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Petroleum and natural gas industries — Field testing of drilling fluids —

Part 1: Water-based fluids

Industries du pétrole et du gaz naturel — Essais in situ des fluides de forage —

Partie 1: Fluides aqueux

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this part of ISO 10414 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 10414-1 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum and natural gas industries*, Subcommittee SC 3, *Drilling and completion fluids, and well cements*.

ISO 10414 consists of the following parts, under the general title *Petroleum and natural gas industries — Field testing of drilling fluids*:

— *Part 1: Water-based fluids*

— *Part 2: Oil-based fluids*

Annexes A to H of this part of ISO 10414 are for information only.

Introduction

This part of ISO 10414 is based on API RP 13B-1, second edition, September 1997 [2].

As with any laboratory procedure requiring the use of potentially hazardous chemicals, the user is expected to have proper knowledge and received training in the use and disposal of these chemicals. The user is responsible for compliance with all applicable local, regional and national requirements for worker and local health, safety and environmental liability.

In this part of ISO 10414, where practical, U.S. customary units are included in brackets for information.

Petroleum and natural gas industries — Field testing of drilling fluids —

Part 1: Water-based fluids

1 Scope

This part of ISO 10414 provides standard procedures for the determining following characteristics of water-based drilling fluids:

a) drilling fluid density (mud weight);

b) viscosity and gel strength;

c) filtration;

d) water, oil and solids contents;

e) sand content;

f) methylene blue capacity;

g) pH;

h) alkalinity and lime content;

i) chloride content;

j) total hardness as calcium.

Annexes A, B, C and E provide additional test methods which may be used for

k) chemical analysis for calcium, magnesium, calcium sulfate, sulfide, carbonate, potassium;

l) determination of shear strength;

m) determination of resistivity;

n) drill pipe corrosion monitoring.

Annexes D, F, G and H provide procedures that may be used for

o) removal of air;

p) sampling, inspection and rejection;

q) rig-site sampling;

r) calibration and verification of glassware, thermometers, viscometers, retort kit cup and drilling fluid balances.

2 Term and definition

For the purposes of this part of ISO 10414, the following term and definition applies.

2.1
ACS reagent grade
chemical meeting the purity standards specified by the American Chemical Society (ACS)

3 Abbreviated terms

ACS American Chemical Society

AISI American Iron and Steel Institute

CAS Chemical Abstracts Service

EDTA ethylenediaminetetraacetic acid

HT/HP high temperature, high pressure

meq milliequivalents

OCMA Oilfield Chemical Manufacturer's Association

PTFE polytetrafluoroethylene

QAS quaternary ammonium salt

STPB sodium tetraphenyl borate

TC to contain

TD to deliver

4 Drilling fluid density (mud weight)

4.1 Principle

This test procedure is a method for determining the mass of a given volume of liquid (= density). Drilling fluid density is expressed as grams per cubic centimetre, or kilograms per cubic metre.

4.2 Apparatus

4.2.1 Any **density-measuring instrument** of accuracy to within 0,01 g/cm^3 or 10 kg/m^3.

The mud balance is the instrument generally used for drilling-fluid density determinations. The mud balance is designed such that the drilling-fluid holding cup, at one end of the beam, is balanced by a fixed counterweight at the other end, with a sliding-weight rider free to move along a graduated scale. A level-bubble is mounted on the beam to allow for accurate balancing. Attachments for extending the range of the balance may be used when necessary.

The instrument should be calibrated frequently with fresh water. Fresh water should give a reading of 1,00 g/cm^3 or 1 000 kg/m^3 at 21 °C (70 °F). If it does not, adjust the balancing screw or the amount of lead shot in the well at the end of the graduated arm as required.

4.2.2 **Thermometer**, with a range of 0 °C to 105 °C (32 °F to 220 °F).

4.3 Procedure

4.3.1 The instrument base should be set on a flat, level surface.

4.3.2 Measure the temperature of the drilling fluid and record.

4.3.3 Fill the clean, dry cup with drilling fluid to be tested; put the cap on the filled drilling-fluid holding cup and rotate the cap until it is firmly seated. Ensure that some of the drilling fluid is expelled through the hole in the cap in order to free any trapped air or gas (see annex D for information on air or gas removal).

4.3.4 Holding the cap firmly on the drilling-fluid holding cup (with cap hole covered), wash or wipe the outside of the cup clean and dry.

4.3.5 Place the beam on the base support and balance it by moving the rider along the graduated scale. Balance is achieved when the bubble is under the centreline.

4.3.6 Read the drilling fluid density at the edge of the rider toward the drilling-fluid holding cup. Make appropriate corrections when a range extender is used.

4.4 Calculation

4.4.1 Report the drilling fluid density to the nearest 0,01 g/cm^3 or 10 kg/m^3.

4.4.2 To convert the reading to other units, use the following:

$$\rho = 1\,000 \times \text{g/cm}^3 \quad (1)$$

$$\rho = 16 \times \text{lb/ft}^3 \quad (2)$$

$$\rho = 119{,}8 \times \text{lb/USgal} \quad (3)$$

where ρ is the density, expressed in kilograms per cubic metre.

$$DFG = 9{,}81 \times \text{g/cm}^3 \quad (4)$$

$$DFG = 0{,}022\,6 \times \text{psi/1 000 ft} \quad (5)$$

where DFG is the drilling fluid gradient, expressed in kilopascals per metre.

A list of density conversions is given in Table 1.

Table 1 — Density conversion

Grams per cubic centimetre[a] g/cm^3	Kilograms per cubic metre kg/m^3	Pounds per US gallon (lb/US gal)	Pounds per cubic foot (lb/ft^3)
0,70	700	5,8	43,6
0,80	800	6,7	49,8
0,90	900	7,5	56,1
1,00	1 000	8,345[b]	62,3
1,10	1 100	9,2	68,5
1,20	1 200	10,0	74,8
1,30	1 300	10,9	81,0
1,40	1 400	11,7	87,2
1,50	1 500	12,5	93,5
1,60	1 600	13,4	99,7
1,70	1 700	14,2	105,9
1,80	1 800	15,0	112,1
1,90	1 900	15,9	118,4
2,00	2 000	16,7	124,6
2,10	2 100	17,5	130,8
2,20	2 200	18,4	137,1
2,30	2 300	19,2	143,3
2,40	2 400	20,0	149,5
2,50	2 500	20,9	155,8
2,60	2 600	21,7	162,0
2,70	2 700	22,5	168,2
2,80	2 800	23,4	174,4
2,90	2 900	24,2	180,7

a Same value as relative density.

b Accurate conversion factor.

5 Alternative drilling fluid density method

5.1 Principle

The density of a drilling fluid containing entrained air or gas can be determined more accurately by using the pressurized mud balance. The pressurized mud balance is similar in operation to the conventional mud balance, the difference being that the slurry sample can be placed in a fixed-volume sample cup under pressure.

The purpose of placing the sample under pressure is to minimize the effect of entrained air or gas upon slurry density measurements. By pressurizing the sample cup, any entrained air or gas will be decreased to a negligible volume, thus providing a slurry density measurement more closely in agreement with that which will be realized under downhole conditions.

5.2 Apparatus

5.2.1 Any **density-measuring instrument** of accuracy to within 0,01 g/cm^3 or 10 kg/m^3.

The pressurized mud balance is the instrument generally used for pressurized drilling-fluid density determinations. The pressurized mud balance is designed such that the drilling-fluid holding cup and screw-on lid, at one end of the beam, is balanced by a fixed counterweight at the other end, with a sliding-weight rider free to move along a graduated scale. A level-bubble is mounted on the beam to allow for accurate balancing.

Calibrate the instrument frequently with fresh water. Fresh water should give a reading of 1,00 g/cm^3 or 1 000 kg/m^3 at 21 °C (70 °F). If it does not, adjust the balancing screw or the amount of lead shot in the well at the end of the graduated arm as required.

5.2.2 **Thermometer**, with a range of 0 °C to 105 °C (32 °F to 220 °F).

5.3 Procedure

5.3.1 Measure the temperature of the drilling fluid and record.

5.3.2 Fill the sample cup to a level slightly below the upper edge of the cup (approximately 6 mm).

5.3.3 Place the lid on the cup with the attached check-valve in the down (open) position. Push the lid downward into the mouth of the cup until surface contact is made between the outer skirt of the lid and the upper edge of the cup. Any excess slurry will be expelled through the check-valve. When the lid has been placed on the cup, pull the check-valve up into the closed position, rinse off the cup and threads with water, and screw the threaded cap on the cup.

5.3.4 The pressurizing plunger is similar in operation to a syringe. Fill the plunger by submersing its end in the slurry with the piston rod completely inside. Then draw the piston rod upward, thereby filling the cylinder with slurry. This volume should be expelled with the plunger action and refilled with fresh slurry sample to ensure that this plunger volume is not diluted with liquid remaining from the last clean-up of the plunger mechanism.

5.3.5 Push the nose of the plunger onto the mating O-ring surface of the cap valve. Pressurize the sample cup by maintaining a downward force on the cylinder housing in order to hold the check-valve down (open) and at the same time to force the piston rod inside. A force of approximately 225 N (50 lbf) or greater should be maintained on the piston rod.

5.3.6 The check-valve in the lid is pressure-actuated; when the inside of the cup is pressurized, the check-valve is pushed upward into the closed position. To close the valve, gradually ease up on the cylinder housing while maintaining pressure on the piston rod. When the check-valve closes, release pressure on the piston rod before disconnecting the plunger.

5.3.7 The pressurized slurry sample is now ready for weighing. Rinse the exterior of the cup and wipe dry. Place the instrument on the knife edge. Move the sliding weight to the right or left until the beam is balanced. The beam is balanced when the attached bubble is centred between the two black marks. Read the density from one of the four calibrated scales on the arrow side of the sliding weight. The density can be read directly in units of g/cm^3, lb/gal, and lb/ft^3 or as a drilling fluid gradient in psi/1 000 ft.

5.3.8 To release the pressure inside the cup, reconnect the empty plunger assembly and push downward on the cylinder housing.

5.3.9 Clean the cup and rinse thoroughly with water. For best operation in water-based slurries, the valve should be greased frequently with waterproof grease.

5.4 Calculation

Report the drilling fluid density to the nearest 0,01 g/cm^3 or 10 kg/m^3.

For conversions, use the formula given in 4.5.2.

6 Viscosity and gel strength

6.1 Principle

Viscosity and gel strength are measurements that relate to the flow properties (rheology) of drilling fluids. The following instruments are used to measure viscosity and/or gel strength of drilling fluids:

a) Marsh funnel — a simple device for indicating viscosity on a routine basis;

b) direct-indicating viscometer — a mechanical device for measurement of viscosity at varying shear rates.

NOTE Information on the rheology of drilling fluids may be found in [3].

6.2 Determination of viscosity using the Marsh funnel

6.2.1 Apparatus

6.2.1.1 **Marsh funnel**, calibrated to out-flow 946 ml (1 quart) of fresh water at a temperature of (21 ± 3) °C [(70 ± 5) °F] in (26 ± 0,5) s, with a graduated cup as a receiver.

6.2.1.1.1 **Funnel cone**, of length 305 mm (12,0 in), diameter 152 mm (6,0 in) and a capacity to bottom of screen of 1 500 ml (1,6 quarts).

6.2.1.1.2 **Orifice**, of length 50,8 mm (2,0 in) and inside diameter 4,7 mm (0,185 in).

6.2.1.1.3 **Screen**, with 1,6 mm (0,063 in) openings (12 mesh); fixed at 19,0 mm (0,748 in) below top of funnel.

6.2.1.2 **Graduated cup**, with capacity at least 946 ml (1 quart).

6.2.1.3 **Stopwatch**.

6.2.1.4 **Thermometer**, with a range of 0 °C to 105 °C (32 °F to 220 °F).

6.2.2 Procedure

6.2.2.1 Cover the funnel orifice with a finger and pour freshly sampled drilling fluid through the screen into the clean, upright funnel. Fill until fluid reaches the bottom of the screen.

6.2.2.2 Remove finger and start stopwatch. Measure the time for drilling fluid to fill to 946 ml (1 quart) mark of the cup.

6.2.2.3 Measure temperature of the fluid, in degrees Celsius (degrees Fahrenheit).

6.2.2.4 Report the time (6.2.2.2), to the nearest second, as the Marsh funnel viscosity. Report the temperature (6.2.2.3) of fluid to the nearest degree Celsius (degree Fahrenheit).

6.3 Determination of viscosity and/or gel strength using a direct-indicating viscometer

6.3.1 Apparatus

6.3.1.1 Direct-indicating viscometer

This type of viscometer is a rotational instrument powered by an electric motor or a hand crank. Drilling fluid is contained in the annular space between two concentric cylinders. The outer cylinder or rotor sleeve is driven at a constant rotational velocity. The rotation of the rotor sleeve in the fluid produces a torque on the inner cylinder or bob. A torsion spring restrains the movement of the bob, and a dial attached to the bob indicates displacement of the bob. Instrument constants have been adjusted so that plastic viscosity and yield point are obtained by using readings from rotor sleeve speeds of 300 r/min and 600 r/min.

A direct-indicating viscometer shall meet the following specifications:

a) **Rotor sleeve**

Inside diameter	36,83 mm (1,450 in)
Total length	87,0 mm (3,425 in)
Scribed line	58,4 mm (2,30 in) above the bottom of sleeve, with two rows of 3,18 mm (0,125 in) holes spaced 120° (2,09 radians) apart, around rotor sleeve just below scribed line.

b) **Bob**, closed, with flat base and tapered top

Diameter	34,49 mm (1,358 in)
Cylinder length	38,0 mm (1,496 in)

c) **Torsion spring constant**

386 dyne-cm/degree deflection.

d) **Rotor sleeve speed**

High speed	600 r/min
Low speed	300 r/min

NOTE Other rotor speeds are available in viscometers from various manufacturers.

6.3.1.2 Stopwatch.

6.3.1.3 Suitable container, e.g. the cup provided with the viscometer.

6.3.1.4 Thermometer, with a range of 0 °C to 105 °C (32 °F to 220 °F).

6.3.2 Procedure

6.3.2.1 Place the sample in a container and immerse the rotor sleeve exactly to the scribed line. Measurements in the field should be made with minimum delay (within 5 min, if possible) and at a temperature as near as practical to that of the drilling fluid at the place of sampling, but not differing by more than 6 °C (10 °F). The place of sampling should be stated on the test report.

WARNING — Maximum recommended operating temperature is 90 °C (200 °F). If fluids have to be tested above this temperature, a solid metal bob or a hollow metal bob with a completely dry interior should be used. Liquid trapped inside a hollow bob may vaporize when immersed in high temperature fluid and cause the bob to explode.

6.3.2.2 Record the temperature of the sample.

6.3.2.3 With the sleeve rotating at 600 r/min, wait for viscometer dial reading to reach a steady value (the time required is dependent on the drilling-fluid characteristics). Record the dial reading for 600 r/min.

6.3.2.4 Reduce the rotor speed to 300 r/min and wait for viscometer dial reading to reach a steady value. Record the dial reading for 300 r/min.

6.3.2.5 Stir drilling fluid sample for 10 s at 600 r/min.

6.3.2.6 Allow drilling fluid sample to stand undisturbed for 10 s. Slowly and steadily turn the hand-wheel in the appropriate direction to produce a positive dial reading. The maximum reading is the initial gel strength. For instruments having a speed of 3 r/min, the maximum reading attained after starting rotation at 3 r/min is the initial gel strength. Record the initial gel strength (10-second gel) in pascals (or in pounds per 100 square feet).

6.3.2.7 Restir the drilling fluid sample at 600 r/min for 10 s and then allow the drilling fluid to stand undisturbed for 10 min. Repeat the measurements as in 6.3.2.6 and report the maximum reading as the 10-minute gel in pascals (or in pounds per 100 square feet).

6.3.3 Calculation

$$\eta_P = R_{600} - R_{300} \tag{6}$$

$$YP = 0{,}48 \times (R_{300} - \eta_P) \tag{7}$$

$$\eta_A = R_{600} / 2 \tag{8}$$

where

η_P is the plastic viscosity, in millipascal seconds;

NOTE Plastic viscosity is commonly known in the industry by the abbreviation PV.

YP is the yield point, in pascals;

η_A is the apparent viscosity, in millipascal seconds;

R_{600} is the dial reading at 600 r/min, in pascals (or in lb/100 ft^2);

R_{300} is the dial reading at 300 r/min, in pascals (or in lb/100 ft^2).

NOTE 1 1 cP = 1 mPa·s

NOTE 2 When calculating values in U.S. customary units, the yield point (in lb/100 ft^2) is calculated as follows:

$$YP = R_{300} - \eta_P$$

7 Filtration

7.1 Principle

Measurement of the filtration behaviour and filter cake-building characteristics of a drilling fluid are fundamental to drilling-fluid control and treatment, as are the characteristics of the filtrate such as oil, water or emulsion content. These characteristics are affected by the types and quantities of solids in the fluid and their physical and chemical interactions which, in turn, are affected by temperature and pressure. Therefore, tests are run at both low pressure/low temperature and high pressure/high temperature, and each requires different equipment and techniques.

7.2 Low temperature/low pressure test

7.2.1 Apparatus

7.2.1.1 **Filter press**, consisting mainly of a cylindrical drilling-fluid cell having an inside diameter of 76,2 mm (3 in) and a height of at least 64,0 mm (2,5 in).

This cell is made of materials resistant to strongly alkaline solutions, and is so fitted that a pressure medium can be conveniently admitted into, and bled from the top. It shall also be fitted such that a sheet of 90 mm (3,54 in) diameter filter paper can be placed in the bottom of the cell just above a suitable support. The filtration area is $(45{,}8 \pm 0{,}6)$ cm^2 [$(7{,}1 \pm 0{,}1)$ in^2]. Below the support is a drain tube for discharging the filtrate into a graduated cylinder. Sealing is accomplished with gaskets, and the entire assembly supported by a stand. Pressure can be applied with any non-hazardous fluid medium. Presses are equipped with pressure regulators and can be obtained with portable pressure cylinders, midget pressure cartridges or means for utilizing hydraulic pressure. To obtain correlative results, one thickness of the proper 90 mm diameter filter paper (e.g. Whatman No. 50, S&S No. 576[1)] or equivalent) shall be used.

The low temperature/low pressure filter press should have a filter area of 45,2 cm^2 to 46,4 cm^2, which corresponds to a diameter of 75,86 mm to 76,86 mm (2,987 in to 3,026 in). The filter press gasket is the determining factor of the filter area. It is recommended that a filter press gasket used be tested by a conical gauge that has the maximum (76,86 mm) and the minimum (75,86 mm) diameters marked on it. Any filter press gasket found out of these ranges (either larger or smaller than the markings) shall be discarded.

NOTE Results obtained from the use of a filter press with different filter area do not directly correlate with the results obtained when using the standard-sized press.

7.2.1.2 **Timer**, with at least a 30 min interval.

7.2.1.3 **Graduated cylinder** (TC), of volume 10 ml or 25 ml.

7.2.2 Procedure

7.2.2.1 Be sure each part of the cell, particularly the screen, is clean and dry, and that the gaskets are not distorted or worn. Pour the drilling fluid sample into the cell to within 1 cm to 1,5 cm (0, 4 in to 0,6 in) of the top (to minimize CO_2 contamination of filtrate), and complete the assembly with the filter paper in place.

7.2.2.2 Place a dry graduated cylinder under the drain tube to collect the filtrate. Close the relief valve and adjust the regulator so that a pressure of 690 kPa $\pm$ 35 kPa (100 psi $\pm$ 5 psi) is applied within 30 s or less. The test period begins at the time of pressure application.

7.2.2.3 At the end of 30 min, measure the volume of filtrate collected. Shut off the flow through the pressure regulator and open the relief valve carefully. The time interval, if other than 30 min, shall be reported.

7.2.2.4 Report the volume of filtrate in millilitres (to the nearest 0,1 ml) and the initial drilling fluid temperature in degrees Celsius (degrees Fahrenheit). Save the filtrate for chemical analysis.

7.2.2.5 Remove the cell from the frame, first making certain that all pressure has been relieved. Carefully save the filter paper with a minimum of disturbance to the cake, disassemble the cell and discard the drilling fluid. Wash the filter cake on the paper with a gentle stream of water.

7.2.2.6 Measure and report the thickness of the filter cake, to the nearest millimetre.

7.2.2.7 Although cake descriptions are subjective, such notations as hard, soft, tough, rubbery, firm, etc., may convey important information of cake quality.

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1) Whatman No. 50 and S&S No. 576 are examples of suitable products available commercially. This information is given for the convenience of users of this part of ISO 10414 and does not constitute an endorsement by ISO of these products.