Recommended Practice for Performance Testing of Cementing Float Equipment

API RECOMMENDED PRACTICE 10F
SECOND EDITION, NOVEMBER 1995

American
Petroleum
Institute

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Exploration and Production Department

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FOREWORD

This recommended practice is under the jurisdiction of the API Subcommittee on Standardization of Well Cements. The purpose of this recommended practice is to provide recommended procedures for the performance testing of cementing float equipment.

Conversions of U.S. Customary units[1] to International System (SI) metric units are provided throughout the text of this document in parentheses, e.g., 4 inches (101.6 millimeters). U.S. Customary units, where stated, are preferential and shall be the standard in this recommended practice. The metric equivalents of U.S. Customary units given in this document may be approximate. The factors used for conversion of U.S. Customary units to metric values are the following:

1 inch (in.) = 25.4 millimeter (mm)

1 foot (ft) = 0.3048 meter (m)

1 pound mass (lbm) = 0.454 kilogram (kg)

1 pound force (lbf) = 4.448222 Newton (N)

1 pound per square inch (psi) = 6.894757 kilopascal (kPa)

1 pound mass per gallon (lbm/gal) = 0.1198264 kilogram per liter (kg/L)

1 barrel (bbl) = 0.1589873 cubic meter (m^3)

degree Fahrenheit (°F) = [1.8 × degree Celsius (°C)] + 32

1 pound mass per gal (lbm/gal) = 119.8264 kilogram per cubic meter (kg/m^3)

1 pound force per 100 square feet ($lbf/100\ ft^2$) = 0.4788 Pascal (Pa)

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

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Suggested revisions are invited and should be submitted to the director of the Exploration and Production Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

[1]U.S. Customary units—Units based upon the yard and the pound commonly used in the United States of America and defined by the National Bureau of Standards. Some of these units have the same name as similar units in the United Kingdom (British, English, or U.K. units) but are not necessarily equal.

Recommended Practice for Performance Testing of Cementing Float Equipment

1 Scope

The main scope of this recommended practice is limited to recommended testing practices to evaluate the performance of cementing float equipment with respect to the criteria indicated in 4.1 and 4.2. Current practice suggests that these criteria are the most important and the most widely applicable measures of float equipment performance. Some procedures relevant to criteria 4.7 are also provided.

The tests recommended in this document are intended for float equipment that will be in contact with water-base fluids used for drilling and cementing wells. Float equipment performance in non-water-base fluids is not specifically addressed.

2 References

The following specification and recommended practices are cited in this publication:

API

Spec 13A *Specification for Drilling-Fluid Materials*

RP 13B-1 *Recommended Practice Standard Procedures for Field Testing Water-Based Drilling Fluids*

3 Functions of Cementing Float Equipment

The term "cementing float equipment" refers to one or more check valves incorporated into a well casing string that prevent fluid flow up the casing while allowing fluid flow down the casing. The primary purpose of cementing float equipment is to prevent cement that has been placed in the casing/wellbore annulus from flowing up the casing (U-tubing). In some cases, such as liner cementing, float equipment may be the only practical means of preventing U-tubing. In other cases, the float equipment serves to allow the cement to set in the annulus without having to increase the pressure inside the casing to prevent U-tubing. Increased pressure in the casing while cement sets is generally undesirable because it may result in gaps (micro-annuli) in the cemented annulus.

Float equipment is also sometimes used for the purpose of lessening the load on the drilling rig. Since float equipment blocks fluid flow up the casing, the buoyant force acting on casing run with float equipment is greater than the buoyant force acting on casing run without float equipment. If either the height or the density of the fluid placed inside casing equipped with float equipment while the casing is being run is less than the fluid outside the casing, the suspended weight of the casing is reduced over what it would be without the float equipment.

The ability of float equipment to prevent fluid flow up the casing is also important in certain well control situations. If the hydrostatic pressure of the fluid inside the casing becomes less than the pressure of formation fluids in formations near the bottom of the casing, the well may try to flow up the casing. In such a situation, the float equipment becomes a primary well control device.

Float equipment is also sometimes used as a device to assist in pressure testing casing. This is normally done by landing one or more cementing plugs on top of the float equipment assembly. The plugs seal the lower portion of the casing so that the pressure integrity of the casing may be tested.

Float equipment is also used by some operators as a device to lessen the free fall of cement inside the casing. The free fall of cement is the tendency of cement to initially fall due to the density differences between the cement and the fluid in the well. The float equipment lessens the free fall, to some extent, by providing a constriction in the flow path.

Casing fill-up float equipment is a special type of float equipment that allows the casing to fill from the bottom as the casing is run. This is desirable, in some cases, to help reduce pressure surges as the casing is lowered. Fill-up type float equipment also helps ensure that the collapse pressure of the casing is not exceeded. Once the casing is run, the check valve mechanism of fill-up type float equipment is activated. This is normally done by either pumping a surface-released ball through the equipment or by circulating above a certain rate.

4 Float Equipment Performance Criteria

There are a number of performance criteria, listed below, that may be used to evaluate the suitability of a particular piece of float equipment for a given well.

4.1 DURABILITY UNDER DOWNHOLE CONDITIONS

As normally used, cementing float equipment must function after a fluid, usually containing abrasive solids, has been circulated through the equipment for a period of time. The equipment must function in various orientations and while exposed to elevated temperatures and pressures.

4.2 DIFFERENTIAL PRESSURE CAPABILITY FROM BELOW

Because the hydrostatic pressure of the fluid occupying the annulus immediately after the cement has been placed is usually greater than the hydrostatic pressure of the corresponding column of fluid inside the casing, float equipment must be capable of withstanding a differential pressure with the higher pressure being exerted from below the check valve mechanism.

4.3 ABILITY TO WITHSTAND FORCE EXERTED THROUGH CEMENTING PLUGS FROM ABOVE

Some operators occasionally pressure test the casing by increasing the pressure shortly after a cementing plug (top plug) used to separate the cement from the displacement fluid has landed downhole. This may cause a force to be applied to the float equipment that could cause the equipment to fail. The ability of the float equipment assembly to withstand this force is another measure of the performance of the equipment.

4.4 DRILLABILITY OF THE EQUIPMENT

In many cases, float equipment must be drilled out after cementing. The ease with which such equipment may be drilled is another performance criterion of the equipment.

4.5 ABILITY TO PASS LOST CIRCULATION MATERIALS

On occasion, the fluid that is circulated through cementing float equipment contains lost circulation material (LCM) designed to bridge on highly permeable formations to lessen the amount of fluid that is lost to the formations. Since float equipment generally provides a constricted flow area for fluid passage, there may be a tendency for the LCM to bridge on the float equipment valve and partially or totally block fluid circulation. Therefore, the ease with which the LCM may pass through the float equipment may be a performance criterion for some wells.

4.6 FLOW COEFFICIENT OF THE VALVE

Since float equipment provides a constriction in the flow path, there will be a pressure loss associated with circulating fluid through the float valve. If the pressure loss through the float equipment is too high, circulation rates may be limited. In some cases, however, a large pressure loss is desirable to reduce free fall of the cement inside the casing. The flow coefficient of the valve provides a means of estimating the pressure loss for a given fluid density and a given rate.

4.7 REVERSE FLOW RESISTANCE OF CASING FILL-UP VALVES

One of the functions of casing fill-up float equipment is to reduce pressure surges as the casing is run by allowing flow into the casing from the bottom. Therefore, the resistance of the valve to reverse flow is indicative of the relative performance of the valve at reducing surge pressure.

5 Recommended Testing Equipment and Materials

5.1 FLOW LOOP

Figure 1 shows a diagram of one possible configuration of a flow loop for durability testing. Other configurations are possible. The major components of the loop are the mud tank, the piping network, the pump, and the instrumentation. These components are discussed in the following paragraphs.

5.1.1 It is suggested that the mud tank consist of two compartments, with each compartment capable of holding about 100 barrels (15.9 cubic meters) of fluid. Each compartment should be fitted with adequate agitation and mixing devices to ensure that the fluids remain well mixed. A valve should be arranged to allow communication between the compartments so that the volume of fluid in the active tank can be adjusted. This will facilitate temperature regulation during a test. A mud hopper should be arranged to facilitate the mixing of mud chemicals.

5.1.2 The piping network should consist of 4–6-inch (101.6–152.4-millimeter) pipe and valves. It is suggested that the low-pressure portion of the piping network be rated to allow an operating pressure of at least 500 pounds per square inch (3,400 kilopascals), and it is suggested that the high-pressure portion of the flow loop, as shown in Figure 1, be rated to at least 5,000 pounds per square inch (34,500 kilopascals) working pressure. To facilitate testing fill-up type float equipment, it is suggested that the piping be laid out in such a manner that the flow direction through the float equipment can easily be changed. Both the high-pressure and the low-pressure portion of the flow loop should be equipped with pressure-release type safety valves. It is suggested that a portion of the low-pressure side of the flow loop be made from a flexible hose or an expansion joint to facilitate spacing out different length float equipment.

5.1.3 A triplex pump is suggested as the primary pump for the flow loop. The pump should be capable of pumping at least 10 barrels per minute (1.6 cubic meters per minute) and pressure testing to 5,000 pounds per square inch (34,500 kilopascals). As an alternative, a centrifugal type pump may be used. However, this will necessitate the use of a second high-pressure type pump to perform the back pressure tests.

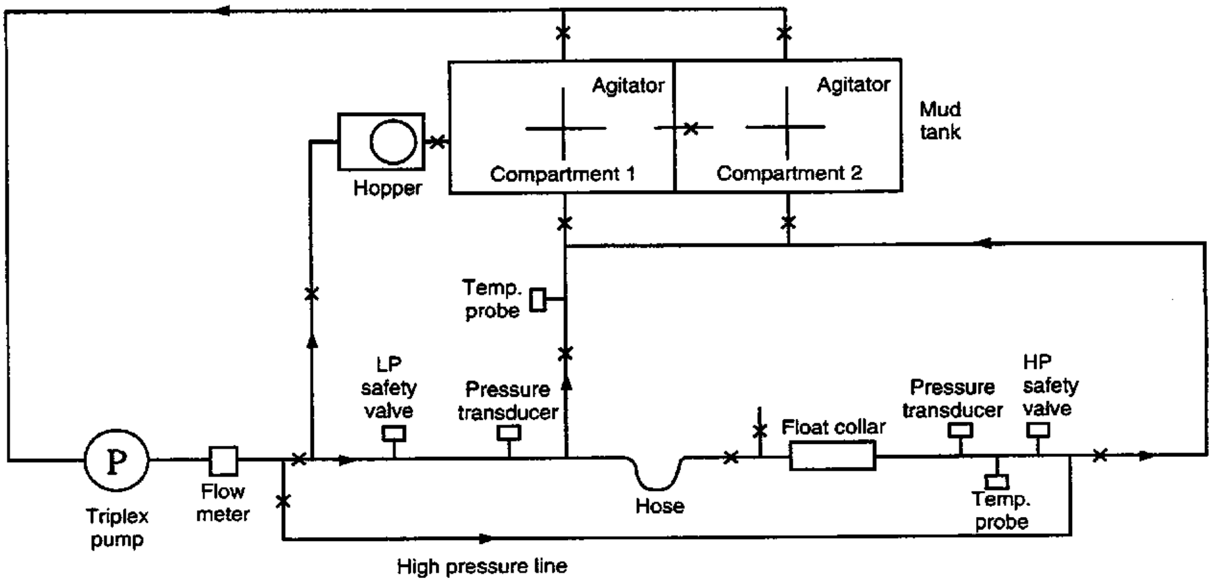


Figure 1—Suggested Layout for Cementing Float Equipment Testing Flow Loop

It is suggested that a backup primary pump be available during testing periods.

5.1.4 The instrumentation for the flow loop should consist of a flow rate meter, temperature probes, and pressure transducers, located as shown in Figure 1. It is suggested that a data acquisition system be provided for recording the outputs from these devices during testing.

5.1.5 In designing and operating the flow loop, the following SAFETY PRECAUTIONS should be followed:

a. The flow loop should be constructed in a controlled-access, isolated area.
b. The piping should be periodically inspected for reduced wall thickness, especially in areas of maximum erosion such as bends, elbows, and tees.
c. The handling and mixing of the test fluid chemicals should be done by qualified personnel using the appropriate safety precautions.
d. During pressure testing, all operating personnel and observers should be a safe distance from the high-pressure portion of the flow loop.
e. The pump controls and maximum pressure transducer readouts should be located a safe distance from the high-pressure portion of the flow loop.

5.2 CIRCULATING TEST FLUID

The circulating test fluid should consist of a water-base drilling fluid that has the following properties at 120°F (48.9°C):

density: 12.0–12.5 lbm/gal (1.44–1.50 kg/L)

plastic viscosity: 10–50 cp

yield point: 5–25 lbf/100 ft² (2.4–12.0 Pa)

10-s gel strength: > 4 lbf/100 ft² (1.9 Pa)

sand content: 2–4 percent by volume

The weighting material used in the test fluid should be barite that meets the specifications in API Spec 13A. The fluid properties should be measured in accordance with API RP 13-B1. The sand used in the test fluid should be 70/200 U.S. mesh sand. This material is available from most well cementing service companies and certain suppliers of blasting sand.

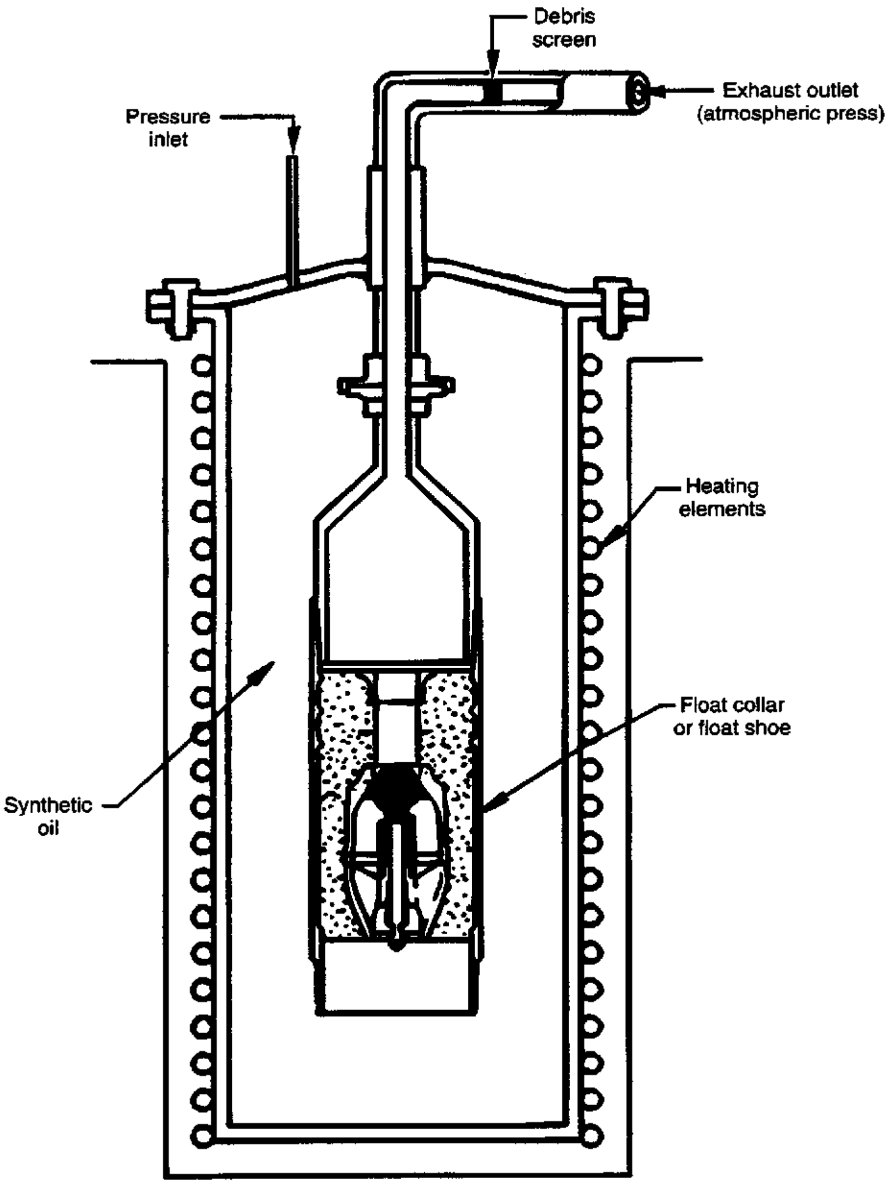
5.3 HIGH-TEMPERATURE/HIGH-PRESSURE TEST CELL

A special test apparatus is recommended for applying temperature and pressure to float equipment as described in later sections of this document. Figure 2 is a schematic diagram of one suggested apparatus for applying temperature and pressure to float equipment. Other apparatus and methods for applying temperature and pressure to float equipment are also acceptable, provided proper precautions are taken. The apparatus shown in Figure 2 is described in the following paragraphs.

5.3.1 The apparatus should be designed for safe operation at temperatures up to 400°F (204°C) and pressures up to 5,000 pounds per square inch (34,500 kilopascals).

5.3.2 The test apparatus shown in Figure 2 consists of a chamber body with attached welded flange and a mating flange to which the float equipment is attached. The chamber body inside diameter (ID) should be larger than the outside diameter (OD) of the largest piece of float equipment to be tested. Economics should be considered when determining the size of the chamber body. For pressure testing all sizes of float equipment, it may be more economical or desirable to build several chambers rather than one large chamber. The chamber body and welded flange should be strong enough to withstand the maximum differential pressure (plus safety factor) applied during testing. A mating flange cap, containing a pressure inlet and relief or exit port, is used to support the float equipment during testing. The pressure rating of the flanged cap should be equal in strength to the chamber body. The equipment to be tested is suspended from the cap by a swage and extension as shown in Figure 2.

The supporting members should be strong enough to



Temperature range—70°F (21.1°C)–400°F (204°C)
Pressure range—0–5,000 psi (34,400 kPa)

Figure 2—Controlled Pressure-Temperature Test Cell

withstand the collapse pressure (plus safety factor) encountered during maximum differential pressure tests. The exhaust, or relief, outlet should contain a safety screen to retain pieces of the float equipment in the advent of an "absolute failure."

During pressure-temperature tests, the entire chamber should be filled with a silicone-base oil with a flash point well above 400°F (204°C). Silicone-base oils are commercially available from several sources. The chamber is completely submerged in oil that is heated from an external heat source or may be heated directly by electrical resistance heaters.

5.3.3 In designing and operating the high-temperature/high-pressure apparatus, the following SAFETY PRECAUTIONS should be followed:

a. The test apparatus should be in an enclosed room (such as a concrete, steel-reinforced test cell) with sufficient wall thickness to contain absolute failure of test apparatus or equipment. The test facility should be in an isolated area to prevent injury to operating personnel or observers.
b. All pump and temperature controls, with relief valves, should be housed outside the test cell. A secondary automatic shutdown control system should also be incorporated. The operator should maintain visual contact with the test apparatus at all times. Visual access may be provided by using a mirror positioned so that the line of sight is not in direct line with the test apparatus. The observation window should be protected by high-impact glass.
c. The test cell should have limited access doorways that are visible to operating personnel at all times.
d. Adequate ventilation or exhaust fans should be incorporated into the test cell to remove smoke or irritating vapors.
e. Oil used as a heating medium should be periodically checked for contamination and replaced when necessary. Contamination lowers the flash point of the silicone-base oil.
f. Adequate fire extinguishers should be located inside and outside the test facility. An automatic fire extinguishing system is desirable.

6 Durability Test

6.1 TEST SET-UP

6.1.1 The test fluid should be prepared in accordance with 5.2. It is suggested that a minimum of 50 barrels (7.9 cubic meters) of fluid be prepared and that the fluid be circulated (bypassing the float equipment) until the fluid properties have stabilized.

6.1.2 The float equipment to be tested should be mounted in the test section of a flow loop such as described in 5.1. The orientation of the float equipment may be either horizontal or vertical. For float equipment to be used in wells with a final deviation angle greater than 45 degrees, it is recommended that the float equipment be tested horizontally. The float equipment orientation during testing should be clearly indicated on a test results reporting form similar to that shown in Figure 3. For horizontal testing of flapper-type float equipment, the hinge of the flapper should be on the bottom (low side) so that closure is not assisted by gravity. For vertical testing, the direction of the flow through the float equipment should be downward.

6.2 TEST CATEGORIES

To facilitate communication between users and suppliers of cementing float equipment, three service categories of flow durability testing are suggested. The categories for flow durability testing are shown in Tables 1 and 2.

6.3 PROCEDURE

6.3.1 Regular Equipment

6.3.1.1 Perform a back pressure test on the float equipment by pressuring the high-pressure portion of the flow loop to 100 pounds per square inch (700 kilopascals) and then opening a valve upstream of the float equipment to atmospheric pressure. Record the volume of fluid necessary to achieve valve closure. If the valve will not close, attempt to achieve valve closure by increasing the reverse flow rate through the valve. Record the rate necessary to obtain valve closure. Increase the pressure to 250 pounds per square inch (1700 kilopascals) and hold for 5 minutes. If the float valve cannot hold 250 pounds per square inch (1700 kilopascals) for 5 minutes, stop the test.

6.3.1.2 Circulate through the float equipment for a total flow period of 8, 12, or 24 hours, depending on the test category being followed. The circulation rate for float equipment larger than 3 $^{1}/_{2}$ inches (88.9 millimeters) should be 10 barrels per minute (1.6 cubic meters per minute). The circulation rate for 3 $^{1}/_{2}$-inch (88.9-millimeter) and smaller float equipment should be 6 barrels per minute (1.0 cubic meters per minute). The test fluid temperature should be at least

Table 1—Categories of Flow Durability Tests for Regular Float Equipment

Category	Duration[a] (hr)	Maximum[b] Pressure psi (kPa)
I	8	1,500 (10,300)
II	12	3,000 (20,700)
III	24	5,000 (34,500)

[a]Circulation rate is 10 barrels per minute (1.6 cubic meters per minute) for float equipment larger than 3 $^{1}/_{2}$ inches (88.9 millimeters) and 6 barrels per minute (1.0 cubic meters per minute) for 3 $^{1}/_{2}$-inch (88.9-millimeter) and smaller float equipment.

[b]The maximum test pressure should be the lesser of the value shown or 80 percent of the manufacturer's rated burst or collapse pressure for the float equipment casing, whichever is applicable.

Table 2—Categories of Flow Durability Tests for Casing Fill-Up Equipment

Category	Duration (hr) Reverse[a]	Forward[b]	Maximum[c] Pressure psi (kPa)
I	2	8	1,500 (10,300)
II	4	12	3,000 (20,700)
III	6	24	5,000 (34,500)

[a]Circulation rate for all categories is 3 barrels per minute (0.5 cubic meters per minute).
[b]Circulation rate is 10 barrels per minute (1.6 cubic meters per minute) for float equipment larger than 3 ½ inches (88.9 millimeters) and 6 barrels per minute (1.0 cubic meters per minute) for 3 ½-inch (88.9-millimeter) and smaller float equipment.
[c]The maximum test pressure should be the lesser of the value shown or 80 percent of the manufacturer's rated burst or collapse pressure for the float equipment casing, whichever is applicable.

110°F (43°C) for at least 75 percent of the flow period. At 2-hour intervals, stop circulation and perform a back pressure test in accordance with 6.3.1.1. The mud properties should be measured at 2-hour intervals and adjusted if necessary.

6.3.1.3 Perform a low-temperature/high-pressure back pressure test in the following manner. It is suggested that the float equipment be removed from the flow loop and installed in an apparatus specifically designed for safely applying high differential pressure across the float valve, such as that described in 5.3. This test may also be performed with the float equipment in the flow loop, provided that all SAFETY PRECAUTIONS are observed. The maximum test pressure should be the lesser of 1,500, 3,000, or 5,000 pounds per square inch (10,300, 20,700, 34,500 kilopascals), depending on the test category being followed, or 80 percent of the manufacturer's rated burst or collapse pressure for the float equipment casing, whichever is applicable. Achieve valve closure, if necessary, by a reverse flow surge. Increase the pressure to the maximum test pressure over a period not greater than 2 minutes and hold for 30 minutes.

6.3.1.4 Disassemble the float equipment and visually inspect the valve mechanism for any signs of abrasion or wear. For cement-filled equipment, visually inspect the cement for any signs of cracking or abrasion. Note any abnormalities.

6.3.2 Casing Fill-Up Equipment

6.3.2.1 Circulate in the reverse direction through the float equipment at 3 barrels per minute (0.5 cubic meters per minute) for 2 hours. Measure and record the pressure drop in the reverse flow direction.

6.3.2.2 Activate the check valve of the float equipment in accordance with the manufacturer's recommendation. Record the pressure and/or rate required to activate the check valve.

6.3.2.3 Perform the durability test for regular float equipment indicated in 6.3.1.

7 Static High-Temperature/High-Pressure Test

7.1 TEST CATEGORIES

To facilitate communication between users and suppliers of cementing float equipment, three service categories of static high-temperature/high-pressure testing are suggested. The categories for static high-temperature/high-pressure testing are shown in Table 3.

7.2 PROCEDURE

7.2.1 Perform a flow durability test in accordance with Section 6.

7.2.2 Review, verify, and observe safety precautions indicated in 5.3.3.

7.2.3 Install the float equipment in a high-temperature/high-pressure test apparatus similar to the one described in 5.3.

7.2.4 Heat the test apparatus until the test piece and test chamber achieve a constant test temperature of 200, 300, or 400 ± 10°F (93, 149, 204 ± 5°C), depending on the test category being followed. Maintain the test temperature for a period of 8 hours.

7.2.5 Pressure test by pumping into the chamber to achieve valve closure and a fluid seal. Pressure to 50 pounds per square inch (340 kilopascals), using an appropriate low-volume, high-pressure pump, to check for low-pressure fluid seal. (Note: Air-activated pumps are recommended for this application.) Ball-type float equipment may require a high-volume pump to initiate valve closure, or the exhaust valve can be closed, the chamber pressurized below the test piece, and the exhaust valve quickly opened to provide a fluid surge to obtain initial valve closure.

7.2.6 Increase pressure to 500 pounds per square inch (3,400 kilopascals) and hold for 15 minutes. Increase pres-

Table 3—Categories of Static High-Temperature/High-Pressure Tests

Category	Temperature[a] °F (°C)	Maximum[b] Pressure psi (kPa)
A	200 (93)	1,500 (10,300)
B	300 (149)	3,000 (20,700)
C	400 (204)	5,000 (34,500)

[a]Duration at temperature is 8 hours for all categories.
[b]The maximum test pressure should be the lesser of the value shown or 80 percent of the manufacturer's rated burst or collapse pressure for the float equipment casing, whichever is applicable.

sure in 500-pound per square inch (3,400-kilopascal) increments every 15 minutes until a maximum test pressure of 1,500, 3,000, or 5,000 pounds per square inch (10,300, 20,700, 34,500 kilopascals), depending on the test category being followed, is reached or until failure occurs, whichever occurs first. If the test pressure and test apparatus cause a collapse load to be imposed on the float equipment casing, the maximum test pressure should be limited to a value less than 80 percent of the manufacturer's rated collapse pressure for the float equipment casing. If the test pressure and test apparatus cause a burst load to be imposed on the float equipment casing, the maximum test pressure should be less than 80 percent of the manufacturer's rated internal yield pressure for the float equipment casing.

7.2.7 Release pressure, cool, and disassemble float equipment. Perform visual inspection. Note any abnormalities.

8 Suggested Test Results Reporting Form

A suggested form for reporting the results of the performance tests described in this document is shown in Figure 3.

Figure 3—Results of API Performance Tests on Cementing Float Equipment

I. GENERAL INFORMATION

Manufacturer ______

Type of Float Equipment Tested ______

Size of Float Equipment Tested ______

Model Number of Float Equipment Tested ______

Location of Plant Where Float Equipment Manufactured ______

Date Float Equipment Manufactured ______

Valve Description ______

Valve Material ______

II. FLOW DURABILITY TESTING

Dates of Testing ______

API Flow Durability Testing Category I. ______ II. ______ III. ______

Pass or Fail Pass ______ Fail ______

Float Equipment Orientation Horizontal ______ Vertical ______

Type of Pump Used for Circulation ______

Average Fluid Temperature During Test ______

Average Sand Concentration During Test ______

If Pass, Maximum Volume for Closure ______

If Pass, Maximum Rate for Closure ______

If Pass, Maximum Test Pressure Used ______

If Fail, Total Duration Until Failure ______

If Casing Fill-Up Equipment, Reverse Flow Pressure Drop Across Valve ______

If Casing Fill-Up Equipment, Rate of Pressure to Activate ______

Description of Valve After Test ______

______

III. HIGH-TEMPERATURE/HIGH-PRESSURE TESTING

Dates of Testing ______

API HT/HP Test Category A. ______ B. ______ C. ______

Pass or Fail Pass ______ Fail ______

Type of Pressure Application Internal Only ______ Internal and External ______

Type of Fluid Contacting Valve ______

If Pass, Maximum Test Pressure Used ______

If Fail, Maximum Test Pressure Achieved ______

Description of Valve After Test ______

______

SIGNATURE ______ TITLE ______

NAME ______ PHONE NUMBER ______

DATE SIGNED ______

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