64, the C_3S shall be calculated as follows:

$C_3S = (4.07 \times \% CaO) - (7.60 \times \% SiO_2) - (4.48 \times \% A_2O_3) - (2.86 \times \% Fe_2C_3) - (2.85 \times \% SO_3)$

[4]The sodium oxide equivalent (expressed as Na_2O equivalent) shall be calculated by the formula:

$Na_2O \text{ equivalent} = (0.658 \times \% K_2O) + (\% Na_2O)$

NR = No Requirement
NA = Not Available

Table 3—Physical and Performance Requirements Summary (Parenthetical values are in metric units)

Well Cement Class	A	B	C	D	E	F	G	H
Mix Water, percent of the weight of cement (Table 6)	46	46	56	38	38	38	44	38
Fineness Tests (Alternative Methods) Section 5								
Turbidimeter (specified surface, minimum m^2/kg)	150	160	220	NR	NR	NR	NR	NR
Air Permeability (specified surface, minimum m^2/kg)	280	280	400	NR	NR	NR	NR	NR
(Free fluid content, maximum mL (Section 7)	NR	NR	NR	NR	NR	NR	3.5	3.5

Minimum Compressive Strength, psi (MPa)

Compressive Strength Test, Eight Hour Curing Time (Section 8)	Schedule Number, Table 7	Final Curing Temp, °F (°C)	Final Curing Pressure psi (kPa)	A	B	C	D	E	F	G	H
	NA	100 (38)	Atmos.	250 (1.7)	200 (1.4)	300 (2.1)	NR	NR	NR	300 (2.1)	300 (2.1)
	NA	140 (60)	Atmos.	NR	NR	NR	NR	NR	NR	1500 (10.3)	1500 (10.3)
	6S	230 (110)	3000 (20700)	NR	NR	NR	500 (3.5)	NR	NR	NR	NR
	8S	290 (143)	3000 (20700)	NR	NR	NR	NR	500 (3.5)	NR	NR	NR
	9S	320 (160)	3000 (20700)	NR	NR	NR	NR	NR	500 (3.5)	NR	NR

Minimum Compressive Strength, psi (MPa)

Compressive Strength Test, Twenty-Four Hour Curing Time (Section 8)	Schedule Number, Table 7	Final Curing Temp, °F (°C)	Final Curing Pressure psi (kPa)	A	B	C	D	E	F	G	H
	NA	100 (38)	Atmos.	1800 (12.4)	1500 (10.3)	2000 (13.8)	NR	NR	NR	NR	NR
	4S	170 (77)	3000 (20700)	NR	NR	NR	1000 (6.9)	1000 (6.9)	NR	NR	NR
	6S	230 (110)	3000 (20700)	NR	NR	NR	2000 (13.8)	NR	1000 (6.9)	NR	NR
	8S	290 (143)	3000 (20700)	NR	NR	NR	NR	2000 (13.8)	NR	NR	NR
	9S	320 (160)	3000 (20700)	NR	NR	NR	NR	NR	1000 (6.9)	NR	NR

Maximum/Minimum Thickening Time, minutes

Pressure Temperature Thickening Time Test (Section 9)	Specification Test Schedule Number Table 10	Maximum Consistency 15-30 Minute Stirring Period B_c[5]	A	B	C	D	E	F	G	H
	4	30	90 min	90 min	90 min	90 min	NR	NR	NR	NR
	5	30	NR	NR	NR	NR	NR	NR	90 min	90 min
	5	30	NR	NR	NR	NR	NR	NR	120 max	120 max
	6	30	NR	NR	NR	100 min	100 min	100 min	NR	NR
	8	30	NR	NR	NR	NR	154 min	NR	NR	NR
	9	30	NR	NR	NR	NR	NR	190 min	NR	NR

[5]Bearden units of consistency (B_c).

B_c—Bearden units of consistency obtained on a pressurized consistometer as defined in Section 9 of API Spec 10A and calibrated as per the same section.

NR = No Requirement

Table 4—Specification Test Equipment For Well Cement Manufacturers

Test or Preparation	Well Cement Classes	Spec 10A Reference	Required Equipment
Sampling	All	Sect. 4	Apparatus specified in ASTM C 183.
Fineness	A, B, C	Sect. 5	Turbidimeter and auxiliary equipment as specified in the latest edition of ASTM C 115: *Fineness of Portland Cement by the Turbidimeter*, or Air Permeability apparatus and auxiliary equipment as specified in the latest edition of ASTM C 204: Fineness of Portland Cement by Air Permeability Apparatus.
Slurry Preparation	All	Sect. 6	Apparatus specified in Par. 6.1.
Free Fluid	G, H	Sect. 7	Apparatus specified in Par. 7.1.
Atmospheric Pressure Compressive Strength	A, B, C, G, H	Sect. 8	Apparatus specified in Par. 8.1, except pressure vessel of Par. 8.1.3.2.
Pressure Cured Compressive Strength	D, E, F	Sect. 8	Apparatus specified in Par. 8.1.
Thickening Time	All	Sect. 9	Pressurized consistometer specified in Par. 9.1

Either of the two fineness test methods may be used at the option of the manufacturer to meet the fineness test requirements. Cement Classes D, E, F, G and H have no fineness requirement.

6 Preparation Of Slurry For Free Fluid, Compressive Strength And Thickening Time Tests

6.1 APPARATUS

6.1.1 Scales

The indicated load on scales shall be accurate within 0.1 percent of the indicated load.

6.1.2 Weights

Weights shall be accurate within the tolerance shown in Table 5. On beam-type scales where the weights are on the beam, the indicated weights shall conform to the requirements given in Par. 6.1.1.

Table 5—Permissible Variation In Weights

Weight, Grams	Variation, Plus or Minus, Grams
1000	0.50
500	0.35
300	0.30
200	0.20
100	0.15
50	0.10

6.1.3 Sieves

An 850 micrometer (No. 20) wire cloth sieve, meeting the requirements given in ASTM E 11 shall be used for sieving cement prior to slurry preparation.

6.1.4 Mixing Devices

The mixing device for preparation of well cement slurries shall be a one quart size, bottom drive, blade type mixer.

Examples of mixing devices in common use are shown in Figure 1. The mixing blade and the mixing container are usually constructed of corrosion-resistant material. It is good practice to replace a blade with an unused blade when 10 percent weight loss has occurred.

6.2 PROCEDURE

6.2.1 Sieving

Prior to mixing, the cement shall be sieved as described in ASTM C 183.

6.2.2 Temperature of Water and Cement

The temperature of the mix water in the container within 60 seconds prior to mixing shall be 73 ±2°F (22.8 ±1.1°C) and that of the cement within 60 seconds prior to mixing shall be 73 ±2°F (22.8 ±1.1°C).

6.2.3 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, etc.

6.2.4 Mixing Quantities

Slurry component quantities shown in Table 6 shall be used for testing.

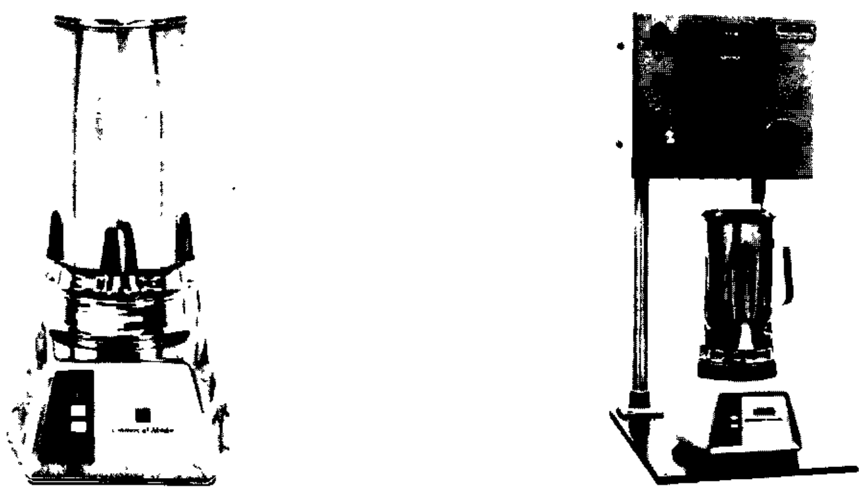


Figure 1—Examples Of Typical Cement Mixing Devices

Table 6—Slurry Requirements[1]
API Class of Cement

Components	A & B Grams	C Grams	D, E F, H Grams	G Grams
Mix Water	355 ±0.5	383 ±0.5	327 ±0.5	349 ±0.5
Cement	772 ±0.5	684 ±0.5	860 ±0.5	792 ±0.5

[1]The use of the quantities of components as shown in this Table will result in mix water percentages (based on the weight of dry cement) consistent with water percentages as shown in Table 3.

6.2.5 Mixing Cement and Water

The mixing container with the required weight of mix water, as specified in Table 6, shall be placed on the mixer base, the motor turned on and maintained at 4000 ± 200 rpm (66.7 ±3.3 rev/sec) while the cement sample is added at a uniform rate in not more than 15 seconds. After all of the cement has been added to the mix water, the cover shall be placed on the mixing container and mixing shall be continued at 12,000 ±500 rpm (200 ±8.3 rev/sec) for 35 ±1 seconds.

7 Free Fluid Test (Free Water)

7.1 APPARATUS

The atmospheric pressure consistometer or the pressurized consistometer (run at atmospheric pressure) shall be used to process the slurry for the free fluid test.

7.1.1 CONSISTOMETERS

7.1.1.1 Pressurized Consistometer

The pressurized consistometer is described in Section 9 and illustrated in Fig. 7, 8, and 9 herein.

7.1.1.2 Atmospheric Pressure Consistometer

The apparatus consists of a rotating cylindrical slurry container equipped with a stationary paddle assembly, in a temperature controlled bath. The paddle and all parts of the slurry container exposed to the slurry are usually constructed of corrosion-resistant materials. See Fig. 2, 3, 4 and 5.

7.1.2 Graduated Glass Cylinders

A 250 mL graduated glass cylinder shall be used. The 0-250 mL graduated portion of the cylinder shall be no less than 232 mm nor more than 250 mm in length, graduated in 2 ml increments or less.

7.2 CALIBRATION

The temperature sensor and controller shall be calibrated to an accuracy of ±3°F (±1.7°C). Calibration shall be no less frequent than monthly and shall be performed according to the procedure described in Appendix A, or according to written procedures that meet or exceed the requirements of Appendix A.

7.2.1 Temperature Measuring System

Temperature for specification testing shall be determined by use of an ASTM classification "special" Type J thermocouple. Calibration of the temperature measuring system will be no less frequent than monthly, and shall be performed according to the procedure described in Appendix A, or in accordance with manufacturer's written procedures which meet or exceed the requirements of Appendix A.

7.2.2 Temperature Controller

Calibration shall be no less frequent than monthly, and shall be performed according to the procedure described in Appendix A.

7.2.3 Motor Speed

Rotation of the slurry container shall be 150 ±15 rpm (2.5 ±0.25 rev/sec) and shall be checked no less frequently than quarterly.

7.2.4 Timer

Timers shall be checked for accuracy semiannually. They must be accurate within ±30 sec/hr.

7.3 PREPARATION OF APPARATUS

Surfaces which come in contact with the cement slurry should be clean.

7.4 PROCEDURE

7.4.1 Prepare the slurry according to the procedure in Section 6 and pour it into the consistometer slurry container. On atmospheric consistometers, fill to the fill indicating groove shown in Figure 3. On pressurized consistometers, fill according to Par. 9.3.2.

7.4.2 Assemble the slurry container and associated parts, place them in the consistometer and start the motor, according to the operating instructions of the manufacturer. The interval between the completion of mixing and the starting of the apparatus shall not exceed 1 min.

7.4.3 Stir to condition the slurry at 80 ±2°F (27 ±1.1°C) for a period of 20 minutes ±30 seconds.

7.4.4 Transfer essentially all the slurry from the consistometer slurry container to the mixer and begin remixing within 30 seconds of the end of conditioning. Care shall be taken to ensure that any solids which may have separated during conditioning are transferred.

7.4.5 Remix the slurry for an additional 35 ±2 seconds at 12,000 ±500 rpm (200 ±8.3 rev/sec) in the mixing device.

7.4.6 Transfer the slurry in less than 20 seconds to the 250 mL +0, -2 mL line of a clean, dry 250 mL graduated cylinder, then seal it to prevent evaporation.

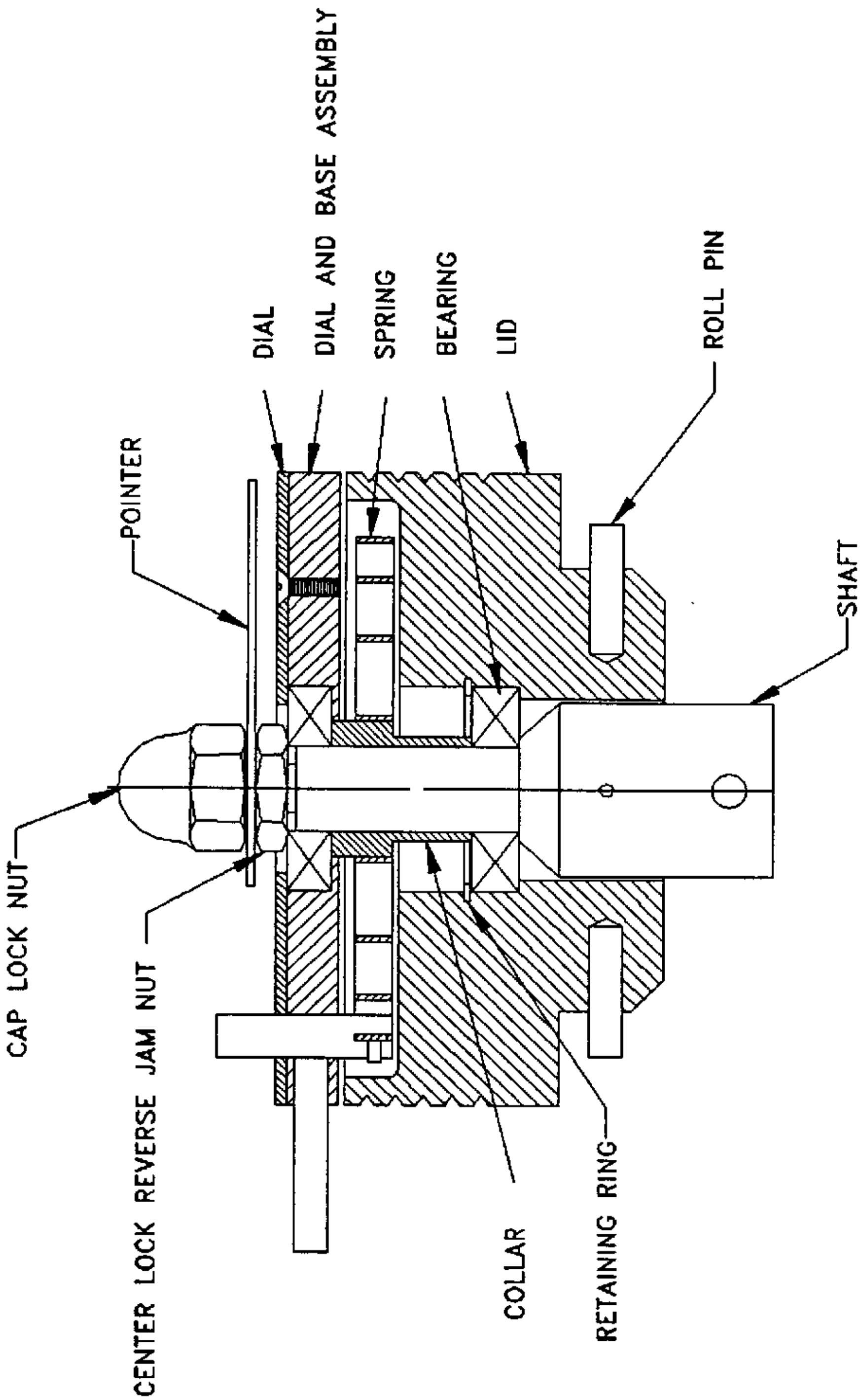


Figure 2—Typical Potentiometer Mechanism for Atmospheric Pressure Consistometer

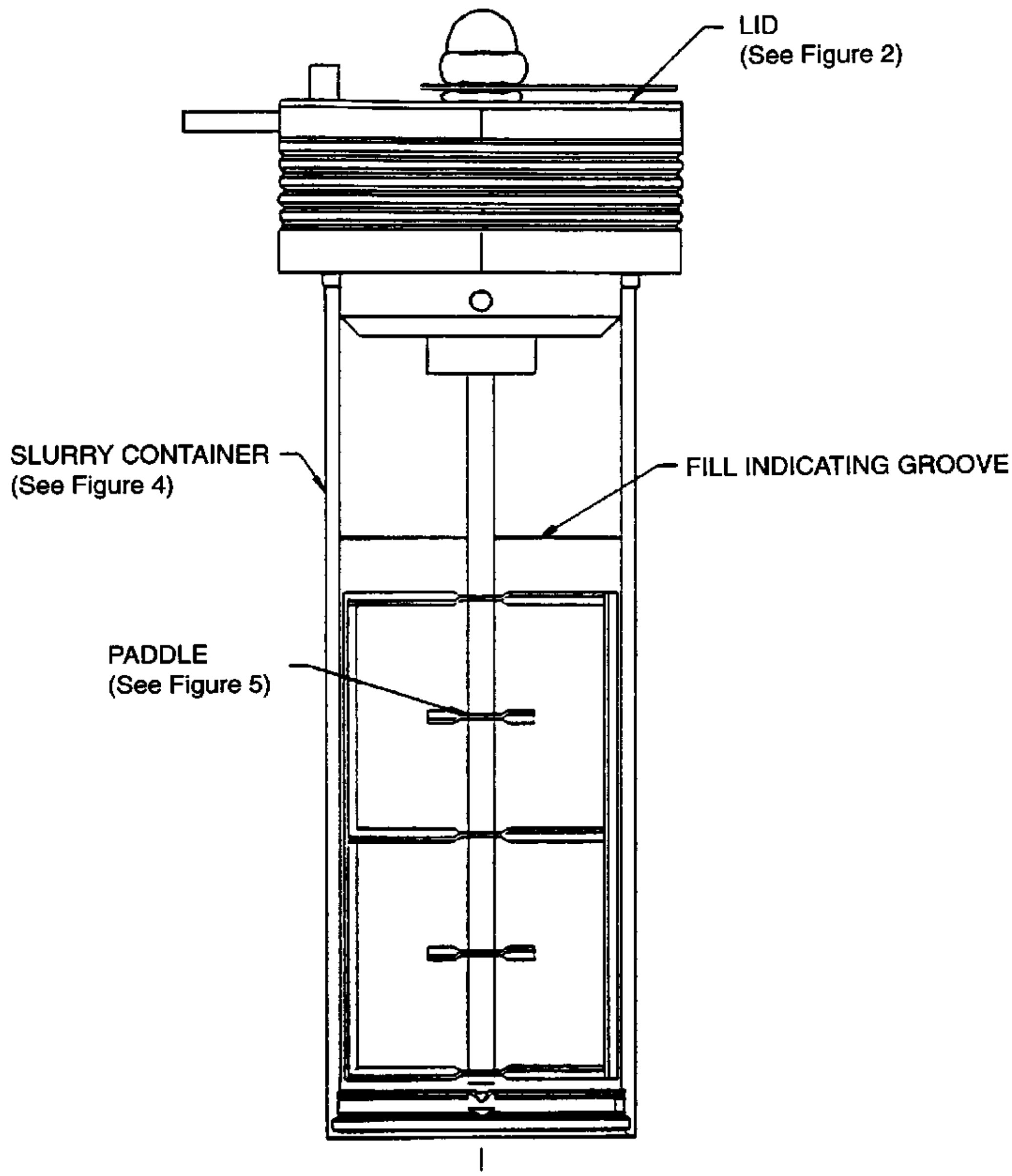
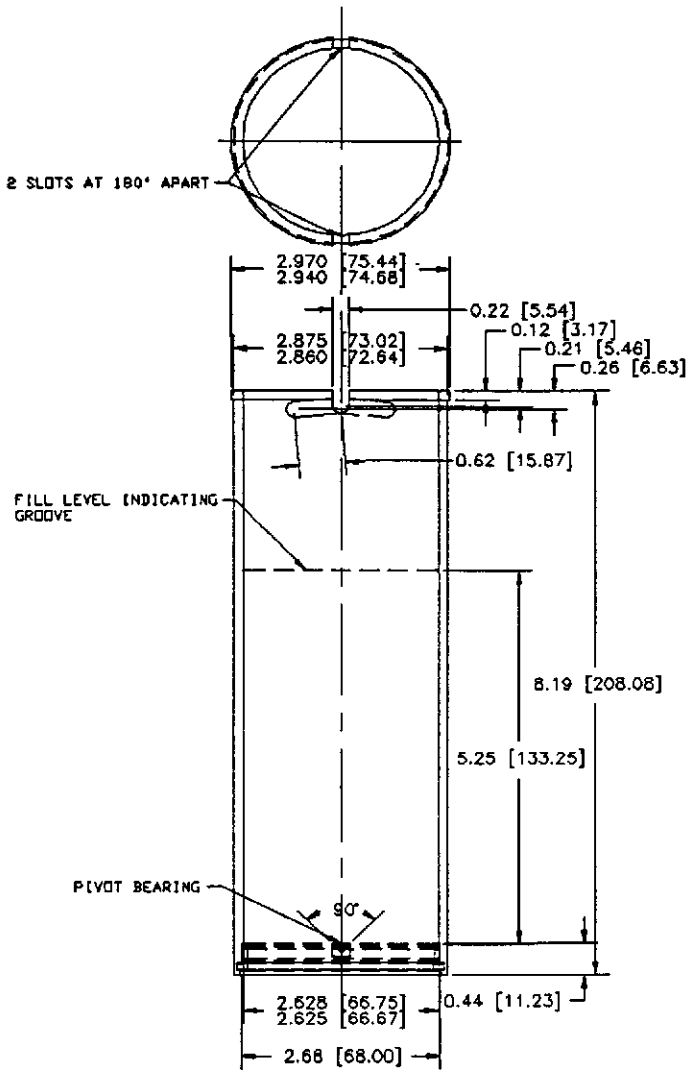
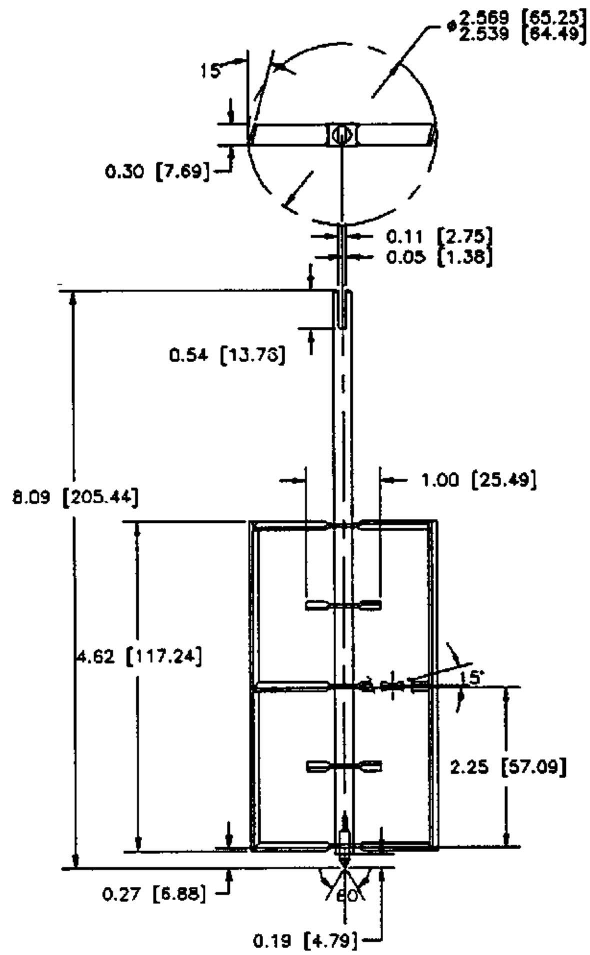


Figure 3—Container Assembly Typical Atmospheric Pressure Consistometer



UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES [MM]		
TOLERANCES ARE:		
.XX [.X]	± .010	[.25]
.XXX [.XX]	± .005	[.13]
ANGLES	± 1°	

Figure 4—Container Typical Atmospheric Pressure Consistometer



NOTES:

1. PADDLES: TYPE 302 STAINLESS .04" X .313" (1.0mm X 7.9 mm) COLD-ROLLED STRIP.

2. SHAFT: TYPE 416 0.25" X 8.313" (6.4mm X 211.1mm) ANNEALED AND GROUND

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES [MM]		
TOLERANCES ARE:		
.XX [.X]	± .010	[.25]
.XXX [.XX]	± .005	[.13]
ANGLES	± 1°	

Figure 5—Paddle Typical Atmospheric Pressure Consistometer

7.4.7 Set the cylinder perpendicular on a nominally level and essentially vibration free surface. The temperature to which the graduated cylinder is exposed shall be 73 ±2°F (22.8 ±1.1°C).

7.4.8 Remove and measure to an accuracy of ±0.1 mL the supernatant fluid developed after standing quiescent for 2 hours ±5 minutes. Document the volume in milliliters and designate it the Free Fluid.

7.5 REQUIREMENTS

Classes G and H cements shall not exceed 3.5 mL of free fluid. Other cement classes have no free fluid requirements.

8 Compressive Strength Tests

8.1 APPARATUS

8.1.1 Two Inch Cube Molds and Compressive Strength-Testing Machine

Molds and testing machine for compressive strength tests shall conform to the requirements in ASTM C 109, except that the molds can be separable into more than two parts. The molds shall be checked for tolerances and the testing machine shall be calibrated within ±1% of the load range to be measured at least once every two years.

8.1.2 Cube Mold Base and Cover Plates

Generally, plate glass, brass or stainless steel plates having a minimum thickness of 1/4 inch (6 mm) are used. Cover plates may be grooved on the surface contacting the top of the cement.

8.1.3 Water Curing Bath

A curing bath or tank having dimensions suitable for the complete immersion of a compressive strength mold(s) in water and maintainable within ±3°F (±1.7°C) of the prescribed test temperatures shall be employed. The two types of water curing baths are:

8.1.3.1 Atmospheric Pressure

An atmospheric pressure vessel for curing specimens at temperatures of 150°F (65.6°C) or less shall have an agitator or circulating system.

8.1.3.2 Pressurized

A pressure vessel suitable for curing specimens at temperatures up to and including 320°F (160°C) and at pressure that can be controlled at 3000 ±50 psi (20,700 ±345 kPa) shall be used. The vessel shall be capable of fulfilling the appropriate specification schedule (Table 7).

8.1.4 Cooling Bath

The cooling bath dimensions shall be such that the specimen to be cooled from the curing temperature can be completely submerged in water maintained at 80 ±5°F (26.7 ±2.8°C).

8.1.5 Temperature Measuring System

The temperature measuring system shall be calibrated to an accuracy of ±3°F (±1.7°C). Calibration shall be no less frequent than monthly. The procedure described in Appendix A is commonly used. Two commonly used temperature measuring systems are:

8.1.5.1 Thermometer

A thermometer with a range including 70° to 180°F (21.1° to 82.2°C) with minimum scale divisions not exceeding 2°F (or 1°C) may be used.

8.1.5.2 Thermocouple

A thermocouple system with the appropriate range may be used.

8.1.6 Puddling Rod

Typically, a corrosion-resistant puddling rod nominally 1/4 inch (6 mm) in diameter is used.

8.1.7 Sealant

Commonly, a sealant having (1) properties to prevent leakage, and (2) water resistance, when subjected to curing temperatures and pressures specified in Table 8, is used to seal specimen mold exterior contact points.

8.2 PROCEDURE

8.2.1 Preparation of Molds

The molds and the contact surfaces of the plates shall be clean and dry. The assembled molds shall be water tight. The interior faces of the molds and the contact surfaces of the plates are commonly lightly coated with release agent, but may be clean and dry.

8.2.2 Preparation and Placement of Slurry

8.2.2.1 Slurry

The cement slurry shall be prepared in accordance with Section 6.

8.2.2.2 Placing Slurry in Molds

The slurry shall be placed in the prepared molds in a layer approximately one-half of the mold depth and puddled, in an evenly-distributed pattern, 27 times per specimen with a puddling rod. The slurry shall be placed in all the specimen compartments before commencing the puddling operation. After puddling the layer, the remaining slurry shall be stirred, by hand, using a puddling rod or spatula to minimize segregation, the molds filled to overflowing, and puddled the same as for the first layer. After puddling, the excess slurry shall be struck off once even with the top of the mold using a straightedge. Specimens in molds which leak shall be discarded. A clean dry cover plate shall be placed on top of the mold. For one test determination, not less than three specimens shall be used.

8.2.2.3 Elapsed Time From Mixing to Placement in the Curing Vessel

The specimens shall be placed in the curing vessel, temperature and/or pressure applied according to the appropriate curing schedule, at 5 minutes ±15 seconds after the end of mixing.

8.2.3 Curing

8.2.3.1 Curing Periods

The curing period is the elapsed time from subjecting the specimens to the specified temperature in the curing vessel to the time when the specimen is tested for strength. The testing of the strength of the specimen shall be at the appropriate time as specified in Table 8.

For specimens cured at atmospheric pressure, the curing period starts when specimens are initially placed in the curing bath preheated to the test temperature.

For specimens cured at pressures above atmospheric, the curing period starts with the initial application of pressure and temperature.

8.2.3.2 Curing Temperature and Pressure

Curing temperature and pressure shall be as specified in Table 8 for the appropriate class of cement. For atmospheric pressure tests, the specimens are placed in the water bath, preheated to the final curing temperature. For pressure greater than atmospheric, the specimens shall be placed in the pressure vessel in water at 80 ±5°F (26.7 ±2.8°C).

8.2.3.3 Specimen Cooling

Specimens cured at 140°F (60°C) and below shall be removed from the curing bath 45 ±5 minutes before the time at which they are to be tested, removed from their molds, and placed in a water bath maintained at 80 ±5°F (26.7 ±2.8°C) for 40 ±5 minutes. For specimens cured at temperatures equal to or greater than 170°F (76.7°C), the maximum scheduled temperature and pressure shall be maintained as specified in Table 8 until 1 hour and 45 ±5 minutes prior to the time at which the specimens are to be tested, at which time heating shall be discontinued. During the next 60 ±5 minutes, the temperature shall be decreased to 170°F (76.7 °C), or less, without reduction of the pressure other than that caused by the reduction in temperature. At 45 ±5 minutes prior to the time at which the specimens are to be tested, the pressure then remaining shall be released and the specimens removed from the molds, transferred to a water bath, and maintained at 80 ±5°F (26.7 ±2.8°C) for 35 ±5 minutes.

8.2.3.4 Specimen Acceptance

Cube specimens that are damaged shall be discarded prior to testing. If less than two specimens are left for determining the compressive strength at any given period, a retest shall be made.

8.3 SPECIMEN TESTING

Cube specimens shall be tested according to the following procedure which is derived from ASTM C 109.

8.3.1 Remove specimen from the water bath

Wipe each specimen to remove any loose material from the faces that will be in contact with the bearing blocks of the testing machine.

8.3.2 Apply the load to specimen faces that were in contact with the plane surfaces of the mold. Place the specimen in the testing machine below the upper bearing block. Prior to the testing of each cube, it shall be ascertained that the spherically seated block is free to tilt. Use no cushioning or bedding materials. Appropriate safety and handling procedures shall be employed in testing the specimen.

8.3.2.1 The rate of loading shall be 4000 ±400 psi (16,000 ±1600 lbf) (71.7 ±7.2 kN) per minute for specimens expected to have greater than 500 psi strength. For specimens expected to have less than 500 psi (3.5 MPa) strength, a 1000 ±100 psi (4000 ±400 lbf) (17.9 ±1.8 kN) per minute rate shall be used. Make no adjustment in the controls of the testing machine while a specimen is yielding before failure.

8.3.2.2 The compressive strength shall be calculated by dividing the maximum load in lbf by cross-sectional area in square inches. The dimensions of the test faces shall be measured to ±1/16 inch (1.6 mm) for calculation of the cross-sectional area.

8.4 COMPRESSIVE STRENGTH ACCEPTANCE CRITERIA

The compressive strength of all acceptance test specimens made from the same sample and tested at the same period shall be recorded and averaged to the nearest 10 psi (69 kPa). At least two-thirds of the original individual specimens and the average of all the specimens tested must meet or exceed the minimum compressive strength specified in Table 8. If less than two strength values are left for determining the compressive strength at any given period, a retest shall be made.

Table 7—Specification Schedules for Pressurized Curing Compressive Strength Specimens

Schedule Number	Final Curing Pressure[1] psi (kPa)	Elapsed Time From First Application of Heat and Pressure, Hours: Minutes (±2 minutes) — TEMPERATURE, °F (°C)										
		0:00	0:30	0:45	1:00	1:15	1:30	2:00	2:30	3:00	3:30	4:00
4S	3000 (20700)	80 (26.7)	116 (47)	120 (49)	124 (51)	128 (53)	131 (55)	139 (59)	147 (64)	155 (68)	162 (72)	170 (77)
6S	3000 (20700)	80 (26.7)	133 (56)	148 (64)	154 (68)	161 (72)	167 (75)	180 (82)	192 (89)	205 (96)	218 (103)	230 (110)
8S	3000 (20700)	80 (26.7)	153 (67)	189 (87)	210 (99)	216 (103)	223 (106)	236 (113)	250 (121)	263 (128)	277 (136)	290 (143)
9S	3000 (20700)	80 (26.7)	164 (73)	206 (97)	248 (120)	254 (123)	260 (127)	272 (133)	284 (140)	296 (147)	308 (153)	320 (160)

Table 8—Compressive Strength Specification Requirements

Cement Class	Schedule No.	Final Curing Temp.[2] °F	°C	Final Curing Pressure[1] psi	kPa	Minimum Compressive Strength at Indicated Curing Period: 8-Hr. ±15 min. psi	MPa	24-Hr. ±15 min. psi	MPa
A	—	100	38	Atmos.		250	1.7	1800	12.4
B	—	100	38	Atmos.		200	1.4	1500	10.3
C	—	100	38	Atmos.		300	2.1	2000	13.8
D	4S	170	77	3000	20700	NR	NR	1000	6.9
	6S	230	110	3000	20700	500	3.4	2000	13.8
E	4S	170	77	3000	20700	NR	NR	1000	6.9
	8S	290	143	3000	20700	500	3.4	2000	13.8
F	6S	230	110	3000	20700	NR	NR	1000	6.9
	9S	320	160	3000	20700	500	3.4	1000	6.9
G, H	—	100	38	Atmos.		300	2.1	NR	NR
	—	140	60	Atmos.		1500	10.3	NR	NR

[1]The test pressure shall be applied as soon as specimens are placed in the pressure vessel and maintained at the given pressure within the following limits for the duration of the curing period: schedule 4S through 9S—3000 ±500 psi (20700 ±3400 kPa).
[2]Curing temperature shall be maintained ±3°F (±1.7°C).
NR = No Requirement

9 Thickening Time Tests

9.1 APPARATUS

A pressurized consistometer shall be used. This apparatus shall consist of a rotating cylindrical slurry container as shown in Figure 9, equipped with a stationary paddle assembly, as shown in Figure 10, all enclosed in a pressure vessel capable of withstanding the pressures and temperatures described in Table 10. The space between the slurry container and the walls of the pressure vessel shall be completely filled with a hydrocarbon oil. The selected oil shall have the following physical properties:

Viscosity	=	49-350 SSU @ 100°F (7-75 cSt)
Specific Heat	=	0.5-0.58 Btu/lb•°F [2.1-2.4 kJ/(kg•K)]
Thermal Conductivity	=	0.0685-0.0770 Btu/ (h•ft²•°F/ft) [0.119-0.133 W/(m•K)]
Specific Gravity	=	0.85-0.91

A heating system capable of raising the temperature of this oil bath at the rate of at least 5°F (2.8°C) per min is required. Temperature measuring systems shall be provided for determining the temperature of the oil bath and also that of the slurry[1]. The slurry container is rotated at a speed of 150 ±15 rpm (2.5 ±0.25 rev/sec). The consistency of the slurry (as defined in Par. 9.2.1) shall be measured. The paddle and all parts of the slurry container exposed to the slurry shall be constructed as illustrated in Figures 9 and 10.

9.2 CALIBRATION

Measurement of the thickening time of a cement slurry requires calibration and maintenance of operating systems of the pressurized consistometer including consistency measurement, temperature measuring systems, temperature controllers, motor speed, timer and gauges.

[1]See Appendix A, Calibration Procedures for Thermocouples and Temperature Measuring Systems.

9.2.1 Consistency

Consistency of a cement slurry is expressed in Bearden units of consistency (B_c). This value shall be determined by a potentiometer mechanism and voltage measurement circuit that shall be calibrated within one month prior to use, and whenever the calibration spring, resistor or contact arm is adjusted or replaced. One of the following methods shall be used.

9.2.1.1 A weight loaded device (see Fig. 6 for typical potentiometer calibrating device) to produce a series of torque equivalent values for consistency shall be used for calibration. The calibrated torque equivalent values are defined by the following equation:

$$T = 78.2 + 20.02\, B_c$$

Where:

T = Torque in g•cm

B_c = Bearden units of consistency.

Weights are used to apply torque to the potentiometer spring, using the radius of the potentiometer frame as a lever arm. As weight is added, the spring is deflected and resulting DC voltage and/or B_c increases[2]. See Table 9.

9.2.1.2 Calibrating the potentiometer mechanism shall be by the use of calibration oil, the viscosity-temperature relationship of which is known over a range of 5 to 100 Bearden units of consistency. (The calibration oil shall be discarded after use.)

9.2.2 Temperature Measuring System

The temperature measuring system shall be calibrated to an accuracy of ±3°F (±1.7°C). Calibration shall be no less frequent than monthly. The procedure described in Appendix A is commonly used.

9.2.3 Motor Speed

Rotation of the slurry container shall be 150 ±15 rpm (2.5 ±0.25 rev/sec) and shall be checked within 3 months prior to use.

9.2.4 Timer

Timers must be accurate within ±30 sec/hr and shall be checked within 6 months prior to use.

9.2.5 Pressure Measuring System

Calibration shall be conducted annually against a deadweight tester or master gauge to an accuracy of 0.25% of full range, at a minimum of 25%, 50% and 75% of full scale.

9.3 PROCEDURE

9.3.1 Operating Instructions

Detailed operating instructions developed by the operator or furnished by the equipment manufacturer, are applicable under this method and shall be followed, provided they conform to the specifications contained herein. In case of conflict, this specification shall supersede.

9.3.2 Filling of Slurry Container

9.3.2.1 The slurry (prepared according to Sect. 6) shall be poured into the inverted slurry container[3].

9.3.2.2 When the slurry container is full, strike the outside of the container to remove entrapped air.

9.3.2.3 The slurry container base shall then be secured in place.

9.3.2.4 The center plug (pivot bearing) shall then be secured into the container base.

9.3.3 Initiation of Test

The slurry container shall be placed on the drive table in the pressure vessel, rotation of the slurry container started, the potentiometer mechanism placed so as to engage the shaft drive bar and filling the vessel with oil begun. Next, the head assembly of the pressure vessel shall be securely closed, the slurry temperature sensing device inserted, and its threads partially engaged. After the pressure vessel is completely filled with oil, tighten the threads of the temperature sensing device. The apparatus shall be placed in operation 5 min ±15 sec after the cessation of mixing.

9.3.4 Temperature[4] and Pressure Control

During the test period, the temperature and pressure of the cement slurry in the slurry container shall be increased in accordance with the appropriate specification schedule given in Table 10. Temperature of the cement slurry for specification testing shall be determined by use of an ASTM classification "special" Type J thermocouple located in the center of the sample container.

9.4 THICKENING TIME AND CONSISTENCY

The elapsed time between the initial application of pressure and temperature to the pressurized consistometer and the time at which a consistency of 100 B_c is reached, shall be recorded as the thickening time for the test. The maximum consistency during the 15-30 minute stirring period shall be reported.

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[2]See manufacturer instruction manual for procedure.

[3]Slurry segregation may occur during the filling operation. This may be reduced by stirring the slurry in the mixing container with a spatula while pouring. Segregation will be less of a problem if the time from cessation of mixing to completing the filling operation is kept to a minimum.

[4]See Appendix A, API Spec 10A for a Calibration Procedure for Thermocouples and Temperature Indicators.

9.5 SPECIFICATION ACCEPTANCE REQUIREMENTS

The acceptance requirements for the maximum consistency during the 15-30 minute stirring period shall be 30 B_c for all classes of cement manufactured in accordance with this specification. The acceptance requirement for the thickening time shall be as listed below for the individual class of cement.

Table 9—Slurry Consistency vs Equivalent Torque

For potentiometer mechanism with a radius of 52 ±1 mm.[5]

Calculated Torque Equivalent g•cm	Weight Grams	Calculated Slurry Consistency in B_c
260	50 ±0.1	9
520	100 ±0.1	22
780	150 ±0.1	35
1040	200 ±0.1	48
1300	250 ±0.1	61
1560	300 ±0.1	74
1820	350 ±0.1	87
2080	400 ±0.1	100

[5]For a potentiometer mechanism with another radius, an appropriate table with equivalent tolerances shall be used.

Table 10—Schedule 4 Specification Test For Classes A, B, C and D

Elapsed Time	Pressure		Temperature	
Min.	psi	kPa	°F	°C
0	750	5200	80	27
2	1100	7600	83	28
4	1400	9700	87	31
6	1700	11700	90	32
8	2000	13800	93	34
10	2300	15900	97	36
12	2600	17900	100	38
14	2900	20000	103	39
16	3200	22100	106	41
18	3600	24800	110	43
20	3870	26700	113	45

Temperature and pressure shall be maintained within ±2°F (±1.1°C) ±100 psi (±700 kPa) of the specified schedule throughout the test.

Table 10—Schedule 5 Specification Test For Classes G and H

Elapsed Time	Pressure		Temperature	
Min.	psi	kPa	°F	°C
0	1000	6900	80	27
2	1300	9000	83	28
4	1600	11100	86	30
6	1900	13100	90	32
8	2200	15200	93	34
10	2500	17300	96	36
12	2800	19300	99	37
14	3100	21400	102	39
16	3400	23400	106	41
18	3700	25500	109	43
20	4000	27600	112	44
22	4300	29600	115	46
24	4600	31700	119	48
26	4900	33800	122	50
28	5160	35600	125	52

Temperature and pressure shall be maintained within ±2°F (±1.1°C) and ±100 psi (±700 kPa) of the specified schedule throughout the test.

Table 10—Schedule 6 Specification Test for Classes D, E and F

Elapsed Time	Pressure		Temperature	
Min.	psi	kPa	°F	°C
0	1250	8600	80	27
2	1600	11000	84	29
4	1900	13100	87	31
6	2300	15900	91	33
8	2600	17900	94	34
10	3000	20700	98	37
12	3300	22800	101	38
14	3700	25500	105	41
16	4000	27600	108	42
18	4400	30300	112	44
20	4700	32400	116	47
22	5100	35200	119	48
24	5400	37200	123	51
26	5700	39300	126	52
28	6100	42100	130	54
30	6400	44100	133	56
32	6800	46900	137	58
34	7100	49000	140	60
36	7480	51600	144	62

Temperature and pressure shall be maintained within ±2°F (±1.1°C) and ±100 psi (±700 kPa) of the specified schedule throughout the test.

Table 10—Schedule 8 Specification Test for Class E

Elapsed Time	Pressure		Temperature	
Min.	psi	kPa	°F	°C
0	1750	12100	80	27
2	2200	15200	85	29
4	2600	18000	90	32
6	3100	21400	95	35
8	3500	24100	99	37
10	4000	27600	104	40
12	4400	30300	109	43
14	4900	33800	114	46
16	5300	36500	119	48
18	5800	40000	124	51
20	6200	42700	128	53
22	6700	46200	133	56
24	7100	49000	138	59
26	7600	52400	143	62
28	8000	55200	148	64
30	8500	58600	153	67
32	8900	61400	158	70
34	9400	64800	162	72
36	9800	67600	167	75
38	10300	71000	172	78
40	10700	73800	177	81
42	11200	77200	182	83
44	11600	80000	187	86
46	12000	82700	191	88
48	12500	86200	196	91
50	12900	88900	201	94
52	13390	92300	206	97

Temperature and pressure shall be maintained within ±2°F (±1.1°C) and ±100 psi (±700 kPa) of the specified schedule throughout the test.

Table 10—Schedule 9 Specification Test for Class F

Elapsed Time Min.	Pressure psi	Pressure kPa	Temperature °F	Temperature °C
0	2000	13800	80	27
2	2500	17200	86	30
4	2900	20000	91	33
6	3400	23400	97	36
8	3900	26900	102	39
10	4400	30300	108	42
12	4800	33100	114	46
14	5300	36500	119	48
16	5800	40000	125	52
18	6200	42700	130	54
20	6700	46200	136	58
22	7200	49600	142	61
24	7700	53100	147	64
26	8100	55800	153	67
28	8600	59300	158	70
30	9100	62700	164	73
32	9500	65500	170	77
34	10000	68900	175	79
36	10500	72400	181	83
38	11000	75800	186	86
40	11400	78600	192	89
42	11900	82000	196	92
44	12400	85500	203	95
46	12800	88300	209	98
48	13300	91700	214	101
50	13800	95100	220	104
52	14300	98600	226	108
54	14700	101400	231	111
56	15200	104800	237	114
58	15700	108200	242	117
60	16140	111300	248	120

Temperature and pressure shall be maintained within ±2°F (±1.1°C) and ±100 psi (±700 kPa) of the specified schedule throughout the test.

Table 11—Thickening Time Acceptance Requirements

Class	Schedule	Minimum Thickening Time in Minutes	Maximum Thickening Time in Minutes
A	4	90	NR
B	4	90	NR
C	4	90	NR
D	4	90	NR
	6	100	NR
E	6	100	NR
	8	154	NR
F	6	100	NR
	9	190	NR
G	5	90	120
H	5	90	120

NR = No Requirement

10 Marking

10.1 REQUIREMENTS

The following information shall be marked on or made available with each shipment of well cement:

10.1.1 Manufacturer's name.

10.1.2 The API monogram shall be applied only by licensed manufacturers. Contact API for regulations governing the use of the API monogram.

10.1.3 API Spec 10A.

10.1.4 Class and sulfate resistance grade of cement.

10.1.5 Net weight.

10.2 SACKED CEMENT

The above information shall be marked on the sack [200 lb (90.7 kg) or less].

10.3 BULK CEMENT

The above information shall be marked or attached to the Bill of Lading on each shipment.

11 Packing

Well cement shall be furnished in bulk or in sacks.

Each sack shall contain a specified net weight ±2%. The average weight of five percent of all sacks in a shipment, taken at random, shall not be less than the specified weight.

A cement sack should be resistant to moisture, resistant to damage during handling and provide a clean cut during transfer to bulk facilities. Cement sacks should typically consist of up to six paper layers (minimum weight 70 g/m^2 each) with up to two polyethylene or polypropylene layers (weight 15-24 g/m^2 each) included between the first and fifth paper layers. Up to two asphalt or bitumen layers may be included to further improve resistance to damage.

Flexible bulk cement containers should provide an acceptable tensile strength (safety factor 5 to 1 minimum). They should also be resistant to ultraviolet radiation when polyethylene or polypropylene layers are used and suitably moisture proof.

12 Bentonite

12.1 DEFINITION

Bentonite is a naturally occurring clay mineral, composed primarily of smectite. Nontreated bentonite, for use in well cementing, is dried and ground, but not chemically treated during processing.

12.2 ACCEPTANCE REQUIREMENTS

Bentonite meeting the requirements of this specification, for use in well cementing shall meet all the requirements for Non-Treated Bentonite of API Specification 13A, Fifteenth Edition.

Table 12—Bentonite Acceptance Requirements[1]

Requirement	Specification
YP/PV Ratio	1.5, maximum
Dispersed Plastic Viscosity	10 cP, minimum
Dispersed Filtrate Volume	12.5 mL, maximum

[1]For test procedure, see API Specification 13A: Specification for Drilling Fluid Materials, Fifteenth Edition, May 1, 1993.

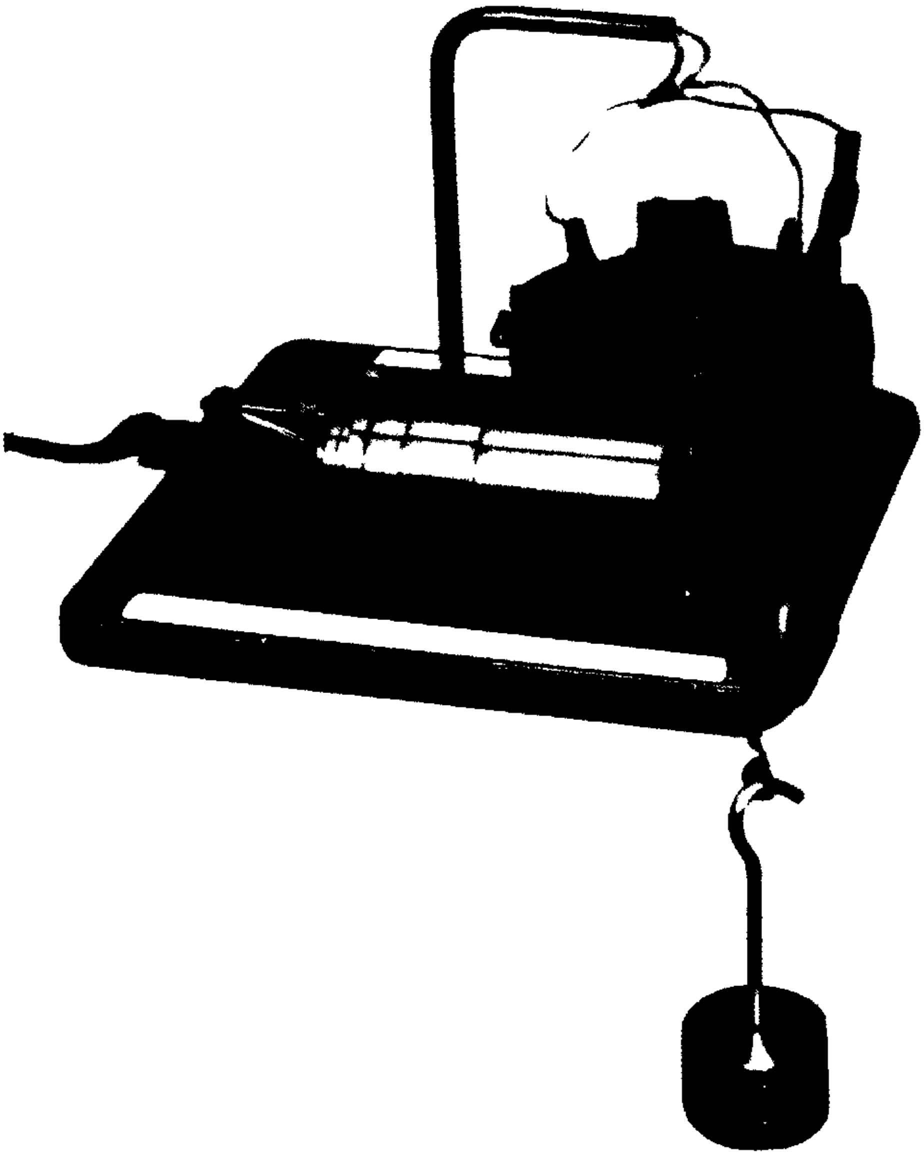


Figure 6—Typical Potentiometer Calibrating Device

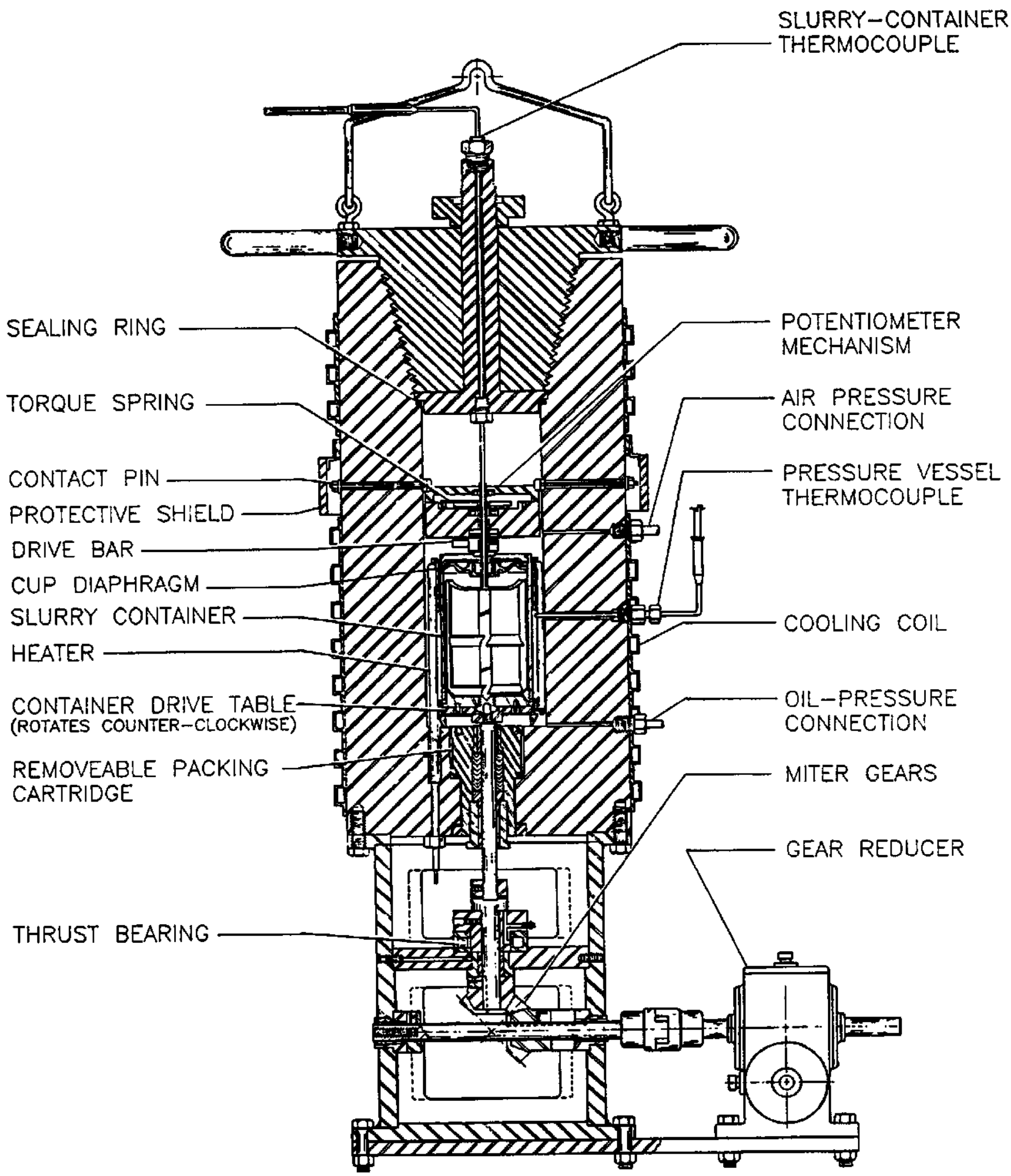


Figure 7—Typical Geardrive Consistometer for Pressurized Specification Thickening Time Test

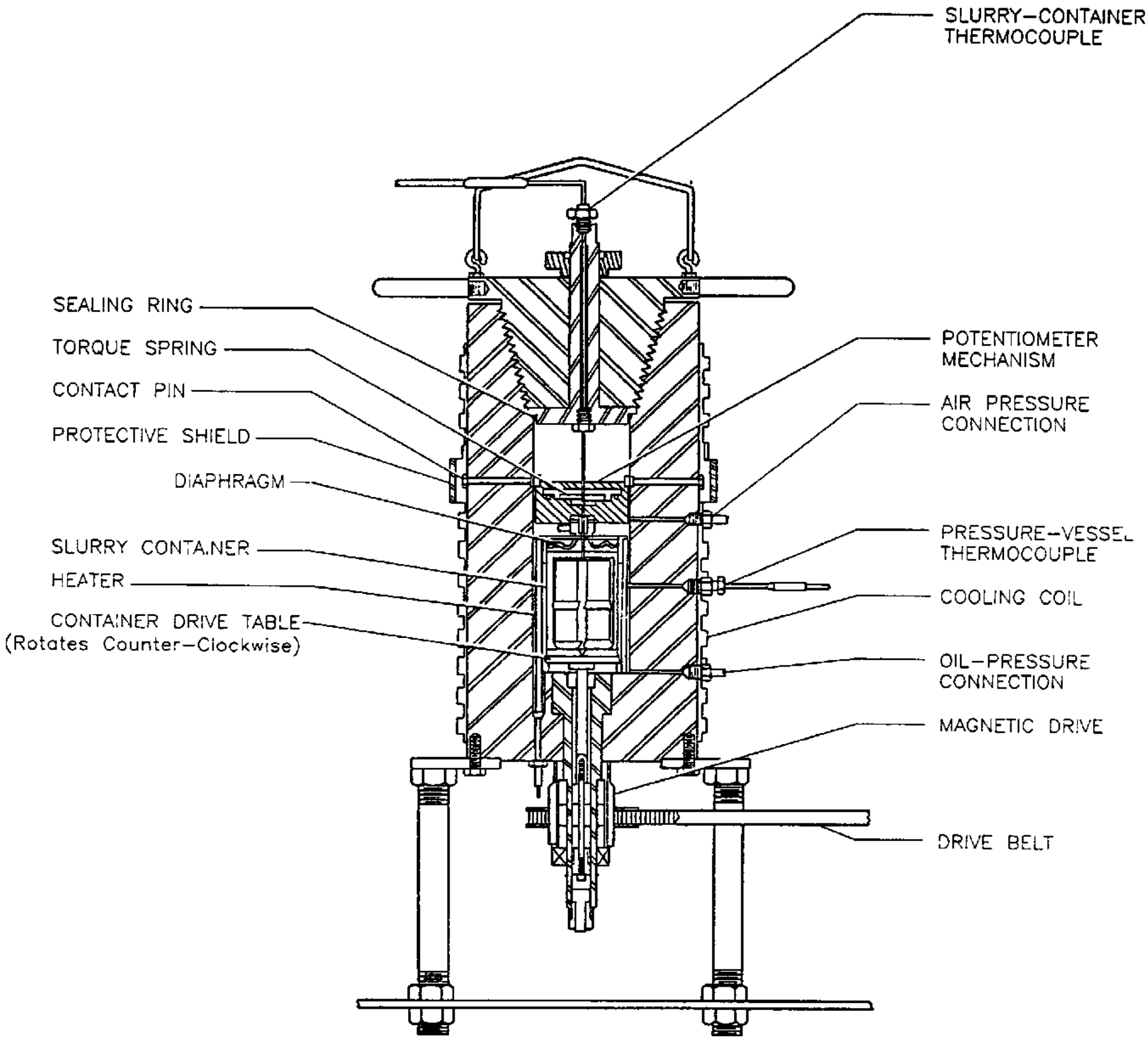
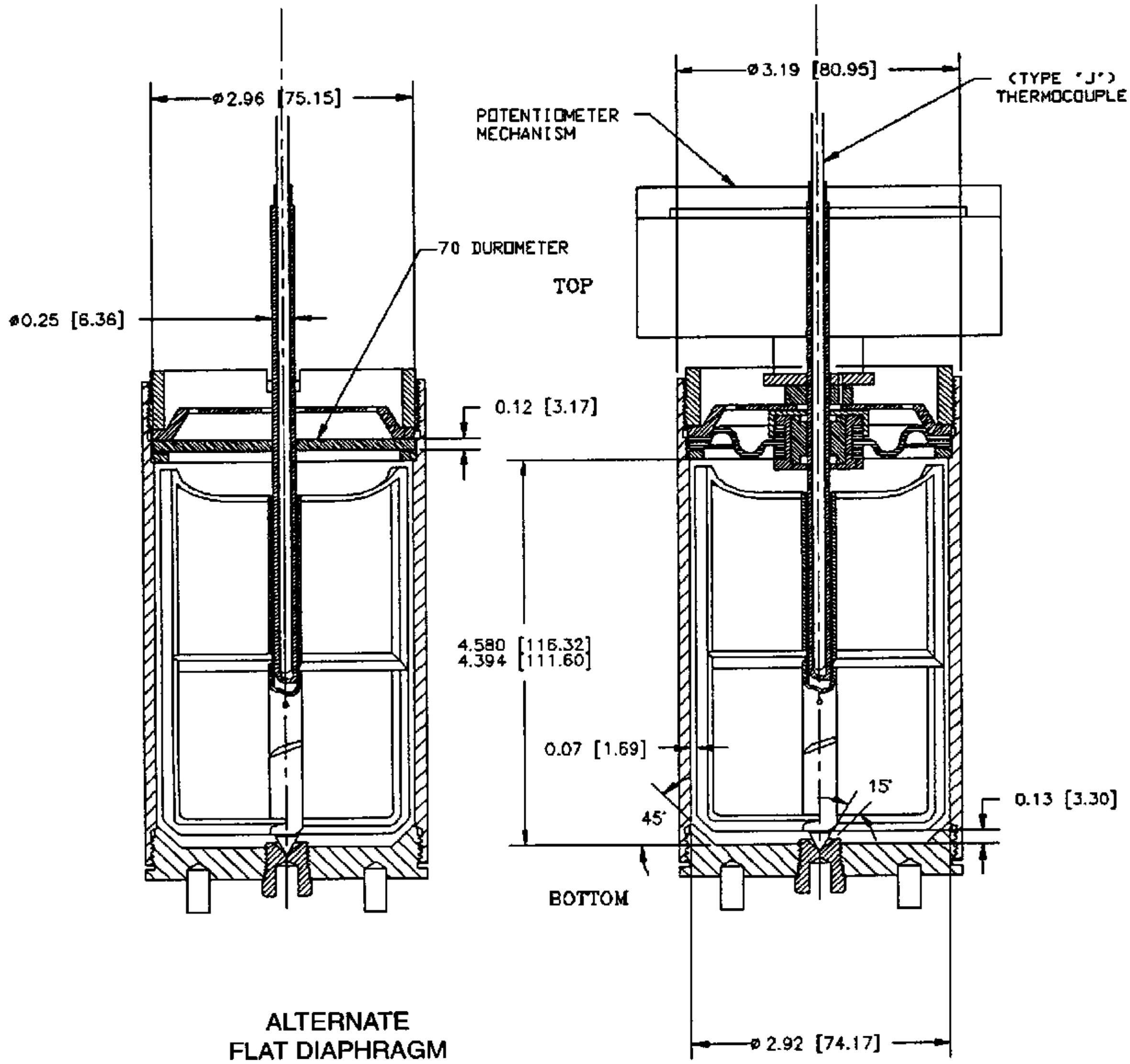


Figure 8—Typical Magnetic Drive Consistometer for Pressurized Specification Thickening Time Test

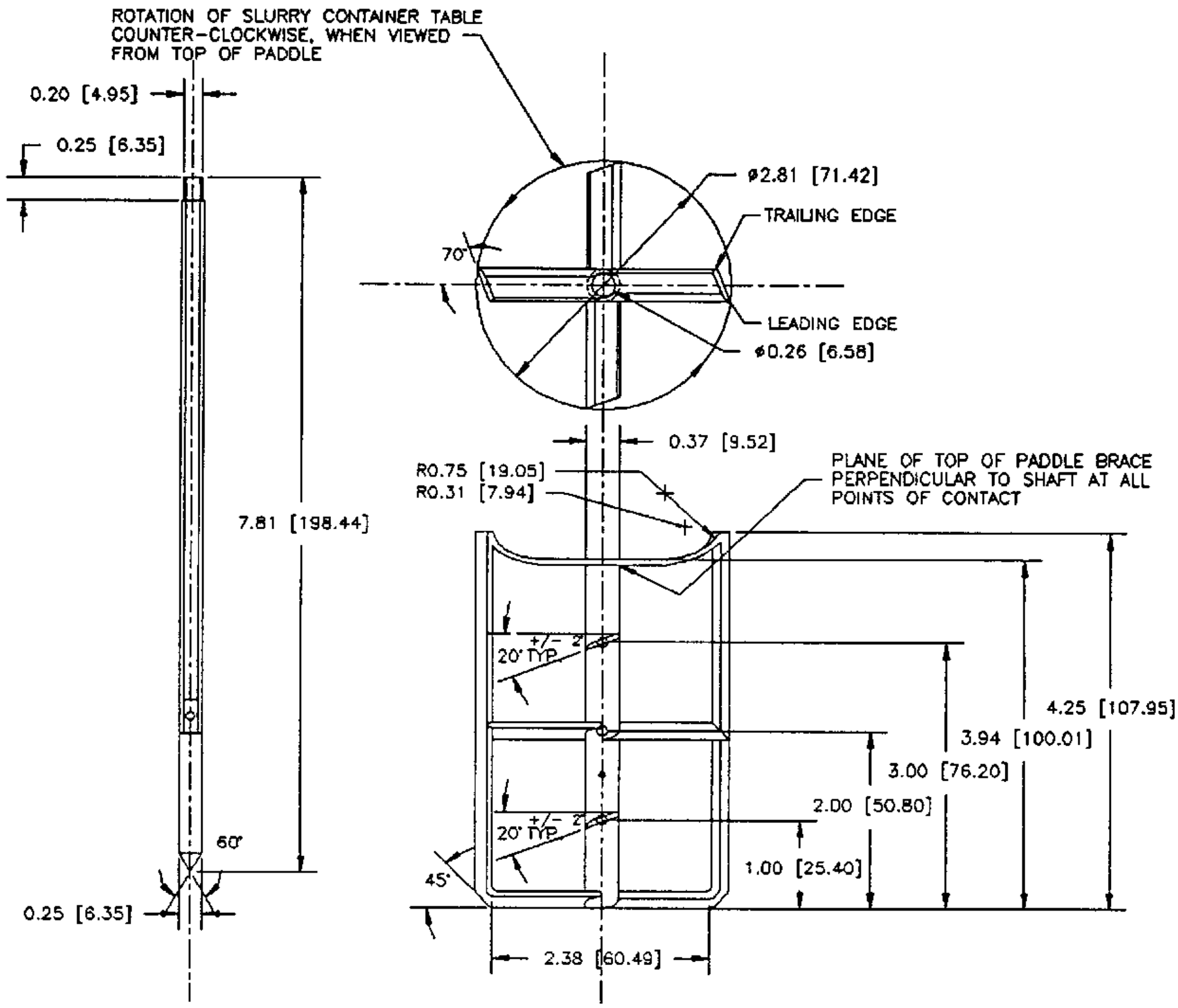


NOTE:

1. MATERIAL: STAINLESS STEEL EXCEPT DIAPHRAGM AND HUB.

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES [MM]		
TOLERANCES ARE:		
.XX [.X]	± .010	[.25]
.XXX [.XX]	± .005	[.13]
ANGLES	± 1°	

Figure 9—Slurry Container Assembly for Pressurized Consistometer



NOTES:
1. PADDLES ARE STAINLESS STEEL
2. ALL FLAT STOCK IS .0625 X .375 (1.6mm X 9.5mm)
3. TAPER ALL LEADING EDGES OUT AND DOWN.
4. ROUND ALL TRAILING EDGES.

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES [MM]		
TOLERENCES ARE:		
.XX [.X]	± .010	[.25]
.XXX [.XX]	± .005	[.13]
ANGLES	± 1°	

Figure 10—Paddle for Pressurized Consistometer Slurry Container

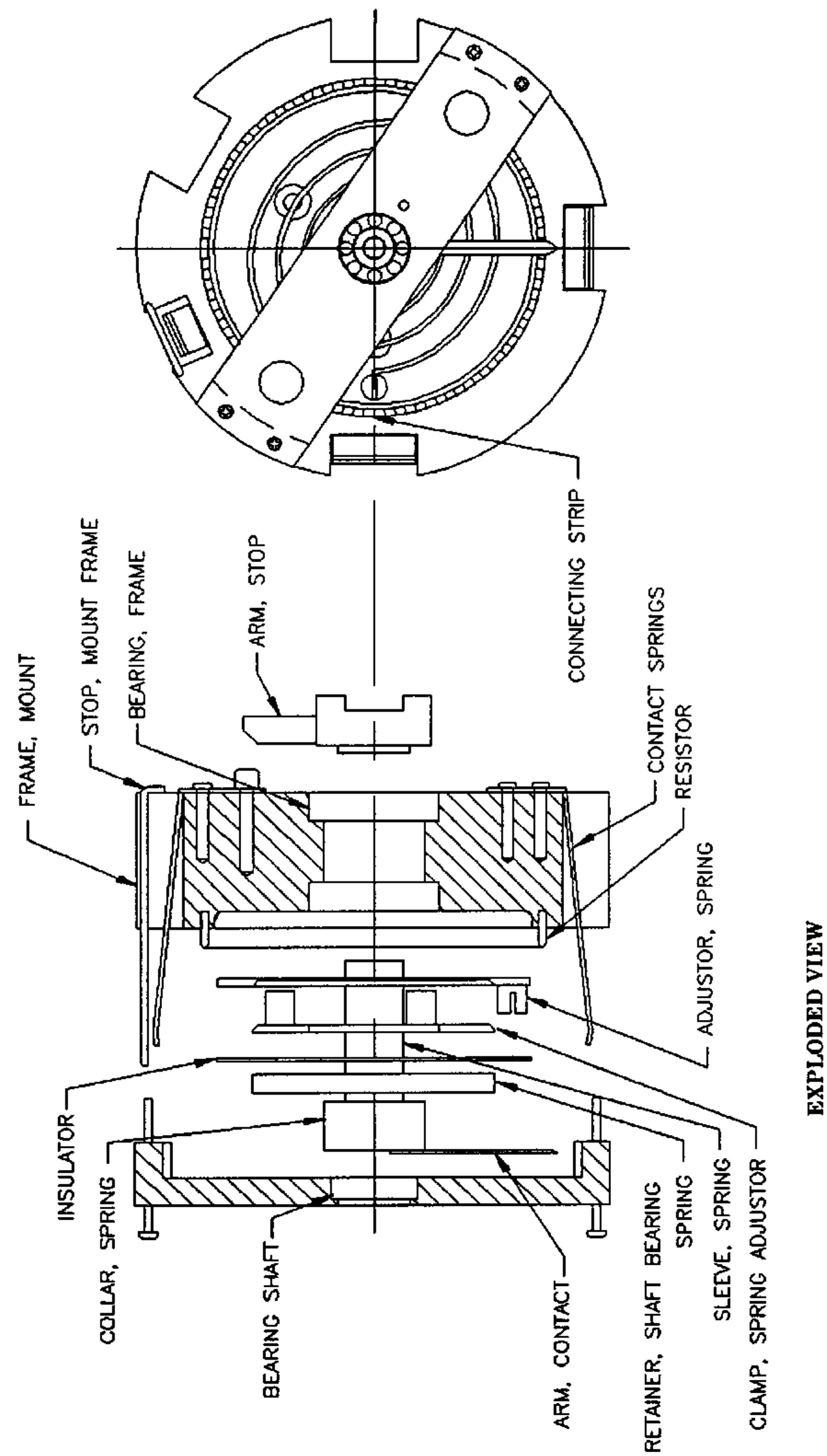


Figure 11—Typical Potentiometer Mechanism for Pressurized Consistometer

APPENDIX A—CALIBRATION PROCEDURES FOR THERMOCOUPLES, TEMPERATURE MEASURING SYSTEMS, AND CONTROLLERS

A.1

There are several satisfactory methods for calibrating thermocouples including methods supplied by equipment manufacturers. The reader is referred to ASTM E220, "Standards Methods for Calibration of Thermocouples by Comparison Techniques" for a more complete discussion of these procedures. No ASTM procedures for calibration temperature measuring systems are available.

A.2 Thermocouple Calibration

A.2.1 EQUIPMENT

The individual pieces of equipment needed to carry out the calibration will depend on the particular technique selected. The following discussion highlights those features which need special attention, regardless of the technique.

a. Heating Environment. The heating medium shall permit proper immersion of both the test thermocouple (the one being calibrated) and the reference thermocouple or reference thermometer. The medium may be a liquid bath, a fluidized solids bath, a heated block or a furnace. The equipment shall be capable of maintaining a stable temperature which is uniform throughout the test section.
b. Temperature Measurement. The reference temperature of the heating medium may be measured by using either a thermometer or a thermocouple. The accuracy of the reference measuring device shall be traceable to a National Bureau of Standards (NBS) certification of test.

If a thermocouple is used to sense the reference temperature, the voltage output from the reference thermocouple and test thermocouple shall be determined as described in ASTM E220. In this case, tables of temperature vs. voltage for the type thermocouple being used must be consulted to determine the temperature. Alternately, a direct-reading, temperature-compensated, readout instrument may be used. The accuracy of the instrument shall be traceable to NBS certification.

A.2.2 PROCEDURE

With the exception of the indicating instruments, the specific procedures are detailed in ASTM E220. The items listed here are those needing special attention or related to the use of the indicating type of equipment.

a. The test and reference thermocouple or thermometer shall be placed as close together in the heating medium as possible.
b. After each change in the heating level, the temperature shall be allowed to remain at a stable value for 15 minutes before reading the reference temperature (or voltage) and the test thermocouple temperature (or voltage).
c. Several (more than three) test temperatures which span the operating range of the equipment shall be used in the calibration procedure.
d. If the test thermocouple does not accurately sense the temperature, a calibration curve shall be drawn and used to correct the indicated temperatures from the test thermocouple. Occasionally, small inaccuracies in thermocouple response can be compensated for during the calibration of the temperature measuring system being used in conjunction with the thermocouple (Section A.3).
e. If the test thermocouple error is greater than that specified by the manufacturer, the thermocouple shall be replaced by one which meets the thermocouple accuracy limits. The special type "J" thermocouple has error limits equal to or better than ±2°F (±1.1°C) up to 530°F (277°C).

A.3 Calibration of Temperature Measuring Systems and Controllers

A.3.1 EQUIPMENT

The calibration of temperature measuring systems and controllers requires a millivolt source, the correct connecting thermocouple extension cable for the type thermocouple being used and, possibly, a thermometer and a table of reference voltages. Signal sources, or calibrators, are of two types, i.e., uncompensated and cold junction compensated. Several commercial calibrators are available which are cold junction compensated and have a digital display of the temperature equivalent of the millivolt signal being supplied. The accuracy of all calibration equipment shall be traceable to NBS certification. Some older galvanometer type temperature indicating instruments and controllers require a stronger signal for operation than the newer potentiometric and digital type temperature measuring systems and controllers and will require a calibrator with sufficient signal strength to give an accurate calibration.

A.3.2 PROCEDURE

The manufacturer's procedure for calibrating temperature measuring systems and controllers shall be followed. The following are reminders of items needing special attention. The thermocouple extension cable shall be fitted with a proper thermocouple grade adapter to permit plugging it into the same receptacle used for connecting the test equipment thermocouple. Care shall be taken to ensure the correct polarity of the connections. Calibrators, temperature measuring systems and controllers shall be allowed proper warm-up time as specified by the manufacturer for greatest accuracy.

a. Thermocouple calibrators with cold junction compensation need only be properly connected with the proper thermocouple extension cable and thermocouple connectors. The temperature measuring systems and/or controllers using this signal shall have the same temperature readout within the accuracy of the temperature or controllers as supplied by the manufacturer.

b. Uncompensated thermocouple calibrators will require a thermometer to determine the cold junction temperature of the thermocouple extension cable connection of the calibrator. This cold junction temperature will be set on the calibrator by the operator.

c. The use of an uncompensated millivolt potentiometer requires that the temperature at the calibrator/thermocouple extension cable terminals be read with a thermometer of known accuracy. The millivolt equivalent of this temperature is then subtracted from the equivalent test millivolt signal to obtain the calibration millivolt signal to obtain the calibrator millivolt signal used. These voltages may be found in reference mv/temperature tables for the type thermocouple in use.

APPENDIX B—SI UNITS

Conversions of U.S. Customary units to International System (SI) metric units are provided throughout the text of this specification in parentheses, e.g., 6000 ft (1830 m). SI equivalents have also been included in all tables. U.S. Customary units are based on the foot and the pound commonly used in the United States of America and defined by the National Bureau of Standards. The factors for conversion of U.S. Customary units to SI are listed below:

Table B-1—SI Units

Quantity	U.S. Customary Unit	SI Unit
Area	1 square inch (in.^{2})	645.16 square millimeters (mm^2) (exactly)
Flow Rate	1 barrel per day (bbl/d)	0.158987 cubic meters per day (m^3/d)
	1 cubic foot per minute (ft^3/min)	0.02831685 cubic meters per minute (m^3/min) or 40.776192 cubic meters per day (m^3/d)
Force	1 pound-force (lbf)	4.448222 newtons (N)
Impact energy	1 foot-pound force (ft•lbf)	1.355818 Joules (J)
Length	1 inch (in.)	25.4 millimeters (mm) (exactly)
	1 square inch (in.^{2})	645.16 square millimeters (mm^2) (exactly)
	1 foot (ft)	304.8 millimeters (mm) (exactly)
	1 cubic foot (ft^2)	0.0283168 cubic meters (m^3) or 28.3168 cubic decimeters (dm^3)
Mass	1 pound (lb)	0.45359237 kilograms (kg) (exactly)
Pressure	1 pound-force per square inch (lbf/in.^{2}) or 1 pound per square inch (psi) (Note: 1 bar = 10^5 Pa)	6894.757 pascals (Pa)
Strength or stress	1 pound-force per square inch (lbf/in.^{2})	6894.757 pascals (Pa)
Temperature	The following formula was used to convert degrees Fahrenheit (°F) to degrees Celsius (°C):	°C = 5/9 (°F – 32)
Torque	1 inch pound-force (in•lbf)	0.112985 newton meters (N•m)
	1 foot-pound force (ft•lbf)	1.355818 newton meters (N•m)
Velocity	1 foot per second (ft/s)	0.3048 meters per second (m/s) (exactly)
Volume	1 cubic inch (in.^{3})	$16.387064 \cdot 10^{-3}$ cubic decimeters (dm^3) (exactly)
	1 cubic foot (ft^3)	0.0283168 cubic meters (m^3) or 28.3168 cubic decimeters (dm^3)
	1 gallon (U.S.)	0.0037854 cubic meters (m^3) or 3.7854 cubic decimeters (dm^3)
	1 barrel (U.S.)	0.158987 cubic meters (m^3) or 158.987 cubic decimeters (dm^3)

APPENDIX C—API MONOGRAM

Manufacturers of well cements have the option to apply for a license to use the API monogram for well cement manufactured in conformance with their specifications. API Spec Q1, *Specification for Quality Programs* includes requirements for quality programs for licensed manufacturers. Manufacturers interested in obtaining a monogram license for these materials should write the API Dallas office at 700 North Pearl, Suite 1840 (LB-382), Dallas, Texas 75201-2845 for an application package. A copy of the *Composite List of Manufacturers Licensed for Use of the API Monogram* can also be obtained from the API Dallas office.

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