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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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Contents

Page

Foreword

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

This second edition cancels and replaces the first edition (ISO 10414-1:2001), to which Annexes I, J and K have been added and other minor changes made to the sentence structure, grammar and other non-technical editing.

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*

Introduction

This part of ISO 10414 is based on API RP 13B-1, third edition, December 2003[2] and ISO 10414 (all parts)[6].

Annexes A to H and K of this part of ISO 10414 are for information only. Annexes I and J are normative.

In this part of ISO 10414, where practical, U.S. Customary (USC) units are included in brackets for information.

Petroleum and natural gas industries — Field testing of drilling fluids

Part 1: Water-based fluids

DANGER — As with any laboratory procedure requiring the use of potentially hazardous chemicals, the user is expected to have proper knowledge and to have 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.

1 Scope

This part of ISO 10414 provides standard procedures for determining the 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 through K provide additional test methods which may be used for

— chemical analysis for calcium, magnesium, calcium sulfate, sulfide, carbonate and potassium;

— determination of shear strength;

— determination of resistivity;

— removal of air;

— drill-pipe corrosion monitoring;

— sampling, inspection and rejection;

- rig-site sampling;
- calibration and verification of glassware, thermometers, viscometers, retort-kit cup and drilling-fluid balances;
- permeability-plugging testing at high temperature and high pressure for two types of equipment;
- example of a report form for water-based drilling fluid.

2 Terms and definitions

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

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

2.2
darcy
permeability of a porous medium, where one darcy is the flow of a single-phase fluid of 1 cP viscosity that completely fills the voids of the porous medium, flowing through the medium under conditions of viscous flow at a rate of 1 $ml \cdot s^{-1} \cdot cm^{-2}$ cross-sectional area and under a pressure or equivalent hydraulic gradient of 1 $atm \cdot cm^{-1}$

NOTE 1 cP = 1 mPa·s.

2.3
quarter
⟨verb⟩ mix and divide into four specimens to ensure homogeneity of specimens

2.4
spurt loss
volume of fluid that passes through the filtration medium before a filter cake is formed

2.5
tube sampling
sampling method consisting of the withdrawal of powdered sample from bag or bulk via a cylindrical device pushed into the sample, locked shut and withdrawn

3 Symbols and abbreviated terms

3.1 Symbols

NOTE Subscript “A” to symbol denotes metric units. Subscript “B” to symbol denotes U.S. customary units.

A_{A}	area, in square centimetres
A_{B}	area, in square inches
$c_{\mathrm{b,A}}$	concentration of weighting material, in kilograms per cubic metre
$c_{\mathrm{b,B}}$	concentration of weighting material, in pounds per barrel
$c_{\mathrm{Ca,A}}$	concentration of calcium ion, in milligrams per litre
$c_{\mathrm{Ca,B}}$	concentration of calcium ion, in parts per million by mass (USC)

$c_{\mathrm{Ca+Mg,A}}$	concentration of calcium and magnesium ion (total hardness), in milligrams per litre
$c_{\mathrm{Ca+Mg,B}}$	concentration of calcium and magnesium ion (total hardness), in parts per million (USC)
$c_{\mathrm{CaSO4,A}}$	concentration of calcium sulfate, in milligrams per litre
$c_{\mathrm{CaSO4,B}}$	concentration of calcium sulfate, in parts per million by mass (USC)
$c_{\mathrm{CO2+CO3+HCO3,A}}$	concentration of total soluble carbonates, in milligrams per litre
$c_{\mathrm{CO2+CO3+HCO3,B}}$	concentration of total soluble carbonates, in parts per million by mass (USC)
$c_{\mathrm{Cl,A}}$	concentration of chloride ion, in milligrams per litre
$c_{\mathrm{Cl,B}}$	concentration of chloride ion, in parts per million by mass (USC)
$c_{\mathrm{ex\text{-}CaSO4,A}}$	concentration of excess, undissolved calcium sulfate, in milligrams per litre
$c_{\mathrm{ex\text{-}CaSO4,B}}$	concentration of excess, undissolved calcium sulfate, in parts per million by mass (USC)
$c_{\mathrm{f,KCl,A}}$	concentration of potassium chloride in filtrate, in milligrams per litre
$c_{\mathrm{f,KCl,B}}$	concentration of potassium chloride in filtrate, in parts per million by mass (USC)
$c_{\mathrm{K,A}}$	concentration of potassium ion, in milligrams per litre
$c_{\mathrm{K,B}}$	concentration of potassium ion, in parts per million by mass (USC)
$c_{\mathrm{KCl,A}}$	concentration of potassium chloride, in milligrams per litre
$c_{\mathrm{KCl,B}}$	concentration of potassium chloride, in parts per million by mass (USC)
$c_{\mathrm{lg,A}}$	concentration of low-gravity solids, in kilograms per cubic metre
$c_{\mathrm{lg,B}}$	concentration of low-gravity solids, in pounds per barrel
$c_{\mathrm{lime,A}}$	lime content of the drilling fluid, in kilograms per cubic metre
$c_{\mathrm{lime,B}}$	lime content of the drilling fluid, in pounds per barrel
$c_{\mathrm{NaCl,A}}$	concentration of sodium chloride, in milligrams per litre
$c_{\mathrm{NaCl,B}}$	concentration of sodium chloride, in parts per million by mass (USC)
$c_{\mathrm{S,A}}$	concentration of sulphide ion, in milligrams per litre
$c_{\mathrm{S,B}}$	concentration of sulphide ion, in parts per million by mass (USC)
$c_{\mathrm{SS,A}}$	suspended solids concentration, in kilograms per cubic metre
$c_{\mathrm{SS,B}}$	suspended solids concentration in pounds per barrel
c_{MBT}	methylene blue capacity
c_{th}	thermometer correction to be added to the working thermometer reading
D	outer diameter
$E_{\mathrm{BE,A}}$	bentonite equivalent, expressed in kilograms per cubic metre

$E_{BE,B}$	bentonite equivalent, expressed in pounds per barrel
f	tube factor from either Table A.1 or Table A.2, for sulfide or carbonate
F_W	fraction (volume fraction) of water
k_{cor}	correction factor
K	cell constant, in metres squared per metre
l_A	submerged length of shear tube, in centimetres
l_B	submerged length of shear tube, in inches
l_{st}	Dräger tube stain length
m_{ds}	mass of the dried sample, in grams
m_s	mass of methylene blue, in grams
m_{st}	mass of shear tube, in grams
m_{tot}	total shear mass, in grams (sum of platform and weights)
m_W	mass of water, in grams
Δm	mass loss, in milligrams
M_f	methyl orange alkalinity of the filtrate
P_{df}	phenolphthalein alkalinity of the drilling fluid
P_f	phenolphthalein alkalinity of the filtrate
q_A	corrosion rate, kilograms per squared metre per year
q_B	corrosion rate, pounds per squared foot per year
r_{df}	drilling fluid resistivity, in ohm metres
r_f	filtrate resistivity, in ohm metres
$R_{QAS/STPB}$	ratio of the concentration of QAS to that of STPB
R_r	resistivity meter reading, in ohms
R_1	average reading for the standard thermometer
R_2	average reading for the working thermometer
$R_{2,cor}$	corrected reading for the working thermometer
R_{300}	viscometer dial reading at 300 r/min
R_{600}	viscometer dial reading at 600 r/min
t	exposure time, in hours
$t_{7,5}$	initial reading taken at 7,5 min

t_{30}	final reading taken at 30 min
V_{df}	volume of drilling fluid sample, in millilitres
V_{EDTA}	volume of EDTA solution, in millilitres
$V_{EDTA,df}$	EDTA volume of whole drilling fluid
$V_{EDTA,f}$	EDTA volume of the drilling fluid filtrate
V_{f}	volume of the filtrate, in millilitres
V_{mb}	volume of methylene blue solution, in millilitres
V_{o}	volume of oil, in millilitres
V_{PPT}	PPT volume, in millilitres
V_{RC}	retort cup volume, expressed in millilitres
V_{s}	volume of the sample, in millilitres
V_{sn}	volume of silver nitrate solution, in millilitres
V_{W}	volume of water, in millilitres
V_{1}	spurt loss, in millilitres
$V_{7,5}$	filtrate volume after 7,5 min, in millilitres
V_{30}	filtrate volume after 30 min, in millilitres
v_{st}	static filtration rate (velocity of flow), millilitres per square root of the minutes, in millilitres per minute
$Y_{P,A}$	yield point, in pascals
$Y_{P,B}$	yield point, in pounds per one hundred square feet
γ_{A}	shear strength, expressed in pascals
γ_{B}	shear strength, expressed in pounds per hundred square feet
$\Gamma_{DFG,A}$	drilling fluid gradient, expressed in kilopascals per metre
$\Gamma_{DFG,B}$	drilling fluid gradient, in pounds per square inch per foot
η_{a}	apparent viscosity, in millipascal seconds
$\eta_{p,A}$	plastic viscosity, in millipascal seconds
$\eta_{p,B}$	plastic viscosity, in pounds per one-hundred square feet
θ	temperature
ρ	density, expressed in g/ml when compared to distilled water
ρ_{A}	density, expressed in kilograms per cubic metre
ρ_{B1}	density, expressed in pounds per gallon

ρ_{B2}	density, expressed in pounds per cubic foot
ρ_b	density of weighting material, in grams per millilitre
ρ_{df}	drilling fluid density, in grams per millilitre
ρ_f	density of filtrate, in grams per millilitre
ρ_{lg}	density of low-gravity solids, in grams per millilitre (use 2,6 if unknown)
ρ_o	density of oil, in grams per millilitre (use 0,8 if unknown)
ρ_W	water density, in grams per millilitre, at test temperature
φ_b	volume fraction of weighting material, in percent
φ_{lg}	volume fraction of low-gravity solids, in percent
φ_o	volume fraction of oil, in percent
φ_S	volume fraction of retort solids, in percent
φ_{SS}	volume fraction of suspended solids, in percent
φ_W	volume fraction of water, in percent

3.2 Abbreviations

AA	atomic absorption spectroscopy
ACS	American Chemical Society
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
BE	bentonite equivalent
CAS	Chemical Abstracts Service
DFG	drilling fluid gradient
DS	drill solids
EDTA	ethylenediaminetetraacetic acid
HTHP	high-temperature, high-pressure
LGS	low-gravity solids
MBT	methylene blue test/capacity
meq	milliequivalents
OCMA	Oil Companies Materials Association (originally, Middle East companies)
PPA	permeability plugging apparatus
PPT	permeability plugging test

PTFE	polytetrafluoroethylene
PV	plastic viscosity, in common oilfield terminology
QAS	quaternary ammonium salt
TC	to contain
TD	to deliver
USC	U.S. Customary units, commonly used in U.S.-based testing

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 (equivalent to density). Drilling-fluid density is expressed as grams per cubic centimetre or kilograms per cubic metre (pounds per gallon or pounds per cubic foot).

4.2 Apparatus

4.2.1 Density-measuring instrument, of accuracy to within 0,01 g/ml or 10 kg/m^3 (0,1 lb/gal or 0,5 lb/ft^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/ml or 1 000 kg/m^3 (8,33 lb/gal or 62,3 lb/ft^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 and record the temperature of the drilling fluid.

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 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/ml, lb/gal, and lb/ft^3, or as a drilling fluid gradient in psi/1 000 ft.

4.4 Calculation

4.4.1 Report the drilling fluid density to the nearest 0,01 g/ml or 10 kg/m^3 (0,1 lb/gal or 0,5 lb/ft^3).

4.4.2 Equations (1) to (3) are used to convert the density, ρ, expressed in grams per cubic centimetre to other units:

$$\rho_A = 1\,000 \times \rho \tag{1}$$

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

$$\rho_{B1} = 8{,}33 \times \rho \tag{2}$$

where ρ_{B1} is the density, expressed in pounds per gallon.

$$\rho_{B2} = 62{,}3 \times \rho \tag{3}$$

where ρ_{B2} is the density, expressed in pounds per cubic foot.

Table 2 is provides the multiplication factor for conversion from one density unit to another.

Equations (4) to (7) are used to convert the density to the drilling fluid gradient, Γ_{DFG}, expressed in kilopascals per metre (pounds per square inch per foot):

$$\Gamma_{DFG,A} = 9{,}81 \times \text{g/ml} \tag{4}$$

$$\Gamma_{DFG,A} = 0{,}022\,6 \times \text{psi/ft} \tag{5}$$

$$\Gamma_{DFG,B} = 0{,}052\,0 \times \text{lb/gal} \tag{6}$$

$$\Gamma_{DFG,B} = 0{,}006\,94 \times \text{lb/ft}^3 \tag{7}$$

where

$\Gamma_{DFG,A}$ is the drilling fluid gradient, expressed in kilopascals per metre;

$\Gamma_{DFG,B}$ is the drilling fluid gradient, expressed in pounds per square inch per foot.

A list of density conversions is given in Table 1.

Table 1 — Density conversion

Grams per cubic centimetre [a] g/ml	**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	74,7
1,30	1 300	10,9	81,0

Table 1 (*continued*)

Grams per cubic centimetre [a] g/ml	Kilograms per cubic metre kg/m³	Pounds per US gallon (lb/US gal)	Pounds per cubic foot (lb/ft³)
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.

Table 2 — Conversion of density units

Measured in	Multiply to get			
	g/ml	kg/m³	lb/gal	lb/ft³
g/ml	1	1 000	8,33	62,3
kg/m³	0,001	1	0,008 3	16,026
lb/gal	0,120	120	1	7,49
lb/ft³	0,016 0	16,03	0,133 5	1

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 is decreased to a negligible volume, thus providing a slurry density measurement more closely in agreement with that which is realized under downhole conditions.