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API
RECOMMENDED PRACTICE
for
TESTING OIL-WELL CEMENTS

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Note

This edition of RP 10B supersedes the 6th edition dated May 1957. It includes changes adopted at the June 1957 meeting, which were reported in detail in Circ. PS 1109.

This recommended practice was originally published in February 1948, as Code 32, and reissued as the 2nd edition in June 1952. In June 1952, this code was transferred to the jurisdiction of the Committee on Standardization of Oil-Well Cements, and redesignated RP 10B. The 3rd edition was issued in May 1954, and the 4th edition in May 1955. It was advanced to "standard" in June 1955. Further revised editions were issued in 1956 and May 1957.

API RECOMMENDED PRACTICE FOR TESTING OIL-WELL CEMENTS

Foreword

a. This recommended practice is under the jurisdiction of the API Committee on Standardization of Oil-Well Cements.

b. This recommended practice describes test procedures for the evaluation and definition of those physical properties of cements of special importance to the oil and gas industry. Certain of these procedures are required methods of test under API Std 10A: Specification for Oil-Well Cements.

c. These procedures are applicable to the following classes and types of oil-well cement (see API Std 10A for specification requirements).

Class A: Intended for use from surface to 6,000-ft depth,* when special properties are not required. Available in regular type only (similar to ASTM C 150, type I).

Class B: Intended for use from surface to 6,000-ft depth.* Available in the regular type (similar to ASTM C 150, type II) for conditions requiring moderate sulfate resistance, and in the high sulfate-resistant type.

Class C: Intended for use from surface to 6,000-ft depth,* for conditions requiring high early strength. Available in the regular type (similar to ASTM C 150, type III) and in the high sulfate-resistant type.

Class N: Intended for use from 6,000 to 9,000-ft depth,* for conditions of moderate temperature and pressure. Available in the regular type (having moderate sulfate resistance) and in the high sulfate-resistant type.

Class D: Intended for use from 6,000 to 12,000-ft depth,* for conditions of moderately high temperature and moderately high pressure. Available in the regular type (having moderate sulfate resistance) and in the high sulfate-resistant type.

Class E: Intended for use from 6,000 to 14,000-ft depth,* for conditions of high temperature and high pressure. Available in the regular type (having moderate sulfate resistance) and in the high sulfate-resistant type.

Class F: Intended for use from 10,000 to 16,000-ft depth,* for conditions of extremely high temperature and extremely high pressure. Available in the regular type (having moderate sulfate resistance) and in the high sulfate-resistant type.

*These depth limits are based on the conditions imposed by the casing cementing well-simulation tests (Schedules 1-9, incl.), and should be considered as approximate values.

SECTION I

SAMPLING

1. In order to secure a sample of cement which is truly representative of the lot in question, it is recommended that the following cement-sampling equipment and methods be employed whenever possible.

2. Apparatus. The following apparatus for sampling cement should be used:

a. **Sacked Cement.** A tube sampler, as shown in Fig. 1, should be used, if possible, for sampling sacked cement.

b. **Bulk Cement.** For sampling bulk cement, either of the following samplers should be used:

I. A tube sampler similar to that shown in Fig. 2 consisting of two polished brass telescopic tubes with registering slots which are opened or closed by rotation of the inner tube, the outer tube being provided with a sharp point to facilitate penetration. The length should be appropriate to the vessel from which the sample is being collected.

II. A small grocers scoop, for sampling during loading or unloading operations.

3. Procedure. The following procedure for sampling cement should be used:

a. **Sacked Cement.** When using the sampler shown in Fig. 1, the Bates valve in the upper right-hand corner of the sack should be opened, the sampler inserted diagonally, and the thumb placed over the air hole. The sampler should then be carefully withdrawn. When it is impossible or not feasible to sample cement with the tube sampler, every effort should be made to secure a representative sample from the lot of cement in question, be it large or small. A minimum of one sample from each 50 sacks (or less) is desirable. The sample should then be placed in an air-tight container, preferably metal, and kept there until immediately before testing is started.

b. **Bulk Cement.** The various procedures given in the latest edition of ASTM C 183*: Method of Testing Hydraulic Cement, should be used for the sampling of bulk cement.

4. Size of Sample. The minimum weights of cement required for test purposes are given in Table 1. The total weight of sample collected should not be less than 25 per cent in excess of the amount required for the tests to be conducted.

*ASTM standards referred to herein are available from American Society for Testing Materials, 1916 Race St., Philadelphia, Pa.

TABLE 1
WEIGHT OF TEST SAMPLES

Method of Test	Quantity for Single Test, min., lb.	Quantity for Complete Tests, min., lb.
Soundness	1	1
Fineness	1	1
Thickening Time		
Atmospheric Pressure Test A	3	12
Atmospheric Pressure Test B	6	24
Pressure Temperature	2	12
Tensile strength	2 (per gang mold)	32
Compressive strength	3 (per gang mold)	48

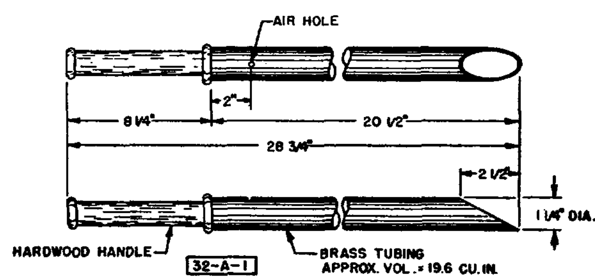


FIG. 1

TUBE SAMPLER FOR SACKED CEMENT

FIG. 2

TUBE SAMPLER FOR BULK CEMENT

SECTION II
PREPARATION OF SLURRY

Apparatus

5. Scales. The indicated load on scales should be accurate within a tolerance of 2 g for loads of 2000 g or more, and within 0.1 per cent of the indicated load for loads smaller than 2000 g, except that for new scales the tolerances on accuracy should be one-half of these values. The sensibility reciprocal should not be greater than twice the permissible tolerance on scale accuracy.

6. Weights. Weights should be accurate within the tolerances shown in Table 2, except that new weights should be accurate within one-half of such tolerances. On beam-type scales where the weights are on the beam, the indicated weights should conform to the requirements given in Par. 5

TABLE 2
PERMISSIBLE VARIATION IN WEIGHTS

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

7. Graduated Glass Cylinders. Graduated glass cylinders should be large enough to measure and deliver, in a single operation, the required volume of mixing water, at 20 C (68 F). The variation in volume should not exceed ±0.2 per cent. The graduations should be subdivided to at least 5 ml. The main graduation lines should be complete circles, and should be numbered. The intermediate graduations should extend around a minimum of one-fifth of the circumference, and the smallest graduations should extend around a minimum of one-seventh of the circumference of the cylinder.

8. Mixing Device. The mixing device for preparation of cement slurries shall be a 1-qt size, two-speed Waring Blendor. This is a propeller-type high-speed mixer capable of rotating at 4,000 rpm or greater at no load on "slow" speed, and 10,000 rpm or greater at no load on "high" speed. The propeller blade and mixing container (1-qt) shall be constructed of corrosion resistant metal.

Procedure

9. Screening. The sample of cement to be tested should be passed through an 840 micron (No. 20) sieve meeting the requirements given in the latest edition of ASTM E 11: Sieves for Testing Purposes, in order to break up lumps and remove foreign materials. The materials retained on the screen should be weighed, the weight recorded as a per cent of the total cement sieved, and a notation made as to its characteristics, after which it should be discarded.

10. Mixing Water. For reference tests, freshly distilled water or distilled water essentially free of CO_2 should be used. For routine tests, any normal potable water may be employed. The mixing water should be measured in a graduated glass cylinder (see Par. 7) or weighed by means of scales and weights (see Par. 5 and 6).

11. Temperature of Water and Cement. The temperature of the water prior to mixing should be 80 ±5 F and that of the cement should be 80 ±10 F.

12. Water Percentage. The water percentage by weight to be added for each class of cement should conform to the values given in Table 3. No water shall be added to compensate for evaporation, wetting, etc.

TABLE 3
CEMENT SLURRY COMPOSITION

1	2	3	4	5
	Water		Required Quantity to Yield 750 ml of Slurry	
API Class of Cement	Percentage by Wt. of Cement	Gal. per Sack	g. water	g. cement
A and B	46	5.19	444	965
C	56	6.32	479	855
N, D, E, and F	40	4.51	420	1050

NOTE: *The addition of bentonite to cement requires that the amount of water be increased. It is recommended, for testing purposes, that 4.5 per cent water be added for each 1 per cent bentonite in classes A, and B, and C, and 3.8 per cent water for each per cent bentonite in classes N, D, E, and F cement. For example, a class A cement slurry having a normal water-cement ratio of 46 per cent, to which is added 3 per cent bentonite, will require an increase in water-cement ratio to 59.5 per cent.*

13. Mixing of Cement and Water. Mixing of the cement and the requisite percentage of water at the given temperature shall conform to the following mixing procedure:

> The required quantity of water shall be placed in the mixing container, the mixer turned on "slow" speed, and the cement sample added in not more than 5 sec. After all of the cement has been added to the water, the cover shall be placed on the mixing container and stirring shall be continued at "high" speed for 35 sec.

14. Volume of Slurry. The volume of slurry in the mixing container shall be 750 ml.

SECTION III

DETERMINATION OF DENSITY OF SLURRY

15. **Apparatus and Calibration.** Cement slurry density should be determined by the use of any accurate instrument, such as a hydrometer or mud balance as described in API RP 29: Recommended Practice for Standard Field Procedure for Testing Drilling Fluids.

16. **Procedure.** The procedure for using a hydrometer or mud balance should be as recommended in the latest edition of API RP 29 except that the slurry, after being poured into the hydrometer or mud-balance cup, should be puddled 25 times to eliminate any air that may be entrapped in the slurry.

SECTION IV

FILTER-LOSS TEST

(Tentative)

17. **Apparatus.** The following apparatus should be used.

a. **Filter Press.** The filter press should consist of a frame and cylinder assembly similar to that shown in Fig. 3. The cylinder should have an internal diameter of 3 ± .07 in. and a height of at least 2½ in. The cylinder assembly should be constructed of materials not affected by alkaline solutions and so fitted that a pressure medium can be conveniently admitted into and bled from the top. The bottom of the cell should be closed by a bottom cap with a drain tube and necessary gaskets to provide an effective seal. The filtration area should be 7.1 sq in. The entire assembly should be supported in a convenient stand.

b. **Pressure Medium.** Pressure should be supplied by compressed air, nitrogen, or any other safe and adequate means of maintaining constant gas pressure.

c. **Filter Medium.** The filter medium should be 28 x 500 Dutch Twill Weave stainless steel metallic filter cloth with a stainless steel binder or a 325-mesh U S Standard Sieve Series screen (ASTM E 11-39) supported by a 14-mesh Sieve Series screen, both fabricated from stainless steel into an integral unit.

d. **Graduated Glass Cylinders.** The graduated glass cylinders should be large enough to contain and measure the expected volume of filtrate.

18. **Preparation of Filter Press and Slurry.** Prior to placing the slurry in the press the filter press and cement slurry should be prepared as follows:

a. **Filter Press.** The cell of the filter press should be assembled dry.

b. **Slurry.** When the cement slurry is prepared in accordance with Sect. II, it is placed in the press as quickly as convenient handling will allow. The time between cessation of stirring and application of pressure shall not exceed 2 min. The temperature of slurry should be determined in degrees Fahrenheit.

c. **Special Slurry.** When the test is used on field prepared slurries or on pressure and/or temperature treated slurries, the method of preparation and handling shall be stated.

Procedure

19. Placing of Slurry in Press and Commencing of Test. The cell should be filled with at least 2 in. of cement slurry, capped, and secured in the frame. A dry graduated cylinder should be placed under the drain tube to receive the filtrate, the relief valve closed, and a gas pressure of 100 ±5 psi applied within 5 sec after the relief valve is closed.

20. Test Period. The test period should be timed from the instant of initial pressure application. Filtrate readings should be taken at ¼, ½, 1, 2, and 5 min, and thereafter at 5-min intervals, until 30 min have elapsed. If dehydration occurs before the end of the 30-min test period, the elapsed time required to dehydrate the sample should be observed. At the completion of the test, the gas pressure should be shut off and the relief valve opened.

21. Recording of Results. Record the initial temperature of the slurry in degrees Fahrenheit. The volume of the filtrate should be recorded as follows:

a. **For 30-Min Test Period.** Report the volume of filtrate as the fluid loss at 100 psi.

b. **For Short Test Periods.** For slurries which dehydrate in less than 30 min, and tests of shorter duration than 30 min, a hypothetical 30-min fluid-loss value may be obtained for comparative purposes by multiplying the quantity of filtrate at that time by 5.477 divided by the square root of that time in minutes. This relationship is shown by the following equation:

$$Q_{30} = Q_t \times \frac{5.477}{\sqrt{t}}$$

Wherein:

Q_{30} = the quantity of filtrate in 30 min.

Q_t = the quantity of filtrate at time t.

All computed 30-min fluid-loss values should be so noted and should not be construed as true fluid-loss values.

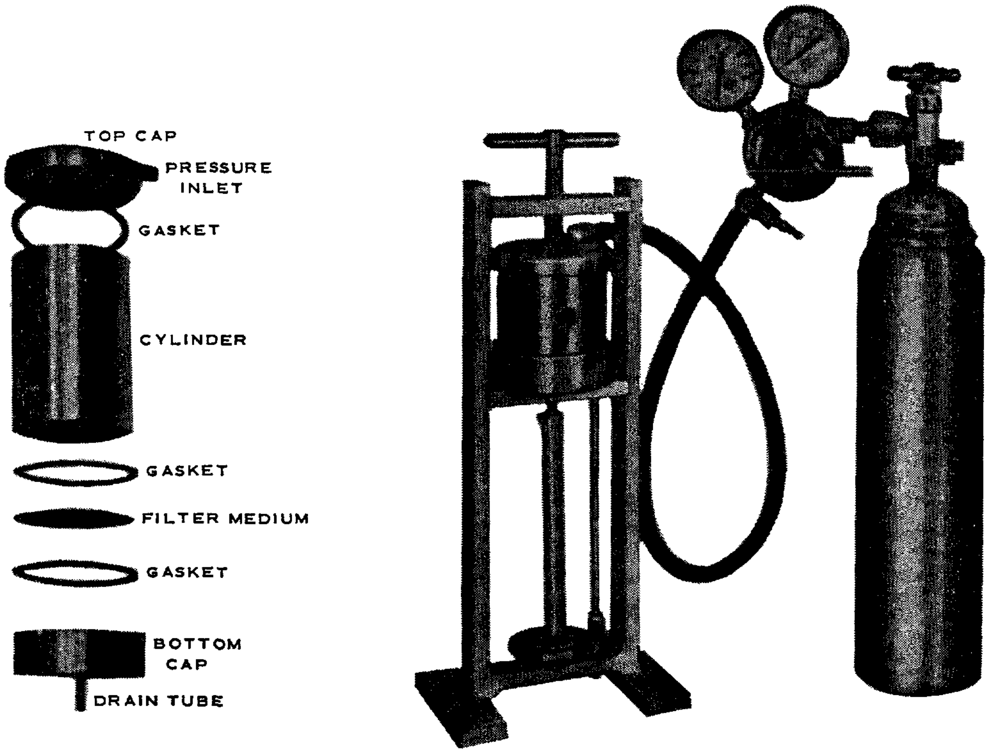


FIG. 3
TYPICAL FILTRATION TESTER

SECTION V

STRENGTH TESTS

NOTE: *Procedures are given for both compressive- and tensile-strength testing. However, comparative tests indicate that the results of tensile-strength tests do not reflect the effect of variation in age of specimens and in temperature of curing as well as do the results of compressive-strength tests.*

22. **Apparatus.** The following apparatus shall be used:

a. **Sieve:** 840 micron (No. 20) woven-wire cloth sieve, meeting requirements given in the latest edition of ASTM E 11: Specification for Sieves for Testing Purposes.

b. **Specimen Molds and Strength-Testing Machine:** Molds and testing machine for the tensile-strength test conforming to requirements in the latest edition of ASTM C 190: Method of Test for Tensile Strength of Hydraulic-Cement Mortars. Molds and testing machine for the compressive-strength test conforming to the requirements in the latest edition of ASTM C 109: Method of Test for Compressive Strength of Hydraulic-Cement Mortars.

c. **Base and Cover Plates:** Plate glass or non-corroding metal plates ¼-in. thick, approximately 4 in. wide, and 12 in. long.

d. **Water Curing Bath:** A curing bath or tank having dimensions suitable for the complete immersion in water of ASTM tensile or compressive molds and operable within ±3F of the prescribed test temperatures. The bath shall have a suitable agitator or circulating system to insure a uniform bath temperature. The two types of water curing bath are as follows:

I. A non-pressure vessel suitable for curing specimens at temperatures of 180 F or less.

II. A pressure vessel suitable for curing specimens at temperatures up to and including 350 F, and at pressures that can be controlled between 0 and 3,000 psi. The vessel shall have sufficient heating capacity to raise the temperature uniformly from 80 to 300 F in 100 min.

e. **Cooling Bath:** A bath in which the specimen to be cooled from the curing temperature, can be completely submerged in water maintained at 80 F, ±5 F.

f. **Thermometers:**

I. Thermometer, range 0-220 F, with minimum scale divisions not exceeding 2 F, for use in non-pressure type vessels.

II. Pyrometer or thermometer, range 0-400 F, with minimum scale divisions not exceeding 5 F, for use in pressure type vessels.

g. **Puddling Rod:** A glass puddling rod approximately 8 in. in length and ¼ in. in diameter.

h. **Cup Grease:** Cup grease, grade No. 2.

i. **Asphalt:** Asphalt for use in sealing specimen molds, having a softening point above 180 F.

Procedure

23. **Preparation of Slurry and Molds.** The cement slurry and molds used for strength-test specimens shall be prepared prior to placing the slurry in the mold as follows:

a. **Slurry.** The cement slurry shall be prepared in accordance with Sect. II.

b. **Molds.** The interior faces of the molds and the contact surface of the plates shall be thinly covered with cup grease. The contact surfaces of the halves of each mold shall also be coated with cup grease to make the joint water tight when assembled. Excess grease shall be removed from the interior faces of the assembled molds, and the molds placed on a thinly greased plate or sealed to the base plate with asphalt heated to a pouring consistency and applied to the exterior contact lines of the molds and base plates. In the event that cup grease is used, it is necessarv that it be applied to the exterior contact line of the mold and the base plate.

24. **Placing of Slurry in Molds.** The slurry shall be placed in the prepared molds in a layer equal to one half of the mold depth, and the layer puddled 25 times per specimen with a puddling rod. The slurry shall be placed in all the specimen compartments before commencing the puddling operation. On completion of the puddling of the layer, the remaining slurry shall be stirred to eliminate segregation, after which the molds shall be filled to overflowing and puddled as for the first layer. After puddling, the excess slurry shall be struck off even with the top of the mold, using a straightedge. Specimens in molds which show evidence of leaking shall be discarded. A greased cover plate shall be placed on top of the mold.

25. **Curing Periods.** The curing period is the elapsed time from that of subjecting the specimen to temperature in the curing vessel to that of testing the specimen for strength.

a. For specimens cured at atmospheric pressure, the curing period starts when specimens are initially placed in the curing bath, immediately after slurry has been placed in the molds. The curing period ends when specimens are tested for strength.

b. For specimens cured at pressures above atmospheric, the curing period starts with the initial application of pressure and temperature, to be applied immediately after specimens are sealed in the curing vessel. The curing period ends when specimens are tested for strength.

c. The recommended curing periods for test specimens are 8, 12, 18, 24, 36, 48, and 72 hr. Tests at 8, 24, 48, and 72 hr are usually sufficient, but in some cases where "waiting on cement" time and further information are wanted, additional tests may be necessary.

Curing Temperatures and Pressures

26. For curing at atmospheric pressure at temperatures of 180 F or less, one or more of the following temperatures are recommended: 80, 100, 120, 140, 160, 180. For curing at pressures above atmospheric, at temperatures of 170 F, or less, one or more of the following schedules are recommended (see Table 4): 1S, 2S, 3S, 4S.

27. For curing at temperatures above 180 F one or more of the following schedules (see Table 4) are recommended: 5S, 5AS, 6S, 7S, 8S, 9S, 10S.

Curing Procedures

28. **Curing at Atmospheric Pressure.** For curing at atmospheric pressure the test specimens, immedi-

ately after being placed in molds and covered, shall be immersed in a water bath maintained at the curing temperature.

a. Where specimens are to be tested at ages of less than 24 hr, they shall be removed from the curing bath approximately 45 min before the age at which they are to be tested, immediately removed from their molds, and placed in a water bath maintained at 80 F ±5 F for approximately 35 min.

b. Where specimens are to be tested at ages of 24 hr or more, they shall be removed from the curing bath 20 to 23 hr after the cement slurry is initially mixed, immediately removed from their molds, and returned to the curing bath. They shall remain in the curing bath until approximately 45 min prior to the age at which they are to be tested, at which time they shall be transferred to a water bath and maintained at 80 F ±5 F for approximately 35 min.

29. Curing at Pressures Above Atmospheric. For curing pressures greater than atmospheric, the test specimens, immediately after molding and covering, shall be immersed in water at 80 F ±5 F in the pressure vessel. Heat and pressure shall be applied in accordance with the appropriate schedule as recommended in Par. 26 and 27 and in Table 2 of API Std 10A. The maximum scheduled temperature and pressure shall be maintained as shown in footnotes 1 and 2 of Table 4 until 1 hr and 45 min prior to the age at which the specimens are to be tested, at which time heating shall be discontinued. During the next 60 min the temperature shall be decreased to 200 F or less without release of the pressure other than that caused by thermal contraction. At 45 min prior to the age at which specimens are to be tested, the pressure then remaining shall be released gradually (to avoid damaging specimens) and the specimens then removed from molds, transferred to a water bath and maintained at 80 F for approximately 35 min.

30. Testing of Specimens. The testing of the specimens shall be carried out immediately after their removal from the cooling-bath water, the testing procedure to conform with the proper ASTM standard method as follows:

a. Cube specimens shall be tested in accordance with the latest edition of ASTM C 109: Method of Test for Compressive Strength of Hydraulic-Cement Mortars, Sect. 12 (b), 12 (c), 13, and 14, except that in the calculation of compressive strengths, variations from the specified cross-sectional area (4.00 sq in.) may be disregarded, provided deviations of $\frac{1}{16}$ in. or more from the specified nominal (cross-sectional) dimensions (2.00 in.) are reported.

b. Briquet specimens shall be tested in accordance with the latest edition of ASTM C 190: Method of Test for Tensile Strength of Hydraulic-Cement Mortars, Sect. 9 (b) and 10, except that in the calculation of tensile strength, variations from the specified cross-sectional area (1.00 sq in.) at the waistline may be disregarded, provided deviations of $\frac{1}{32}$ in. or more from the specified nominal dimensions (1.00 in.) are reported.

TABLE 4
WELL-SIMULATION TEST SCHEDULES FOR CURING STRENGTH SPECIMENS

1	2	3	4	5	6	7	8	9	10	11	12	13
			TEMPERATURE, deg. F.									
			Elapsed Time from First Application of Heat and Pressure, hr-min.									
Schedule Number	Depth, ft.	Pressure,[1] psi	0:30	0:45	1:00	1:15	1:30	2:00	2:30	3:00	3:30	[2]4:00
1S	1,000	800	80	81	82	83	84	86	88	90	92	95
2S	2,000	1,600	90	91	92	93	94	96	99	102	106	110
3S	4,000	3,000	100	105	109	113	117	121	125	130	135	140
4S	6,000	3,000	100	115	120	124	128	136	144	152	160	170
5S	8,000	3,000	105	115	125	135	140	150	165	175	190	200
5AS	9,000	3,000	105	120	130	140	145	160	175	185	200	215
6S	10,000	3,000	110	125	140	150	155	170	185	200	215	230
7S	12,000	3,000	115	135	155	175	185	200	215	230	245	260
8S	14,000	3,000	125	150	170	195	215	230	245	260	275	290
9S	16,000	3,000	135	165	190	220	245	260	275	290	305	320
10S	18,000	3,000	145	180	210	245	280	305	315	325	335	350

[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 1S .... 800 psi ± 100 psi
Schedule 2S ....1600 psi ± 200 psi
Schedules 3S through 10S............3000 psi ± 500 psi

[2]Final temperature (Col. 13) shall be maintained ± 3 F throughout the remainder of the curing period.

SECTION VI
SOUNDNESS AND FINENESS TESTS

31. Soundness Tests. Tests for soundness of oil-well cement should be made in accordance with the provisions of the testing procedure provided by the American Society for Testing Materials in the latest edition of ASTM C 151: Method of Test for Autoclave Expansion of Portland Cement.

32. Fineness Tests. Tests for fineness of oil-well cement should be made in accordance with the testing procedure provided by the American Society for Testing Materials in the latest edition of ASTM C 115: Method of Testing Fineness of Portland Cement by the Turbidimeter.

SECTION VII
THICKENING-TIME TESTS

NOTE: *Thickening-time tests are designed to determine the length of time a given cement slurry remains in a fluid state under given laboratory conditions, and thus serve as a method of comparing various cements. Following is a description of three recommended methods of test.*

PRESSURE-TEMPERATURE THICKENING-TIME TEST

33. Apparatus. The following apparatus should be used:

a. Thickening-time tester unit as developed by Pan American Petroleum Corp., formerly Stanolind Oil & Gas Co.* This apparatus consists essentially of a rotating cylindrical slurry container equipped with a stationary paddle assembly, all enclosed in a pressure chamber capable of withstanding the pressures and temperatures described herein. The space between the slurry container and the walls of the pressure container should be completely filled with white mineral oil, grade 95NF (National Formulary). A heating element capable of raising the temperature of this oil bath at the rate of at least 5 F per min is provided. Thermocouples are provided for determining the temperature of the oil bath and also that of the cement slurry. The slurry container is rotated at a speed of 50 rpm. The consistency of the cement slurry is indicated by the amount of deformation of a standardized coil spring connecting the stirring paddle and a stationary head. The stirring paddle and all metal parts of the slurry container exposed to the slurry are made of corrosion-resistant alloys.

b. Interval counter (stopwatch).

34. **Calibration.** The apparatus should be calibrated with Paratone calibration oil,** the viscosity of which is known over a range of 5 to 100 poises. The apparatus should be recalibrated at least once each year, also whenever wear of any metallic part in contact with the cement slurry becomes noticeable or when such part is replaced, and when the coil spring of the indicating mechanism is replaced. (Paratone should be discarded after use, because of possible contamination during the calibration test.) The thermocouples should be calibrated at frequent intervals to insure the accuracy of temperature measurements.

Procedure

35. Operating Instructions. Detailed operating instructions, as furnished by the manufacturer, are applicable under this method and should be followed. The apparatus should be at room temperature at the start of each test.

36. **Filling of Apparatus.** The slurry (prepared according to Sect. II) should be quickly poured into the slurry container. During this filling operation, the slurry should be lightly stirred to prevent segregation. When the slurry container is completely filled, the bottom should be screwed in, care being taken to insure that all air is excluded. The center plug should then be screwed in tightly, the container placed in the pressure chamber, and the chamber filled with the bath oil. Next, the head assembly of the pressure chamber should be screwed in place, the slurry container set to rotating, and the oil-pressure pump started. With the pump in operation, any air in the top of the chamber should be vented through the top vent. The operation of filling and sealing the slurry container, placing the container in the pressure chamber, sealing and venting the pressure chamber, and placing the apparatus in operation should be completed within 5 min after completion of the mixing period.

37. **Temperature and Pressure Control.** During the test period, the temperature of the cement slurry, determined with the thermocouple in position in the center of the slurry container, and the pressure in the slurry container, should be increased in accordance with the well-simulation schedules given herein.

38. **Casing-Cementing Schedules.** Well-simulation test procedures for casing cementing are given in Schedules 1 through 10. These schedules are designed to represent field practices in cementing wells having depths ranging from 1,000 to 18,000 ft, based on assumed conditions shown in Table 5, and on the mud-circulating pressures and bottom-hole temperatures shown in Fig. 6 and 7.

39. **Squeeze-Cementing Schedules.** Well-simulation test procedures for squeeze cementing are given in Schedules 12 through 20. These schedules are designed to represent field practices in squeeze cementing of wells having depths ranging from 1,000 to 16,000 ft. These schedules are based on the data shown in Table 6 and Fig. 6 and 7.

40. **Temperature and Pressure Ranges.** The thickening time for classes A, B, and C cement should be determined in accordance with Schedules 1 through 4 for casing-cementing simulation tests, and in accordance with Schedules 12 through 15 for squeeze-cementing simulation tests. The thickening time for classes N, D, E, and F cement should be determined in accordance with Schedules 4 through 9 for casing-cementing simulation tests, and in accordance with Schedules 15 through 20 for squeeze-cementing simulation tests. If only limited data are required it is not necessary to conduct tests in accordance with all of the above mentioned schedules.

41. **Thickening Time.** The elapsed time between the starting of the apparatus and the occurrence of a consistency of 100 poises should be reported as the thickening time for the cement under test for the particular schedule followed in the test. For the schedules involving the higher temperatures, it is permissible to stop the test at a consistency of approximately 70 poises; and, by plotting the results, to extrapolate to the 100-poise value.

42. **Recording of Results.** The results of the thickening-time tests should be recorded on forms similar to that shown on Fig. 4. The results should be reported in poises.

*As illustrated in Fig. 8, 9, and 10 herein. Further information pertaining to the Pan American thickening-time tester may be obtained from Refinery Supply Co., Tulsa, Okla.

**Paratone calibration oil is obtainable in gallon lots from Refinery Supply Co., Tulsa, Okla. A certification will be furnished with each lot showing the viscosity-temperature relations (four points between 5-30 poises and four between 30-100 poises) as determined in a Precision Interchemical Rotational Viscometer at a constant shear rate of 50 rpm, by the Armour Research Foundation of Illinois Institute of Technology. It is recommended that any lot of oil not be used after two years from its date of certification.

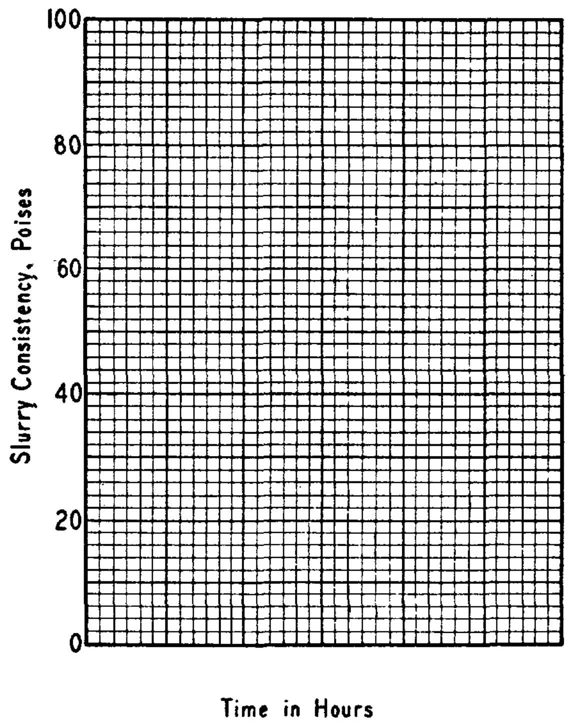
API CEMENT EVALUATION TESTS
PAN AMERICAN[1] THICKENING-TIME TESTER

Brand.. Source..

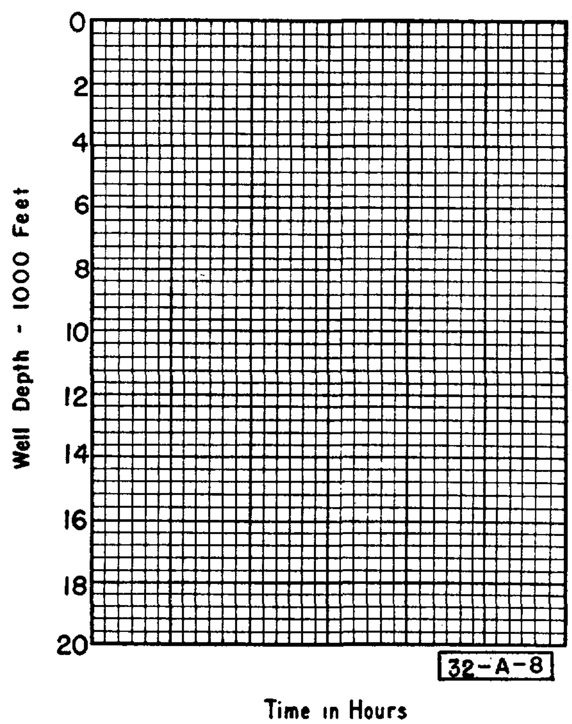
Class.................... Mixing Water, per cent.................................... Slurry Weight, lb. per gal.................................... lb. per cu. ft.

Tested by.. Date Tested..

THICKENING TIME DATA



SUMMARY OF THICKENING TIME DATA



Compressive (1) and/or Tensile Strength (2), psi.

Bath Temp., deg. F., or Test Schedule	Time cured under water, hr. 8 (1)	8 (2)	12 (1)	12 (2)	18 (1)	18 (2)	24 (1)	24 (2)	36 (1)	36 (2)	48 (1)	48 (2)	72 (1)	72 (2)
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Remarks:..

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FIG. 4

FORM FOR REPORTING STRENGTH TESTS AND RESULTS OBTAINED FROM THICKENING-TIME TESTS ON THE PAN AMERICAN[1] THICKENING-TIME TESTER.

[1]Formerly Stanolind.

ATMOSPHERIC PRESSURE THICKENING-TIME TEST—A

43. **Apparatus.** The following apparatus should be used:

a. Thickening-time tester unit as developed by the Halliburton Oil Well Cementing Co.* This unit is furnished complete with motor, switches, thermo-regulator, base board, and carrying case.

b. Interval counter (stopwatch).

44. **Calibration.** The apparatus should be calibrated with Paratone calibration oil,** the viscosity of which is known over a range of 5 to 100 poises. The apparatus should be recalibrated at least once each year, also whenever wear of any metallic part in contact with cement slurry becomes noticeable or when such part is replaced. (Paratone should be discarded after use, because of possible contamination during the calibration test.)

Preparation of Apparatus

45. **Cleaning and Lubricating.** Care should be taken to insure that all surfaces which come in contact with the cement slurry are clean. After each test such surfaces (particularly the outside edges of the paddles) should be cleaned and brushed with a brass cement-mold brush. Surfaces which come in contact with the slurry should be given a thin coating of water-proof grease or light oil before each test. The ball bearings in the top of the cylinder and those in the torque-indicating mechanism should be kept clean by frequent washings in kerosine and should be oiled with a light grade of lubricating oil.

46. **Water Bath.** Water should always be used as the bath liquid. For this reason, all exposed steel parts should be kept clean and lightly oiled or greased. The water bath should always be filled with water before turning on the heater.

47. **Assembly.** The slurry container mechanism should be assembled and the paddle rotated by hand to insure that none of the parts scrape. The index of the torque-indicating mechanism should point to zero when the pendulum hangs free. If it does not, the quadrant scale should be adjusted.

Procedure

48. **Filling of Apparatus.** The slurry (prepared according to Sect. II) should be quickly poured into the slurry container to the proper fill level, which is indicated by the groove around the inside of the container. The paddle should then be inserted, the lid placed in position, and the slotted shaft engaged with the pin in the torque shaft in the lid. The assembly should then be placed in the bath, the gears engaged, and the torque-indicator cord passed around the torque drum and looped over the pin. Care should be taken to insure that the cord is properly aligned on the 1¾-in. drums of both the torque-indicator ring and the torque drum in order to preserve a constant radius of pull. The motor should then be started. The interval between the completion of mixing and the starting of the apparatus should not exceed 1 min.

49. **Temperature Ranges.** The thickening time for classes A, B, and C cement should be determined for temperature ranges of 80-100 F, 80-120 F, and 80-140 F; and the thickening time for classes N, D, E, and F cement for ranges of 80-140 F, 80-160 F, 80-180 F, and 80-200 F. If only limited data are required, it is not necessary to conduct tests at all of these temperature ranges.

50. **Temperature Control.** When testing slurries within the ranges of 80-100 F, 80-120 F, and 80-140 F, the rate of temperature increase should be 1 F per min. When testing within the ranges of 80-160 F, 80-180 F, and 80-200 F, the rate of increase should be 2 F per min. When the final temperature of the range is reached, that temperature should be maintained within ±1 F.

51. **Test Readings.** Readings of the torque-indicator scale should be taken at 10-min intervals for the first hour and at 30-min intervals thereafter, until the slurry starts to stiffen, when readings should be taken at 10-min intervals or at increments of 10 poises.

52. **Thickening Time.** The elapsed time between the initial starting of the apparatus and the occurrence of a consistency of 100 poises should be reported as the thickening time of the cement under test, for the particular temperature range. Under some test conditions, the slurry stiffens very rapidly; and in order to avoid difficulty in removing the thickened cement slurry, it may be advisable to stop the test when a consistency of approximately 70 poises is reached. In such cases, the data should be plotted and the curve extrapolated to the 100-poise value. If the slurry stiffens very slowly, the test may be stopped at the end of an 8-hr test period, and the results reported as "8+ hr."

53. **Recording of Results.** The results of the thickening-time tests should be recorded on a form similar to that shown in Fig. 5. The results should be reported in poises.

NOTE: *In the operation of the apparatus, a moment is created which pulls the pendulum from the vertical position. This moment is a maximum when the pendulum is in a horizontal position. The quadrant scale behind the pendulum is graduated in ten equal increments of torque, and readings taken on this scale must be converted to poises, on the basis of the calibration chart.*

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*As illustrated in Fig. 11, 12, 13 and 14 herein. Further information pertaining to the Halliburton thickening-time tester may be obtained from Halliburton Oil Well Cementing Co., Duncan, Okla.

**Paratone calibration oil is obtainable in gallon lots from Refinery Supply Co., Tulsa, Okla. A certification will be furnished with each lot showing the viscosity-temperature relation (four points between 5-30 poises and four between 30-100 poises) as determined in a Precision Interchemical Rotational Viscometer at a constant shear rate of 50 rpm, by the Armour Research Foundation of Illinois Institute of Technology. It is recommended that any lot of oil not be used after two years from its date of certification.

ATMOSPHERIC PRESSURE THICKENING-TIME TEST—B

54. Apparatus. The following apparatus should be used:

a. **Thickening-time tester unit as developed by the Standard Oil Company of California*. The apparatus is mounted on a base and is furnished complete with motor, immersion heater, thermostat, pulleys, two V-belts, and two spring scales.**

b. **Interval counter (stopwatch).**

55. Calibration. The torque-measuring spring scales (0 to 8 oz and 0 to 64 oz) should be calibrated frequently with dead weights.

Preparation of Apparatus

56. Accuracy. The apparatus should first be checked carefully to make certain that the paddles and slurry container are dimensionally accurate, that the outer paddles rotate freely about the stationary ones without play or wobble, that the torque measuring arm is $2\frac{13}{32}$ in. in length, and that the two spring scales are accurate.

57. Cleaning and Lubricating. Care should be taken to insure that all surfaces which come in contact with the cement slurry are clean. After each test such surfaces should be cleaned and brushed with a brass cement-mold brush. The following places should be well lubricated with water-proof grease before the start of each test: a, the bearing surface on the bottom of the slurry container which supports the container in the water bath; b, the inside of the bottom of the stationary paddle and the brass ring between this paddle and the movable paddle (sufficient grease should be used to prevent the slurry from entering the bearing); c, the top of the stationary paddle which is inserted into the revolving frame; and d, the threads between the container and the container bottom, in order to prevent loss of water to or from the cement slurry and to facilitate disassembly of the apparatus for cleaning after the test.

58. Assembly. After lubrication, the apparatus should be assembled in the water bath and rotated at the higher speed (60 rpm) to determine that none of the parts scrape. The spring scale may indicate a small torque at this speed. If so, this value should be recorded and subtracted from subsequent test readings. Care should be exercised that the water in the water bath covers the immersion heaters and is slightly above the height to which the slurry will fill the shell. Also, care should be taken to insure that the flexible chain which attaches to the spring scale does not touch the sides of the water bath, and that the direction of pull of the chain is tangential to the segment of the shell to which the chain is attached.

*As illustrated in Fig. 15 and 16 herein. Further information pertaining to the Standard of California thickening-time tester may be obtained from Cook Laboratories, Menlo Park, Calif.

Procedure

59. Pretest Temperature. Prior to testing, the apparatus should be heated to the desired pretest temperature (usually 80 F).

60. Spring Scale. The spring scale with the range of 0 to 8 oz should be used at the start of the test and until the pull reaches 8 oz, at which time it should be replaced with the scale with the range of 0 to 64 oz.

61. Filling of Apparatus. The slurry (prepared according to Sect. II) should be quickly poured into the slurry container of the apparatus. A funnel may be used to facilitate this transfer. The cement should fill the slurry container to the proper height which is indicated by a mark 1¼ in. from the top of the container. The time for filling the slurry container and placing the apparatus in operation should not exceed 1 min.

62. Testing Speeds. The apparatus should then be started at the higher speed (approximately 60 rpm), and the test continued at this speed for 15 min, after which the speed should be reduced to 14.5 rpm by placing the V-belt on the larger pulley. It is important that this speed be held within ±0.2 rpm since variations in speed affect the thickening time considerably.

63. Temperature Ranges. The thickening time for classes A, B, and C cement should be determined for temperature ranges of 80-100 F, 80-120 F, and 80-140 F; and the thickening time for classes N, D, E, and F cement for ranges of 80-140 F, 80-160 F, 80-180 F, and 80-200 F. If only limited data are required, it is not necessary to conduct tests at all of these temperature ranges.

64. Temperature Control. When testing slurries within the ranges of 80-100 F, 80-120 F, and 80-140 F the rate of temperature increase should be 1 F per min. When testing within the ranges of 80-160 F, 80-180 F, and 80-200 F, the rate of increase should be 2 F per min. When the final temperature of the range is reached, that temperature should be maintained within ±1 F.

65. Test Readings. Minimum readings of the pull exerted by the slurry should be taken at 10-min intervals, starting when the test apparatus is started at the higher speed. Also, readings should be taken immediately before and after the speed is changed.

66. Thickening Time. The elapsed time between the initial starting of the apparatus and the occurrence of a consistency of 40 oz should be reported as the thickening time of the cement under test.

67. Recording of Results. The results of the thickening-time tests should be recorded on a form similar to that shown in Fig. 5. The results should be reported in ounces.

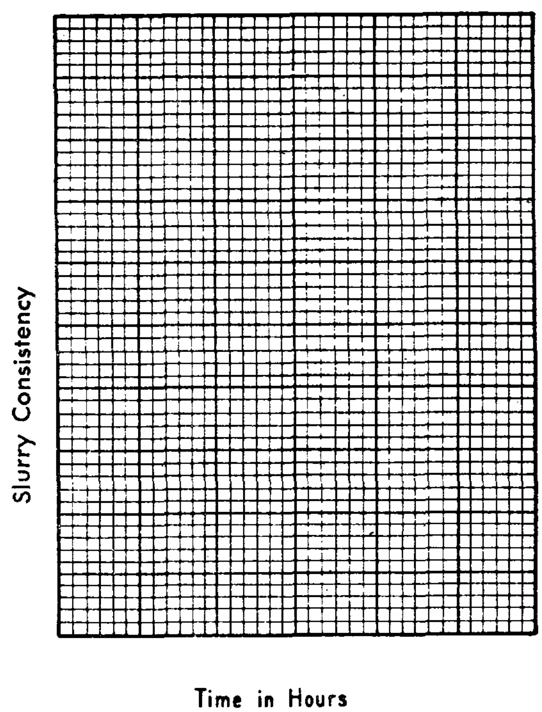
API CEMENT EVALUATION TESTS
..................................THICKENING-TIME TESTER

Brand...Source...

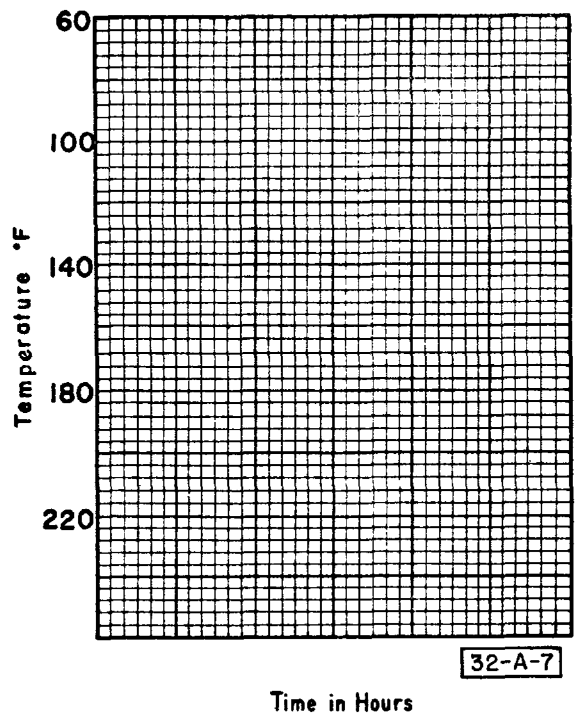
Class..............................Mixing Water, per cent...Slurry Weight, lb. per gal. lb. per cu. ft...

Tested by...Date Tested...

THICKENING TIME DATA



SUMMARY OF THICKENING TIME DATA



Bath Temp., deg. F., or Test Schedule	Compressive (1) and/or Tensile Strenth (2), psi. — Time cured under water, hr. 8		12		18		24		36		48		72	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)

Remarks:...

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FIG. 5

FORM FOR REPORTING STRENGTH TESTS AND RESULTS OBTAINED FROM THICKENING-TIME TESTS ON THE HALLIBURTON OR STANDARD OF CALIFORNIA THICKENING-TIME TESTER.

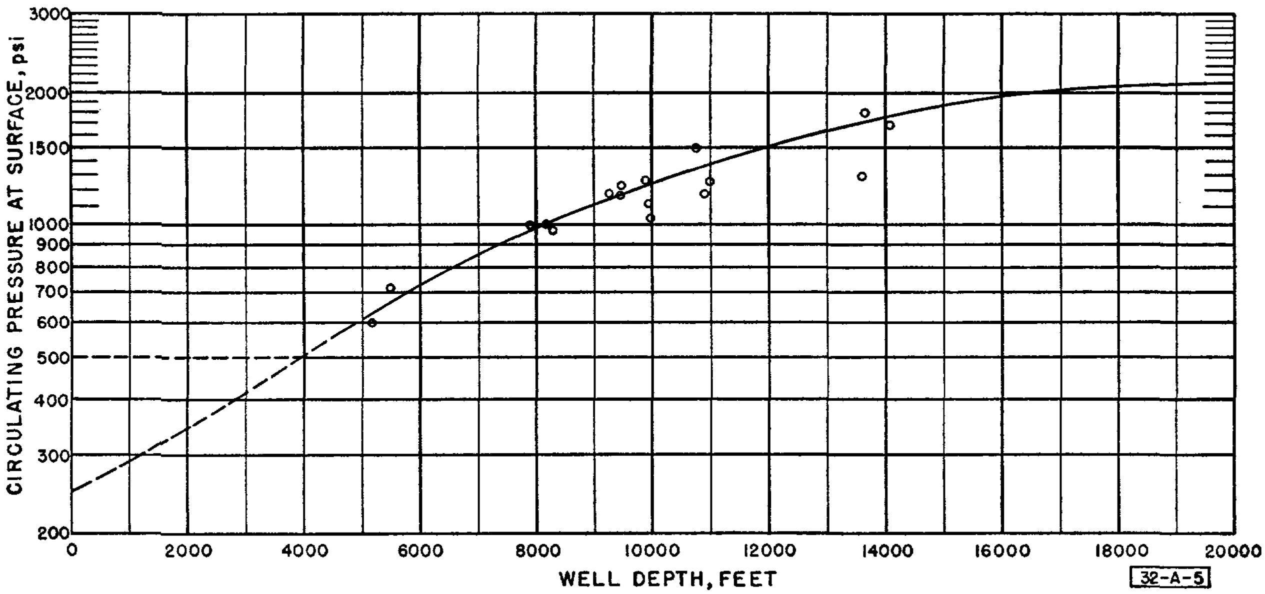

FIG. 6

AVERAGE MUD-CIRCULATING PRESSURES

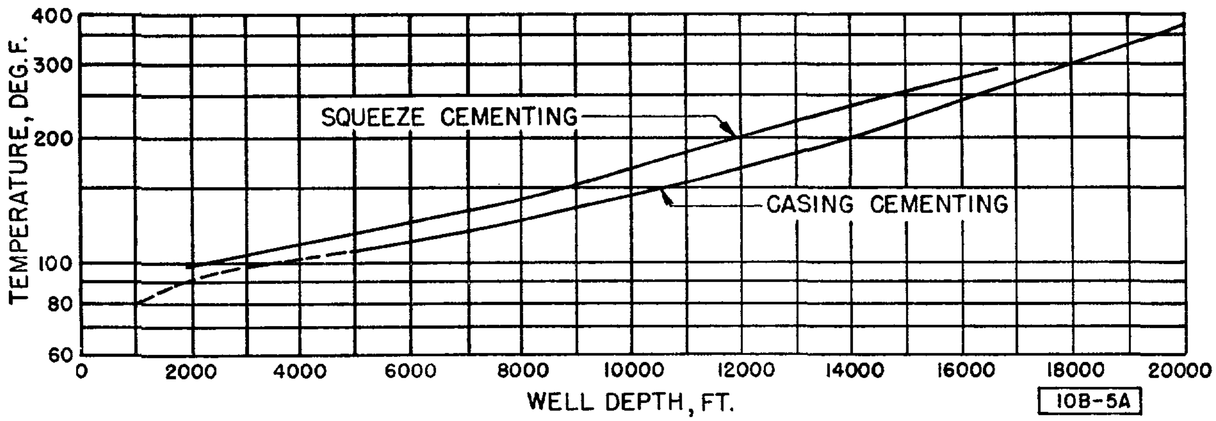

FIG. 7

BOTTOM-HOLE CASING-CEMENTING AND SQUEEZE-CEMENTING TEMPERATURES

TABLE 5

BASIS FOR CASING-CEMENTING WELL-SIMULATION TEST SCHEDULES

1	2	3		4	5	6	7
Schedule No.	Depth, ft.	Mud-Weight, lb. per gal.	Mud-Weight, lb. per cu. ft.[1]	Surface Pressure, psi[2]	Bottom-Hole Circulating Temperature, deg. F.[3]	Bottom-Hole Pressure, psi[4]	Total Cementing Time, min.[5]
1	1,000	10	74.8	500	80	1,020	23
2	2,000	10	74.8	500	91	1,540	27
3	4,000	10	74.8	500	103	2,580	37
4	6,000	10	74.8	750	113	3,870	46
5	8,000	10	74.8	1,000	125	5,160	55
5A	9,000	11	82.3	1,120	135	6,270	60
6	10,000	12	89.8	1,250	144	7,480	65
7	12,000	14	104.7	1,500	172	10,230	74
8	14,000	16	119.7	1,750	206	13,390	84
9	16,000	17	127.2	2,000	248	16,140	91
10	18,000	18	134.6	2,000	300	18,800	100

[1]Mud weights obtained from a review of field data.

[2]Surface pressure obtained from a review of field data.

[3]Bottom-hole circulating temperatures averaged from actual field tests run at various depths.

[4]Bottom-hole pressures calculated from surface pressures and mud weights.

[5]Total cementing time calculated from the following assumed conditions:

Casing size: 7-in. outside diameter
Size of job: 300 sacks of cement
Pumping rate: 50 cu ft per min

TABLE 6

BASIS FOR SQUEEZE-CEMENTING WELL-SIMULATION TEST SCHEDULES

1	2	3		4	5	6	7
Schedule No.	Depth, ft.	Mud-Weight, lb. per gal.	Mud-Weight, lb. per cu. ft.[1]	Surface Pressure, psi[2]	Bottom-Hole Circulating Temperature, deg. F.[3]	Bottom-Hole Pressure, psi[4]	Total Cementing Time, min.[5]
12	1,000	10	74.8	500	89	3,300	29
13	2,000	10	74.8	500	98	4,200	31
14	4,000	10	74.8	500	116	4,600	35
15	6,000	10	74.8	800	136	6,700	40
16	8,000	10	74.8	1,000	159	7,800	45
16A	9,000	11	82.3	1,200	171	8,500	47
17	10,000	12	89.8	1,300	186	9,400	49
18	12,000	14	104.7	1,500	213	11,800	50
19	14,000	16	119.7	1,800	242	14,000	55
20	16,000	17	127.2	2,000	271	16,500	60

[1]Mud weights obtained from a review of field data.

[2]Surface pressure obtained from a review of field data.

[3]Bottom-hole circulating temperatures averaged from actual field tests run at various depths.

[4]Bottom-hole pressures calculated from surface pressures and mud weights.

[5]Total cementing time calculated from the following assumed conditions:

Tubing size: 2½ in.
Size of job: 100 sacks of cement
Pumping rate: 14.0 cu ft per min displacing; 14.0 cu ft to 1.4 cu ft per min squeezing

SCHEDULE 1

1000-ft CASING-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	500 psi
Size of job:	300 sacks
Mud weight:	10 lb per gal 74.8 lb per cu ft
Bottom-hole temperature:	80 F
Bottom-hole pressure:	1020 psi
Mixing time:	18 min
Total cementing time:	23 min

Time, min.	Pressure, psi	Temperature, deg. F.
0	500	80
2	550	80
4	590	80
6	640	80
8	680	80
10	730	80
12	780	80
14	820	80
16	870	80
18	910	80
20	960	80
22	1010	80
23	1020	80

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

SCHEDULE 2

2000-ft CASING-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	500 psi
Size of job:	300 sacks
Mud weight:	10 lb per gal 74.8 lb per cu ft
Bottom-hole temperature:	81 F
Bottom-hole pressure:	1540 psi
Mixing time:	18 min
Total cementing time:	27 min

Time, min.	Pressure, psi	Temperature, deg. F.
0	500	80
2	580	81
4	650	82
6	730	82
8	810	83
10	890	84
12	960	85
14	1040	86
16	1120	86
18	1190	87
20	1270	88
22	1350	89
24	1420	90
26	1500	90
27	1540	91

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

SCHEDULE 3

4000-ft. CASING-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	500 psi
Size of job:	300 sacks
Mud weight:	10 lb per gal 74.8 lb per cu ft
Bottom-hole temperature:	103 F
Bottom-hole pressure:	2580 psi
Mixing time:	18 min
Total cementing time:	37 min

Time, min.	Pressure, psi	Temperature, deg. F.
0	500	80
2	610	81
4	730	82
6	840	84
8	960	85
10	1070	86
12	1180	88
14	1300	89
16	1410	90
18	1530	91
20	1640	92
22	1750	94
24	1870	95
26	1980	96
28	2100	98
30	2210	99
32	2320	100
34	2440	101
36	2550	102
37	2580	103

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

SCHEDULE 4

6000-ft CASING-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	750 psi
Size of job:	300 sacks
Mud weight:	10 lb per gal
	74.8 lb per cu ft
Bottom-hole temperature:	113 F
Bottom-hole pressure:	3870 psi
Mixing time:	18 min
Total cementing time:	46 min

Time min.	Pressure, psi	Temperature, deg. F.
0	750	80
2	890	81
4	1020	83
6	1160	84
8	1290	86
10	1420	87
12	1560	89
14	1700	90
16	1830	91
18	1970	93
20	2100	94
22	2230	96
24	2370	97
26	2500	99
28	2640	100
30	2780	101
32	2910	103
34	3040	104
36	3180	106
38	3310	107
40	3450	109
42	3590	110
44	3720	111
46	3870	113

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

SCHEDULE 5

8000-ft CASING-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	1000 psi
Size of job:	300 sacks
Mud weight:	10 lb per gal
	74.8 lb per cu ft
Bottom-hole temperature:	125 F
Bottom-hole pressure:	5160 psi
Mixing time:	18 min
Total cementing time:	55 min

Time min.	Pressure, psi	Temperature, deg. F.
0	1000	80
2	1150	82
4	1300	83
6	1450	85
8	1600	87
10	1750	88
12	1900	90
14	2050	91
16	2200	93
18	2350	95
20	2500	96
22	2650	98
24	2800	100
26	2950	101
28	3100	103
30	3250	104
32	3400	106
34	3550	108
36	3700	109
38	3850	111
40	4000	112
42	4150	114
44	4300	116
46	4450	117
48	4600	119
50	4750	121
52	4900	122
54	5050	124
55	5160	125

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

SCHEDULE 5A

9,000-ft CASING-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	1120 psi
Size of job:	300 sacks
Mud weight:	11 lb per gal
	82.3 lb per cu ft
Bottom-hole temperature:	135 F
Bottom-hole pressure:	6270 psi
Mixing time:	18 min
Total cementing time:	60 min

Time, min.	Pressure, psi	Temperature, deg. F.
0	1120	80
2	1290	82
4	1460	84
6	1640	85
8	1810	87
10	1980	89
12	2150	91
14	2320	93
16	2500	95
18	2670	96
20	2840	98
22	3010	100
24	3180	102
26	3350	104
28	3520	106
30	3700	107
32	3870	109
34	4030	111
36	4210	113
38	4380	115
40	4550	117
42	4730	118
44	4900	120
46	5070	122
48	5240	124
50	5410	126
52	5580	128
54	5760	129
56	5930	131
58	6100	133
60	6270	135

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

SCHEDULE 6

10,000-ft CASING-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	1250 psi
Size of job:	300 sacks
Mud weight:	12 lb per gal
	89.8 lb per cu ft
Bottom-hole temperature:	144 F
Bottom-hole pressure:	7480 psi
Mixing time:	18 min
Total cementing time:	65 min

Time, min.	Pressure, psi	Temperature, deg. F.
0	1250	80
2	1440	82
4	1630	84
6	1830	86
8	2020	88
10	2210	90
12	2400	92
14	2590	94
16	2790	96
18	2980	98
20	3170	100
22	3360	102
24	3550	104
26	3750	106
28	3940	108
30	4130	110
32	4320	111
34	4510	113
36	4710	115
38	4900	117
40	5090	119
42	5280	121
44	5470	123
46	5670	125
48	5860	127
50	6050	129
52	6250	131
54	6440	133
56	6630	135
58	6930	137
60	7020	139
62	7210	141
64	7400	143
65	7480	144

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

SCHEDULE 7

12,000-ft CASING-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	1500 psi
Size of job:	300 sacks
Mud weight:	14 lb per gal
	104.7 lb per cu ft
Bottom-hole temperature:	172 F
Bottom-hole pressure:	10,230 psi
Mixing time:	18 min
Total cementing time:	74 min

Time, min.	Pressure, psi	Temperature, deg. F.
0	1,500	80
2	1,740	82
4	1,970	85
6	2,210	87
8	2,440	90
10	2,680	92
12	2,910	95
14	3,140	97
16	3,380	100
18	3,610	102
20	3,850	105
22	4,080	107
24	4,320	110
26	4,560	112
28	4,790	115
30	5,020	117
32	5,260	120
34	5,490	122
36	5,730	125
38	5,970	127
40	6,200	130
42	6,430	132
44	6,670	135
46	6,910	137
48	7,140	140
50	7,380	142
52	7,610	144
54	7,850	147
56	8,090	149
58	8,320	152
60	8,560	154
62	8,790	157
64	9,030	159
66	9,270	162
68	9,500	164
70	9,740	167
72	9,970	169
74	10,230	172

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

SCHEDULE 8

14,000-ft CASING-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	1750 psi
Size of job:	300 sacks
Mud weight:	16 lb per gal
	119.7 lb per cu ft
Bottom-hole temperature:	206 F
Bottom-hole pressure:	13,390 psi
Mixing time:	18 min
Total cementing time:	84 min

Time, min.	Pressure, psi	Temperature, deg. F.
0	1,750	80
2	2,030	83
4	2,310	86
6	2,580	89
8	2,860	92
10	3,140	95
12	3,420	98
14	3,700	101
16	3,970	104
18	4,250	107
20	4,530	110
22	4,810	113
24	5,090	116
26	5,370	119
28	5,650	122
30	5,920	125
32	6,200	128
34	6,480	131
36	6,760	134
38	7,040	137
40	7,320	140
42	7,600	143
44	7,880	146
46	8,160	149
48	8,440	152
50	8,710	155
52	8,990	158
54	9,270	161
56	9,550	164
58	9,830	167
60	10,110	170
62	10,390	173
64	10,670	176
66	10,950	179
68	11,230	182
70	11,500	185
72	11,780	188
74	12,060	191
76	12,340	194
78	12,620	197
80	12,900	200
82	13,180	203
84	13,390	206

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

SCHEDULE 9

16,000-ft CASING-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	2000 psi
Size of job:	300 sacks
Mud weight:	17 lb per gal
	127.2 lb per cu ft
Bottom-hole temperature:	248 F
Bottom-hole pressure:	16,140 psi
Mixing time:	18 min
Total cementing time:	91 min

Time, min.	Pressure, psi	Temperature, deg. F.
0	2,000	80
2	2,310	84
4	2,620	87
6	2,930	91
8	3,240	95
10	3,550	99
12	3,860	102
14	4,170	106
16	4,480	110
18	4,790	113
20	5,100	117
22	5,410	121
24	5,720	124
26	6,030	128
28	6,340	132
30	6,650	135
32	6,960	139
34	7,270	143
36	7,580	147
38	7,890	150
40	8,200	154
42	8,510	158
44	8,820	161
46	9,130	165
48	9,440	169
50	9,750	172
52	10,060	176
54	10,370	180
56	10,680	183
58	10,990	187
60	11,300	191
62	11,610	194
64	11,920	198
66	12,230	202
68	12,540	206
70	12,850	209
72	13.160	213
74	13,470	217
76	13,780	220
78	14,090	224
80	14,400	228
82	14,710	231
84	15,020	235
86	15,330	239
88	15,640	243
90	15,950	246
91	16,140	248

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

SCHEDULE 10

18,000-ft CASING-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	8000 psi
Size of job:	300 sacks
Mud weight:	18 lb per gal
	134.6 lb per cu ft
Bottom-hole temperature:	300 F
Bottom-hole pressure:	18,800 psi
Mixing time:	18 min
Total cementing time:	100 min

Time, min.	Pressure, psi	Temperature, deg. F.
0	2,000	80
2	2,340	84
4	2,670	89
6	3,010	93
8	3,340	98
10	3,680	102
12	4,020	106
14	4,350	111
16	4,690	115
18	5,020	120
20	5,360	124
22	5,700	128
24	6,030	133
26	6,370	137
28	6,700	142
30	7,040	146
32	7,380	150
34	7,710	155
36	8,050	159
38	8,380	164
40	8,720	168
42	9,060	172
44	9,390	177
46	9,730	181
48	10,060	186
50	10,400	190
52	10,740	194
54	11,070	199
56	11,410	203
58	11,740	208
60	12,080	212
62	12,420	216
64	12,750	221
66	13,090	225
68	13,420	230
70	13,760	234
72	14,100	238
74	14,430	243
76	14,770	247
78	15,100	252
80	15,440	256
82	15,780	260
84	16,110	265
86	16,450	269
88	16,780	274
90	17,120	278
92	17,460	282
94	17,790	287
96	18,130	291
98	18,460	296
100	18,800	300

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

NOTE: Data for Schedule 11, "20,000-ft Casing-Cementing Well-Simulation Test" has not yet been developed.

SCHEDULE 12

1,000-ft SQUEEZE-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	500 psi
Size of job:	100 sacks
Mud weight:	10 lb per gal
	74.8 lb per cu ft
Bottom-hole temperature:	89 F
Bottom-hole pressure:*	3300 psi
Mixing time:	8 min
Total cementing time:	29 min

Time, min.	Pressure, psi	Temperature, deg. F.
0	500	80
1	900	83
2	1200	86
3	1300	89
4	1300	89
25	1300	89
26	1300	89
27	2300	89
28	2800	89
29	3300	89

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

SCHEDULE 13

2000-ft SQUEEZE-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	500 psi
Size of job:	100 sacks
Mud weight:	10 lb per gal
	74.8 lb per cu ft
Bottom-hole temperature:	98 F
Bottom-hole pressure:*	4200 psi
Mixing time:	8 min
Total cementing time:	31 min

Time, min.	Pressure, psi	Temperature, deg. F.
0	500	80
1	900	84
2	1200	87
3	1600	91
4	1900	94
5	2300	98
6	2300	98
27	2300	98
28	2800	98
29	3300	98
30	3300	98
31	4200	98

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

*Bottom-hole pressure is the final squeeze pressure and is equal to the calculated static pressure plus 2500 psi surface pressure.

SCHEDULE 14

4000-ft SQUEEZE-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	500 psi
Size of job:	100 sacks
Mud weight:	10 lb per gal
	74.8 lb per cu ft
Bottom-hole temperature:	116 F
Bottom-hole pressure:*	5600 psi
Mixing time:	8 min
Total cementing time:	35 min

Time, min.	Pressure, psi	Temperature, deg. F.
0	500	80
1	900	84
2	1200	88
3	1600	92
4	1900	96
5	2300	100
6	2700	104
7	3000	108
8	3400	112
9	3600	116
10	3600	116
31	3600	116
32	4100	116
33	4600	116
34	5100	116
35	5600	116

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

SCHEDULE 15

6000-ft SQUEEZE-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	800 psi
Size of job:	100 sacks
Mud weight:	10 lb per gal
	74.8 lb per cu ft
Bottom-hole temperature:	136 F
Bottom-hole pressure:*	6700 psi
Mixing time:	8 min
Total cementing time:	40 min

Time, min.	Pressure, psi	Temperature, deg. F.
0	800	80
1	1200	84
2	1500	88
3	1900	92
4	2200	96
5	2600	100
6	3000	104
7	3300	108
8	3700	112
9	3900	116
10	4100	120
11	4300	124
12	4600	128
13	4800	132
14	5000	136
15	5000	136
36	5000	136
37	5400	136
38	5900	136
39	6300	136
40	6700	136

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

SCHEDULE 16
8000-ft SQUEEZE-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	1000 psi
Size of job:	100 sacks
Mud weight:	10 lb per gal
	74.8 lb per cu ft
Bottom-hole temperature:	159 F
Bottom-hole pressure:*	7800 psi
Mixing time:	8 min
Total cementing time:	45 min

Time, min.	Pressure, psi	Temperature, deg. F.
0	1000	80
1	1400	84
2	1700	88
3	2100	93
4	2400	97
5	2800	101
6	3200	105
7	3500	109
8	3900	114
9	4100	118
10	4300	122
11	4500	126
12	4800	131
13	5000	135
14	5200	139
15	5400	143
16	5600	148
17	5900	152
18	6100	156
19	6300	159
20	6300	159
41	6300	159
42	6600	159
43	7000	159
44	7400	159
45	7800	159

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

*Bottom-hole pressure is the final squeeze pressure and is equal to the calculated static pressure plus 2500 psi surface pressure.

SCHEDULE 16A
9000-ft SQUEEZE-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	1200 psi
Size of job:	100 sacks
Mud weight:	11 lb per gal
	82.3 lb per cu ft
Bottom-hole temperature:	171 F
Bottom-hole pressure:*	8500 psi
Mixing time:	8 min
Total cementing time:	47 min

Time, min.	Pressure, psi	Temperature, deg. F.
0	1200	80
1	1500	84
2	1800	89
3	2100	93
4	2300	97
5	2600	102
6	2900	106
7	3200	110
8	3500	115
9	3800	119
10	4100	123
11	4300	128
12	4600	132
13	4900	136
14	5200	141
15	5500	145
16	5800	149
17	6100	154
18	6300	158
19	6600	162
20	6900	167
21	7200	171
43	7200	171
44	7500	171
45	7900	171
46	8200	171
47	8500	171

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

SCHEDULE 17
10,000-ft SQUEEZE-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	1300 psi
Size of job:	100 sacks
Mud weight:	12 lb per gal
	89.8 lb per cu ft
Bottom-hole temperature:	186 F
Bottom-hole pressure:*	9400 psi
Mixing time:	8 min
Total cementing time:	49 min

Time, min.	Pressure, psi	Temperature, deg. F.
0	1300	80
1	1700	85
2	2000	89
3	2400	94
4	2700	98
5	3100	103
6	3500	108
7	3800	112
8	4200	117
9	4500	121
10	4700	126
11	5000	131
12	5300	135
13	5500	140
14	5800	144
15	6100	149
16	6300	154
17	6600	158
18	6900	163
19	7200	167
20	7400	172
21	7700	177
22	8000	181
23	8200	186
24	8200	186
45	8200	186
46	8500	186
47	8800	186
48	9100	186
49	9400	186

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

SCHEDULE 18
12,000-ft SQUEEZE-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	1500 psi
Size of job:	100 sacks
Mud weight:	14 lb per gal
	104.7 lb per cu ft
Bottom-hole temperature:	213 F
Bottom-hole pressure:*	11,800 psi
Mixing time:	8 min
Total cementing time:	50 min

Time, min.	Pressure, psi	Temperature, deg. F.
0	1,500	80
1	1,900	85
2	2,200	90
3	2,600	94
4	2,900	99
5	3,300	104
6	3,700	109
7	4,000	113
8	4,400	118
9	4,700	123
10	5,000	128
11	5,300	132
12	5,700	137
13	6,100	142
14	6,400	147
15	6,700	151
16	7,000	156
17	7,300	161
18	7,600	166
19	8,000	170
20	8,300	175
21	8,600	180
22	8,900	184
23	9,200	189
24	9,500	194
25	9,800	199
26	10,200	203
27	10,500	208
28	10,800	213
29	10,800	213
46	10,800	213
47	11,000	213
48	11,200	213
49	11,500	213
50	11,800	213

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

*Bottom-hole pressure is the final squeeze pressure and is equal to the calculated static pressure plus 2500 psi surface pressure.

SCHEDULE 19

14,000-ft SQUEEZE-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	1800 psi
Size of job:	100 sacks
Mud weight:	16 lb per gal 119.7 lb per cu ft
Bottom-hole temperature:	242 F
Bottom-hole pressure:*	14,000 psi
Mixing time:	8 min
Total cementing time:	55 min

Time, min.	Pressure, psi	Temperature, deg. F.
0	1,800	80
1	2,200	85
2	2,500	90
3	2,900	95
4	3,200	100
5	3,600	105
6	4,000	110
7	4,300	115
8	4,700	120
9	5,000	125
10	5,400	130
11	5,800	135
12	6,100	140
13	6,500	145
14	6,800	150
15	7,200	155
16	7,600	160
17	7,900	165
18	8,300	170
19	8,600	175
20	9,000	180
21	9,400	185
22	9,700	190
23	10,100	195
24	10,400	200
25	10,800	205
26	11,200	210
27	11,500	215
28	11,900	220
29	12,200	226
30	12,600	231
31	13,000	237
32	13,300	242
33	13,300	242
51	13,300	242
52	13,500	242
53	13,700	242
54	13,900	242
55	14,000	242

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

SCHEDULE 20

16,000-ft SQUEEZE-CEMENTING WELL-SIMULATION TEST

Field Conditions Assumed

Surface temperature:	80 F
Surface pressure:	2000 psi
Size of job:	100 sacks
Mud weight:	17 lb per gal 127.2 lb per cu ft
Bottom-hole temperature:	271 F
Bottom-hole pressure:*	16,500 psi
Mixing time:	8 min
Total cementing time:	60 min

Time, min.	Pressure, psi	Temperature, deg. F.
0	2,000	80
1	2,400	85
2	2,700	90
3	3,100	95
4	3,400	100
5	3,800	106
6	4,200	111
7	4,500	116
8	4,900	121
9	5,300	126
10	5,600	131
11	6,000	136
12	6,400	141
13	6,800	146
14	7,200	151
15	7,600	157
16	7,900	162
17	8,300	167
18	8,700	172
19	9,100	177
20	9,500	182
21	9,800	187
22	10,200	192
23	10,600	197
24	11,000	202
25	11,400	208
26	11,800	213
27	12,100	218
28	12,500	223
29	12,900	228
30	13,300	233
31	13,700	238
32	14,000	243
33	14,400	248
34	14,800	253
35	15,200	259
36	15,600	265
37	16,000	271
38	16,000	271
56	16,000	271
57	16,100	271
58	16,200	271
59	16,300	271
60	16,500	271

Final temperature and pressure should be held constant to completion of test, within ±2 F and ±10 psi respectively.

*Bottom-hole pressure is the final squeeze pressure and is equal to the calculated static pressure plus 2500 psi surface pressure.

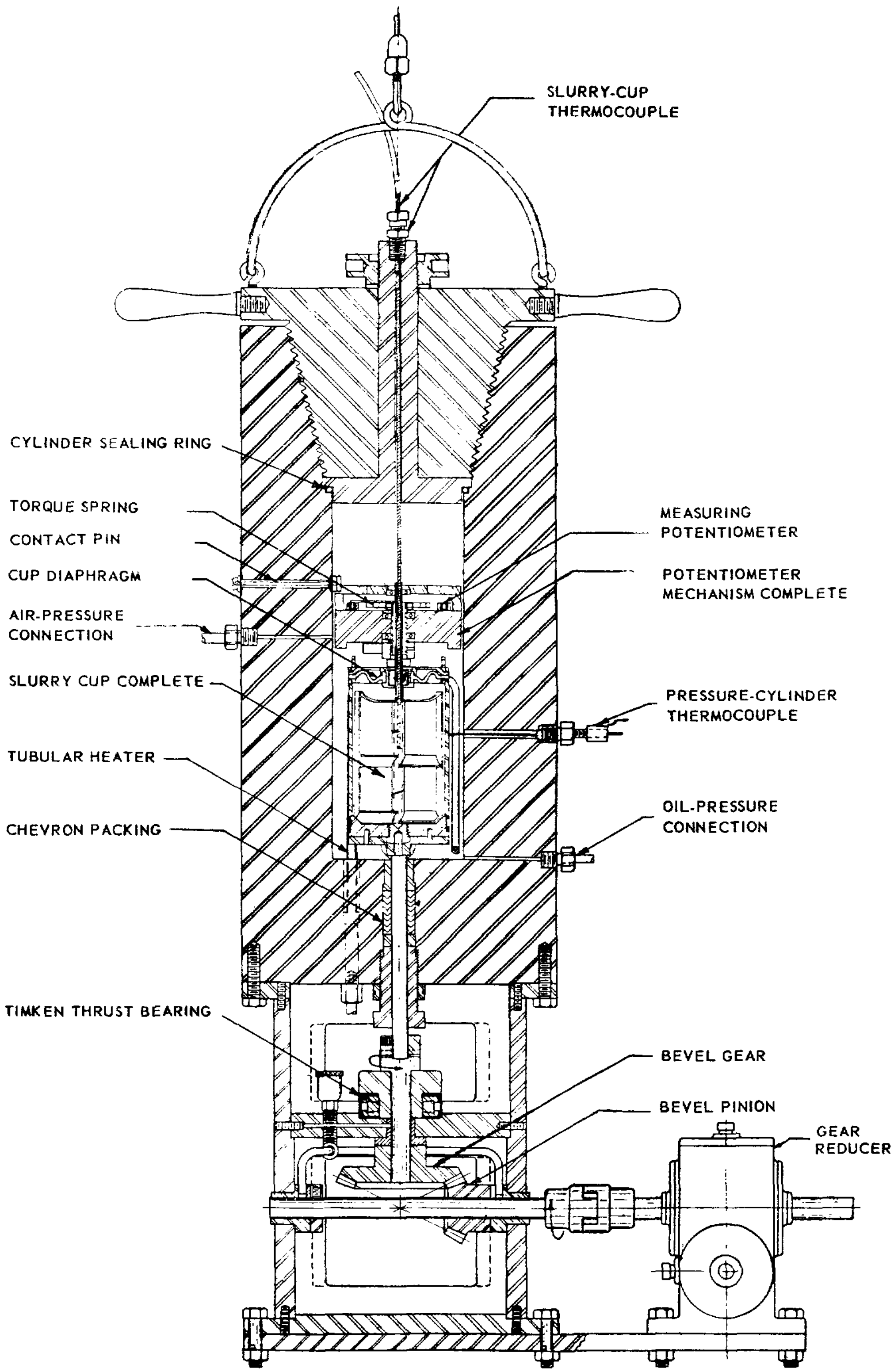

FIG. 8
ASSEMBLY
PAN AMERICAN[1] THICKENING-TIME TESTER

[1]Formerly Stanolind.

NOTES:

1. MATERIAL: STAINLESS STEEL EXCEPT DIAPHRAGM HUB.
2. CONTAINER PRESSURE: 20,000 PSI.
3. HEAT RATE: 5 DEG. F. PER MIN.

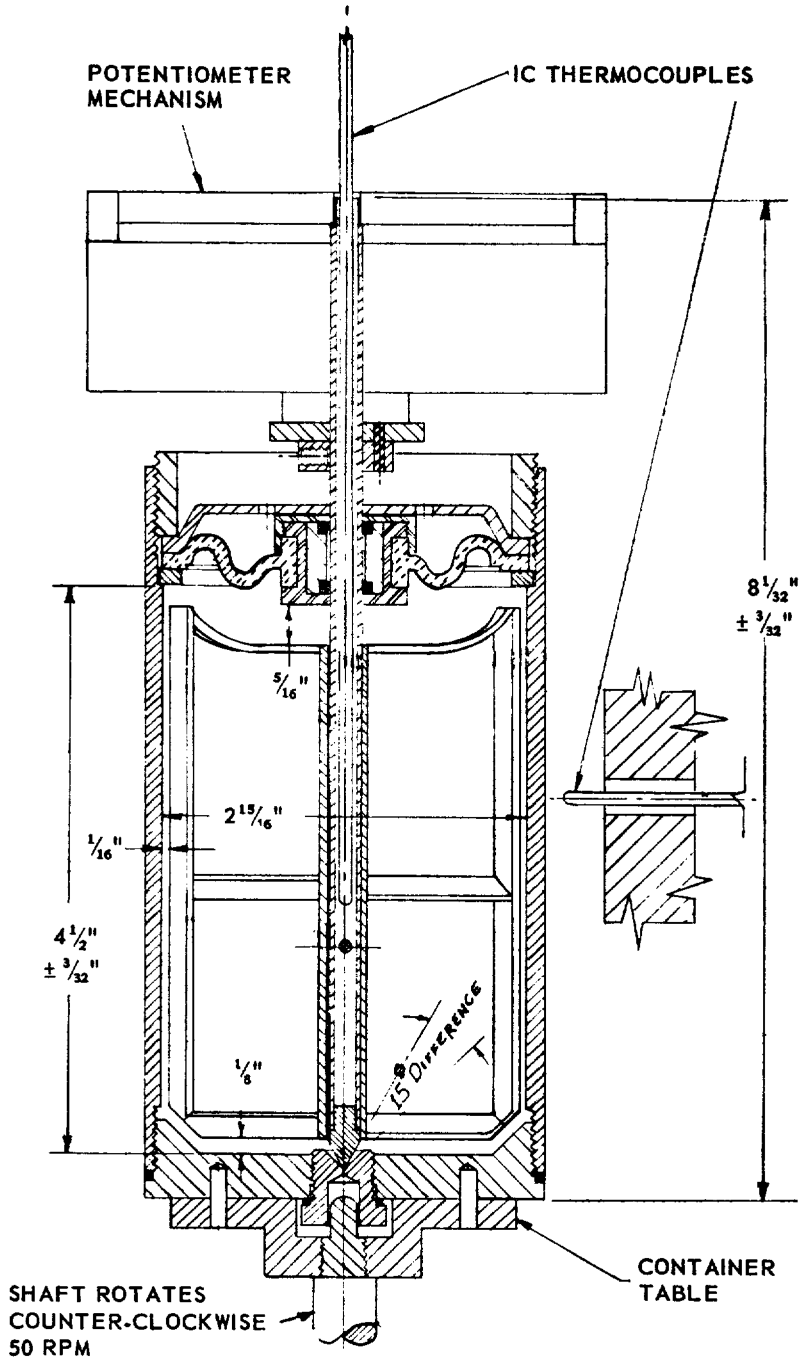

FIG. 9

SLURRY CONTAINER

PAN AMERICAN[1] THICKENING-TIME TESTER

[1]Formerly Stanolind.

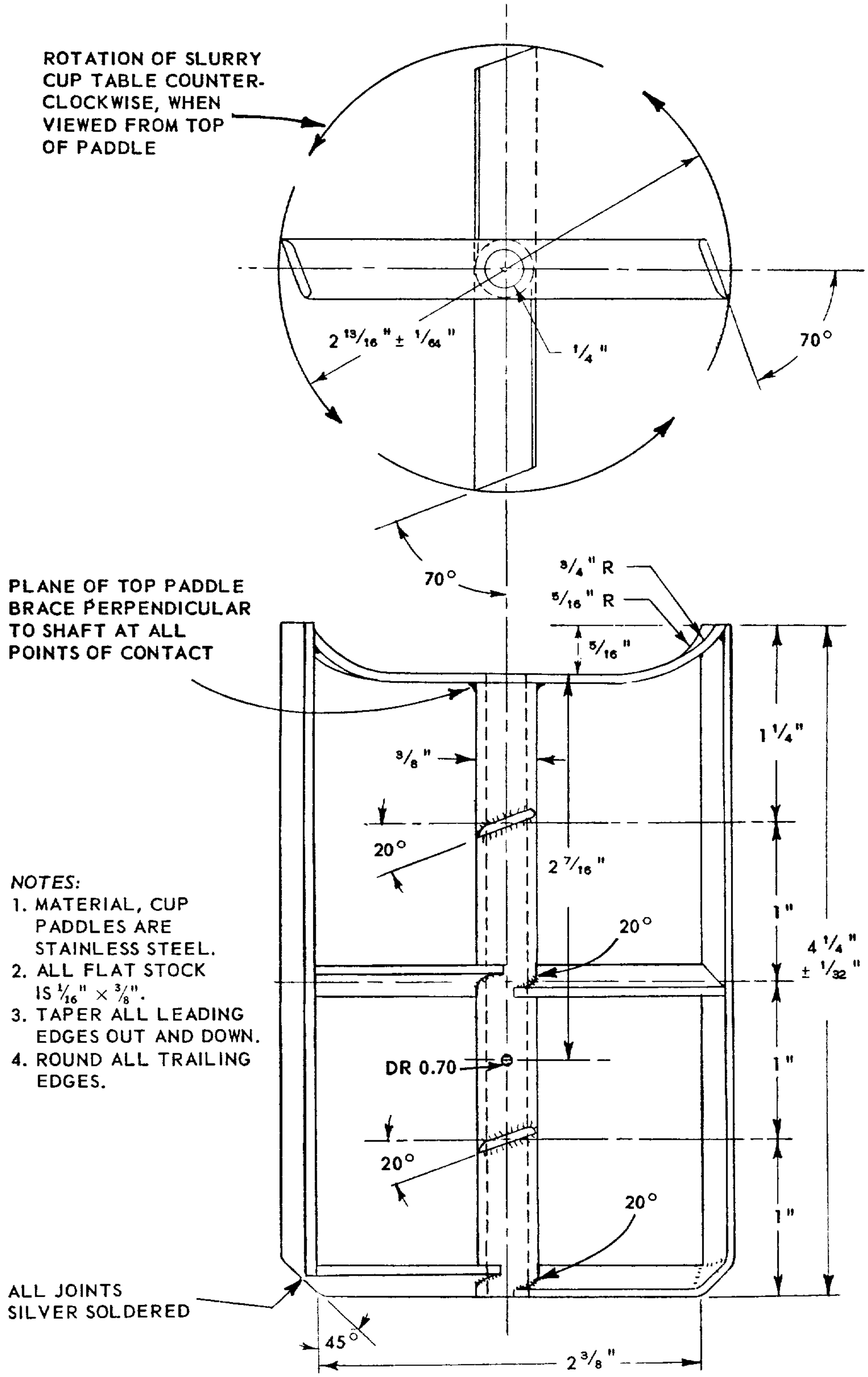

FIG. 10
PADDLE
PAN AMERICAN[1] THICKENING-TIME TESTER

[1]Formerly Stanolind.

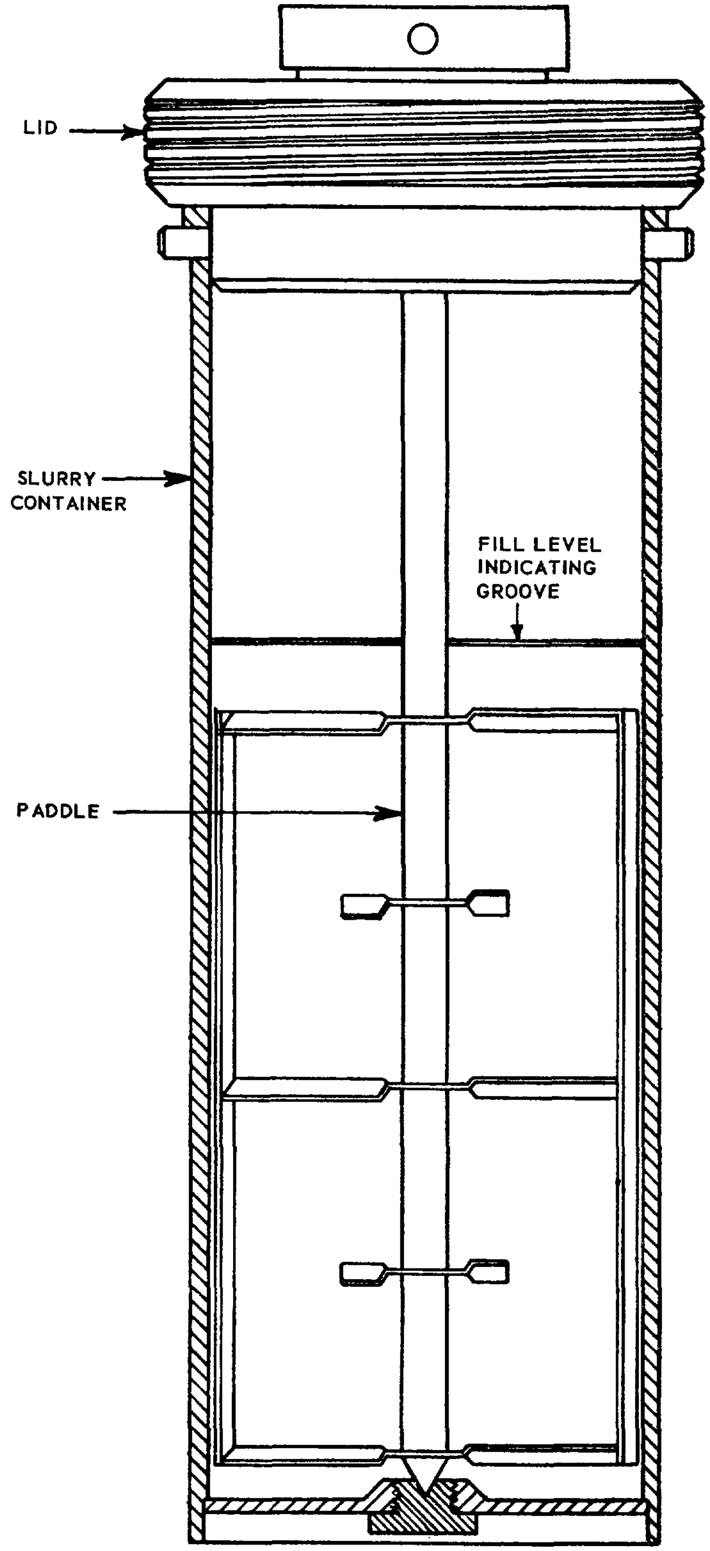

FIG. 11
ASSEMBLY
HALLIBURTON THICKENING-TIME TESTER

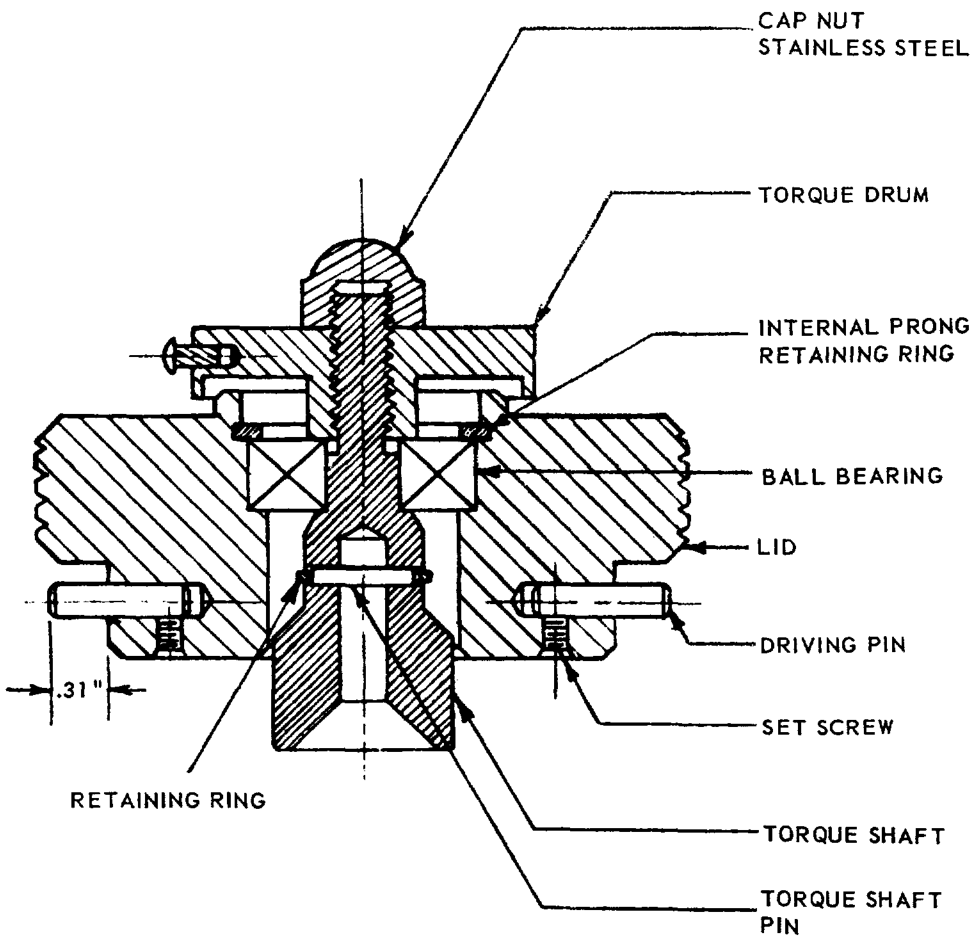

FIG. 12
SLURRY CONTAINER LID
HALLIBURTON THICKENING-TIME TESTER

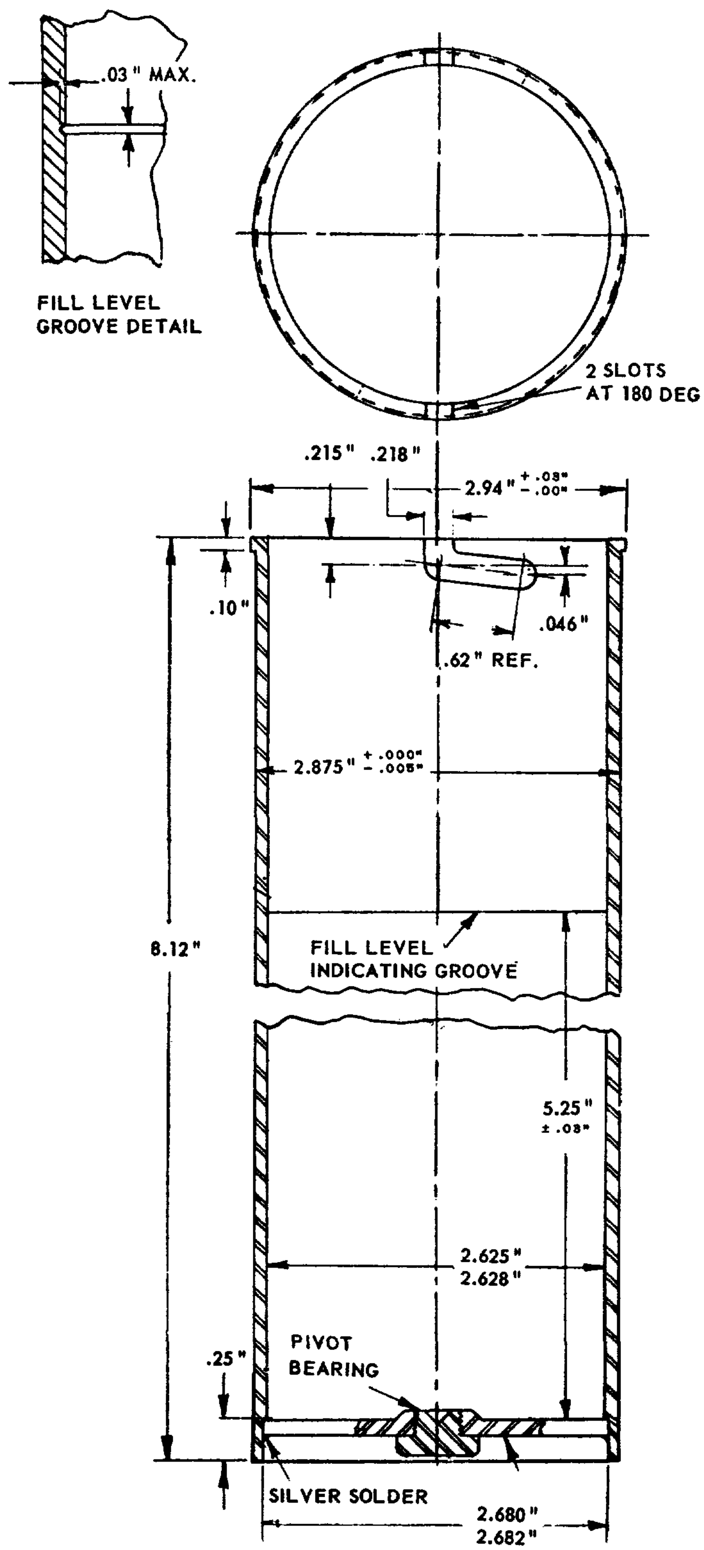

FIG. 13
SLURRY CONTAINER
HALLIBURTON THICKENING-TIME TESTER

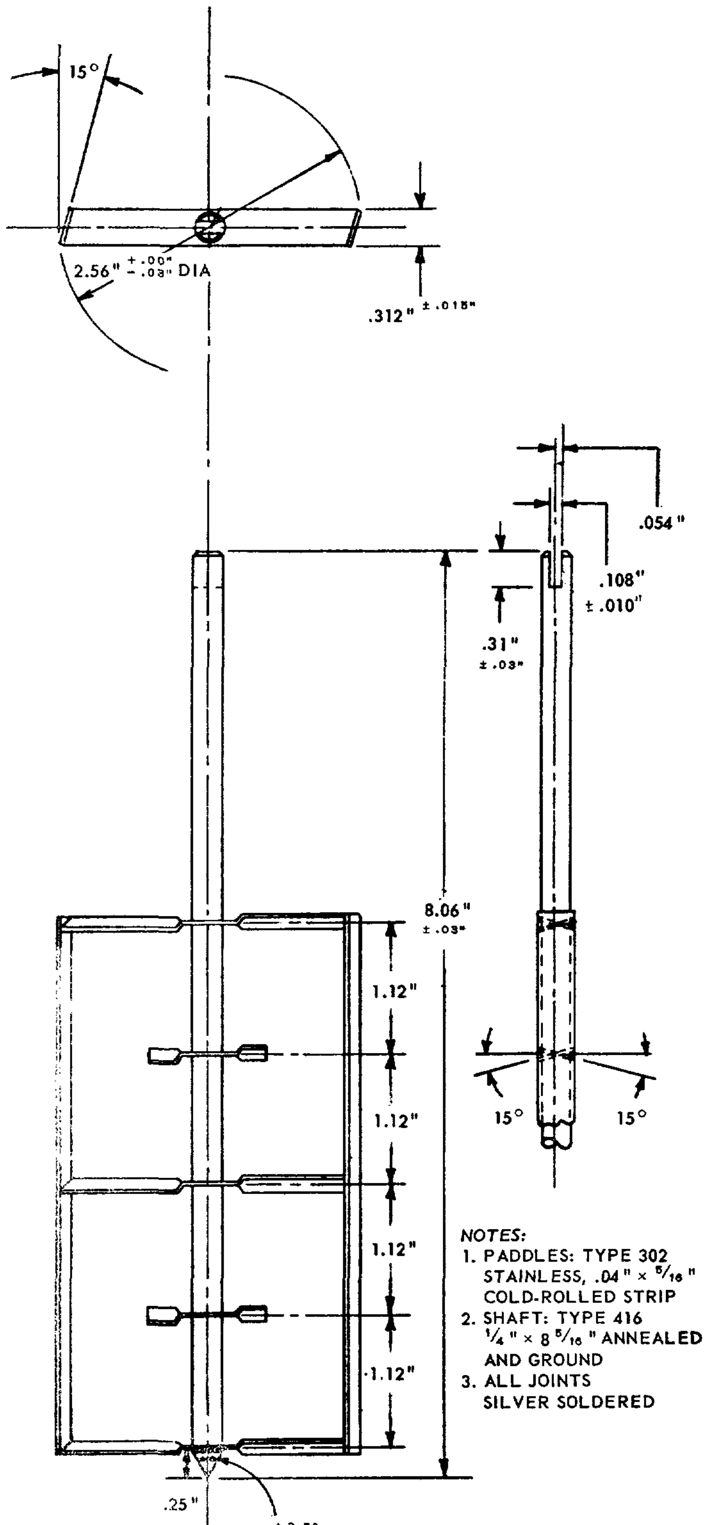

FIG. 14
PADDLE
HALLIBURTON THICKENING-TIME TESTER

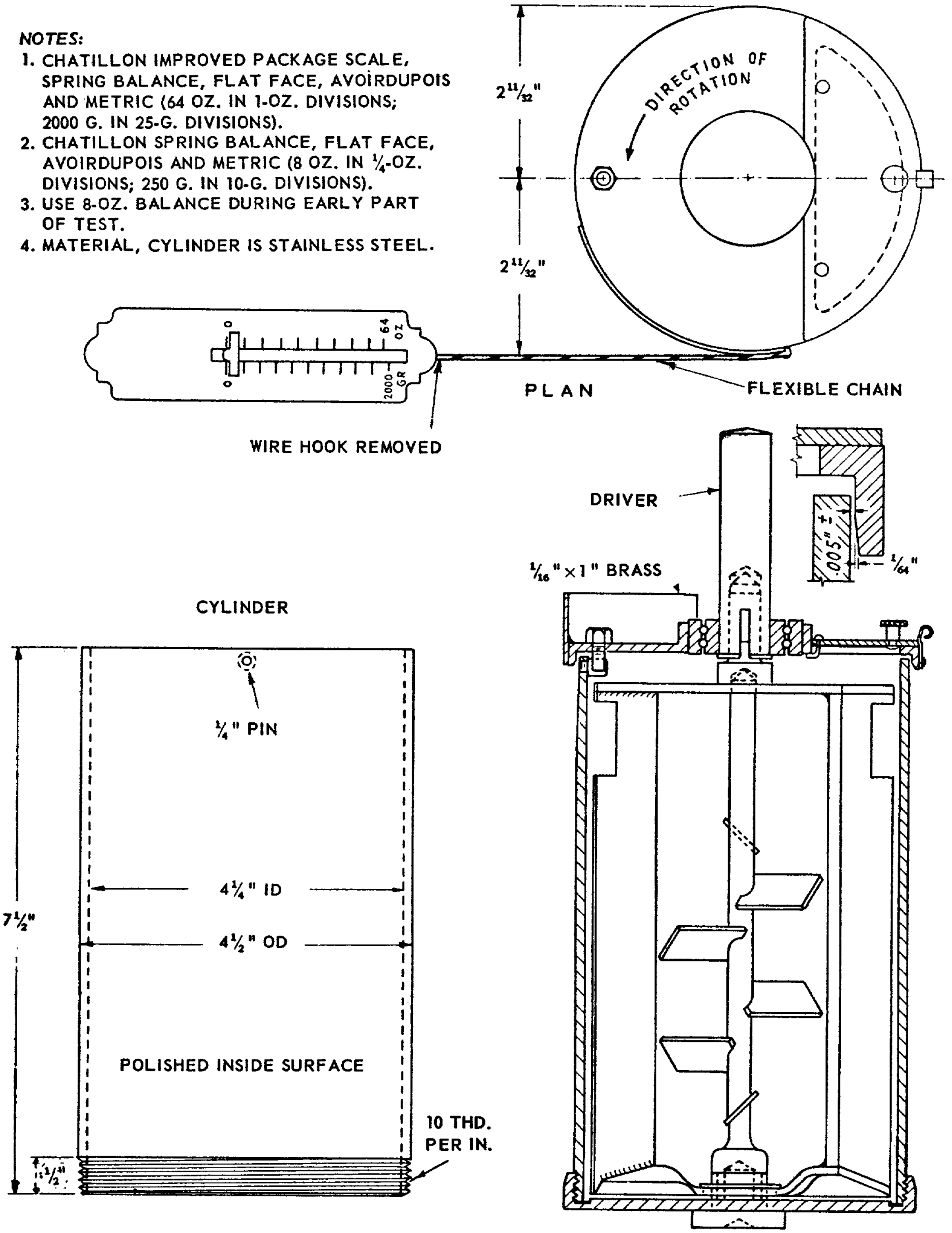

FIG. 15
ASSEMBLY
STANDARD OIL COMPANY OF CALIFORNIA THICKENING-TIME TESTER

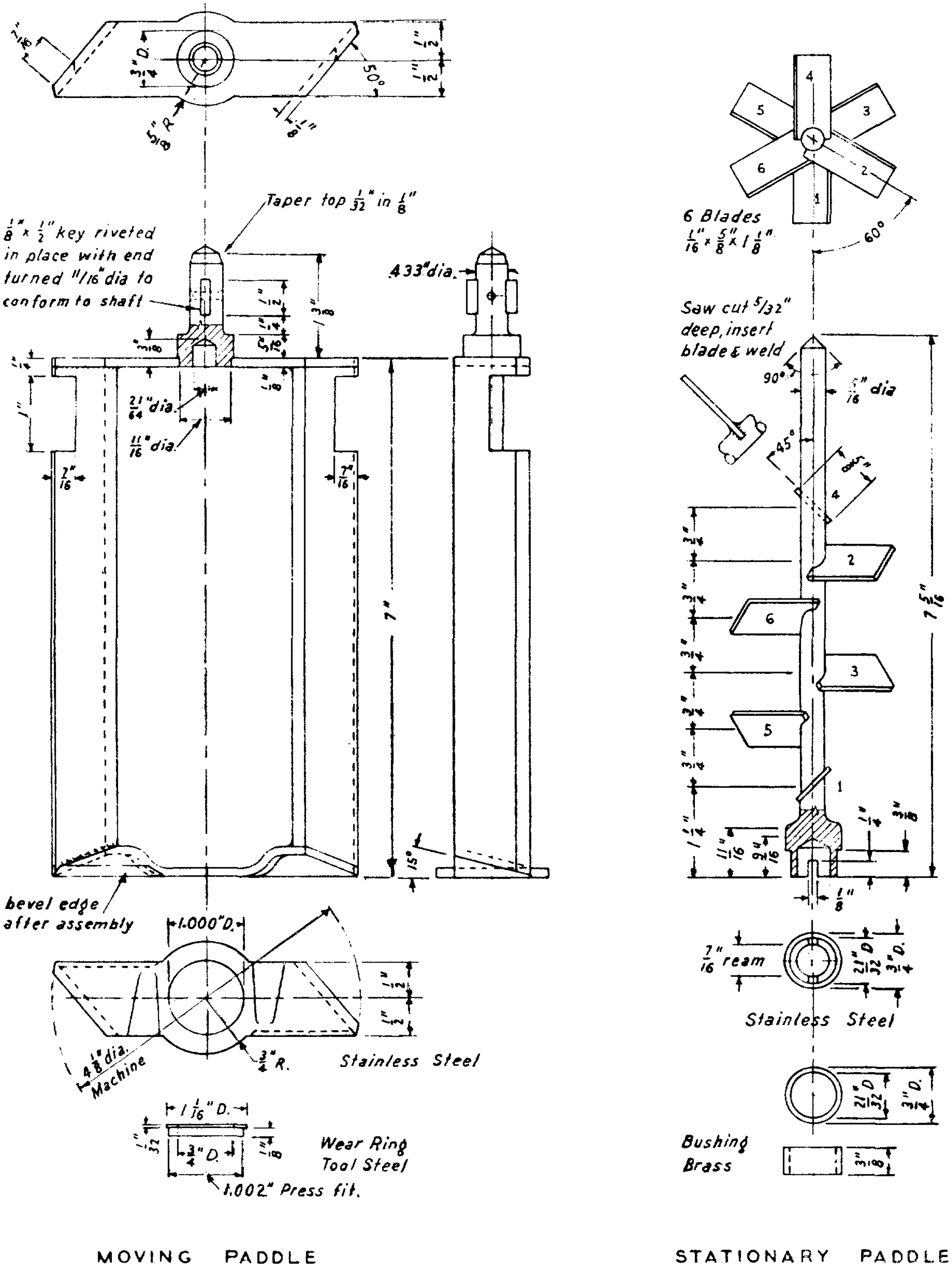

FIG. 16
PADDLES
STANDARD OIL COMPANY OF CALIFORNIA THICKENING-TIME TESTER