

Drilling-fluid Processing Systems Evaluation

API RECOMMENDED PRACTICE 13C
SIXTH EDITION, DECEMBER 2023



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Drilling-fluid Processing Systems Evaluation

1 Scope

This recommended practice specifies procedures for assessing and modifying the performance of solids control equipment systems commonly used in the field in petroleum and natural gas drilling-fluids processing.

The procedures described in this standard are not intended for the comparison of similar types of individual pieces of equipment.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Recommended Practice 13B-1, *Field Testing Water-based Drilling Fluids*

API Recommended Practice 13B-2, *Field Testing Nonaqueous-based Drilling Fluids*

ASTM E11 ¹, *Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves*

3 Terms, Definitions, Symbols, Acronyms, and Abbreviations

3.1 Terms and Definitions

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

3.1.1

addition section

Compartment(s) in the surface drilling-fluid system, between the removal section and the suction section, which provides (a) well-agitated compartment(s) for the addition of drilling-fluid additives.

3.1.2

agitator

mechanical stirrer

Mechanically driven mixer that stirs the drilling fluid by turning an impeller near the bottom of a mud compartment to blend additives, suspend solids, and maintain a uniform consistency of the drilling fluid.

3.1.3

aperture

(screen cloth)

Opening between the wires in a screen cloth.

3.1.4

aperture

(screen surface)

Opening in a screen surface.

3.1.5

apex

Opening at lower end of a hydrocyclone.

¹ ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428, www.astm.org.

3.1.6**API screen number**

API system screen designation from the measured D100 separation of a screen cloth based on the ASTM E11 separation range (see 3.1.22).

NOTE See 9.6 and Table 5 for further information. The 31 API screen numbers listed in Table 5 are the only acceptable API number designations.

3.1.7**backing plate**

Support plate attached to the back of screen cloth(s).

3.1.8**baffle**

Plate or obstruction built into a compartment to change the direction of fluid flow.

3.1.9**barite**

Natural barium sulfate (BaSO_4) used for increasing the density of drilling fluids.

NOTE The two grades of API barite have a minimum specific gravity of 4.20 or 4.10 (see Reference [1], API 13A). Commercial API 13A barite can be produced from a single ore or a blend of ores and can be a straight-mined product or processed by flotation or other purification methods. They contain accessory minerals other than barium sulfate. Because of mineral impurities, commercial barite can vary in color from off-white to grey to red or brown. Common accessory minerals are silicates such as quartz and chert, carbonate compounds such as siderite and dolomite, and metallic oxide or sulfide compounds.

3.1.10**base fluid**

Water or brine used to prepare water-based drilling fluids or nonaqueous fluid (NAF) used to prepare nonaqueous drilling fluids (NADFs) (see 3.1.55).

3.1.11**blinding**

Reduction of open area in a screening surface caused by coating or plugging. Most often the plugging is caused by particles that are similar in size to the screen openings. Blinding may be prevented by installing finer screens.

3.1.12**bonding material**

Material used to secure screen cloth to a backing plate or support screen.

3.1.13**capture**

Mass fraction of incoming suspended solids that are conveyed to the reject stream.

3.1.14**centrate**

Discharge stream from a centrifugal separation that contains a higher percentage of liquids than the feed does.

3.1.15**centrifugal pump**

Machine for moving fluid by spinning it using a rotating impeller in a casing with a central inlet and a tangential outlet.

NOTE The path of the fluid is an increasing spiral from the inlet at the center to the outlet, tangent to the impeller annulus. In the annular space between the impeller vane tips and the casing wall, the fluid velocity is roughly the same as

that of the impeller vane tips. Useful work is produced by the pump when some of the spinning fluid flows out of the casing tangential outlet into the pipe system. Power from the motor is used to accelerate the fluid entering the inlet up to the speed of the fluid in the annulus. Some of the motor power is expended as friction of the fluid in the casing and impeller.

3.1.16

centrifuge

Device, rotated by an external force, for the purpose of separating materials of various masses (depending upon specific gravity and particle sizes) from a slurry to which the rotation is imparted primarily by the rotating container walls.

3.1.17

clay (mineral)

Soft, often sticky, naturally occurring shallow minerals with a layered (sheetlike) structure of hydrous aluminum silicate.

NOTE Clay minerals are essentially insoluble in water but disperse under hydration, grinding, heating, or shearing.

3.1.18

clay (particle)

Colloidal particles of clay mineral having less than 2 μm equivalent spherical diameter (see colloidal solid, 3.1.19).

3.1.19

colloidal solid (or particle)

Any solid particle of diameter less than 2 μm .

NOTE This term is commonly used as a synonym for clay particle size.

3.1.20

conductance

Permeability per unit thickness of a static (not in motion) shale shaker screen.

NOTE Conductance is expressed in units of kilodarcys per millimeter ².

3.1.21

cuttings

Formation pieces dislodged by the drill bit and brought to the surface in the drilling fluid.

NOTE Field practice is to refer to all solids removed by the shaker screen as "cuttings," although some can be sloughed material.

3.1.22

D100 separation

Particle size, expressed in micrometers, determined by plotting the percentage of aluminum oxide (AIO) sample separated by the test screen on the plot of cumulative mass fraction (expressed as a percentage) retained vs standard sieve opening (expressed in micrometers) for the sieve analysis of the AIO test sample.

NOTE 100 % of the particles larger than the D100 separation are retained by the test screen.

² The darcy is not an SI unit, but kilodarcys per millimeter (kD/mm) is the recommended unit for this standard. The SI unit of permeability to fluid flow is defined as the amount of permeability that permits 1 m³ of fluid of a viscosity of 1 Pa·s to flow through a section that is 1 m thick with a cross-section of 1 m² in 1 s at a pressure difference of 1 Pa. Therefore, in SI units, permeability is expressed in square meters: 1 m² = 1.01325 × 10¹² darcys.

3.1.23**decanting centrifuge**

Centrifuge that removes solids from a feed slurry by rotating the liquid in cylindrical bowl at high speed and discharges the higher mass particles as a damp underflow.

NOTE Colloidal solids are discharged with the liquid overflow or light slurry. The decanting centrifuge has an internal auger that moves solids that have settled to the bowl walls out of a pool of liquid and to the underflow.

3.1.24**density****(relative density or volumic mass)**

Mass divided by volume.

NOTE 1 In SI units, density is expressed in kilograms per cubic meter; in USC units, it is expressed as pounds per gallon or pounds per cubic foot. Other units include what is commonly referred to as specific gravity with units of g/mL.

NOTE 2 Drilling-fluid density is commonly referred to as “drilling-fluid weight” or “mud weight.”

3.1.25**desander**

Hydrocyclone with an inside diameter of at least 152 mm (6 in.) that removes a high proportion of the particles with a diameter of at least 74 μm from a drilling fluid. Typically used to separate the highest mass solids from the lightest in the feed slurry of an unweighted drilling fluid.

3.1.26**desilter**

Hydrocyclone with an inside diameter of less than 152 mm (6 in.).

3.1.27**dilution**

Method of decreasing or maintaining the drilled-solids content of a slurry by adding additional liquid volumes, usually a clean drilling fluid or the base fluid (water or NAF).

3.1.28**drilled-solids**

Formation solids that enter the drilling-fluid system, whether excavated solids produced by the drill bit (see 3.1.36) or from the enlargement of the borehole due to mechanical erosion, spalling, or dissolution.

3.1.29**drilled-solids removal system**

Equipment and processes used while drilling a well that remove the solids generated from the hole and carried by the drilling fluid.

NOTE These processes include settling, screening, desanding, desilting, centrifuging, and dumping.

3.1.30**drilled-solids removal system efficiency (η_{DSR})****drilled-solids removal system performance**

Measure of the removal of drilled solids by surface solids control equipment.

NOTE Defined as the ratio of the total volume of drilled solids discarded by processing equipment divided by the volume of excavated drilled solids as a percent.

3.1.31**drilling fluid**

Liquid or slurry pumped down the drill string and up the annulus of a wellbore during the drilling operation, processed through the surface fluid processing system then recirculated.

3.1.33**eductor
(fluid stream)**

Device using a fluid stream that discharges under high pressure from a jet through an annular space to create a low-pressure region.

NOTE When properly arranged, it can evacuate degassed drilling fluid from a vacuum-type degasser or pull solids through a hopper.

3.1.32**eductor
pressure jet**

Device using a high-velocity jet to create a low-pressure region that draws liquid or dry material to be blended with the drilling fluid.

NOTE The use of a high-velocity jet to create a low-pressure region is known as the Bernoulli principle.

3.1.34**effluent**

Discharge of liquid from a piece of equipment, generally a stream, after some attempt at separation of drill solids or purification has been made. In this document, it does not necessarily mean a waste being discarded.

3.1.35**equalizer**

Opening or piping for flow between compartments in the surface fluid-processing system, which allows for the desired flow path and fluid levels. Often adjustable such that the inlet is from the bottom of the last processing pit and the outlet is into the upper section of the product additions or suction pit.

3.1.36**excavated drilled solids**

Volume of solids drilled over a specified interval.

3.1.37**flow capacity**

Rate at which equipment, such as a shaker or centrifuge, can process drilling fluid.

NOTE For a shale shaker, flow capacity is a function of many variables, including screen opening sizes, shaker configuration, design and motion, drilling-fluid rheology, solids loading, screen design, open area, plus any blinding by near-size particles. No standard exists for reported flow capacity so reported values may not be indicative of actual performance with drilling fluids and excavated drilled solids.

3.1.38**flow line**

Piping or trough that directs drilling fluid from the rotary nipple to the surface drilling-fluid system.

3.1.39**flow rate**

The volume of liquid or slurry that passes per unit of time.

NOTE Flow rate is expressed as cubic meters per minute, gallons per minute, barrels per minute, etc.

3.1.40**gumbo**

Drilled solids that agglomerate and form a sticky mass as they are circulated up the wellbore.

3.1.41**head**

Height that a fluid column would reach in an open-ended pipe if the pipe were attached to the point of interest.

NOTE The head at the bottom of a 300 m (1000 ft) well is 300 m (1000 ft), but the pressure at that point depends upon the density of the drilling fluid in the well.

3.1.42**hook strip**

Hooks on the edge of a screen section of a shale shaker that accept the tension member for screen mounting.

3.1.43**hopper****mud hopper**

Funnel-shaped or coned-shaped device, into which dry (or liquid) components are poured to facilitate uniform blending with liquids or slurries that are flowing through the lower part of the cone.

3.1.44**hydrocyclone****cone****cyclone**

Liquid-solids separation device using centrifugal force for settling. Desanders and desilters are hydrocyclones used most often for processing unweighted drilling fluids.

NOTE Fluid enters tangentially and spins inside the hydrocyclone. The heavier solids settle to the walls of the hydrocyclone and move downward until they are discharged at the hydrocyclone apex. The discharge from the apex of the cone is called the underflow. The spinning fluid travels part way down the hydrocyclone and back up to exit out the top of the hydrocyclone through a vortex finder. The discharged fluid from the top of the cone is called the effluent or overflow.

3.1.45**impeller**

Spinning disc in a centrifugal pump with protruding vanes, used to accelerate the fluid in the pump casing.

3.1.46**manifold**

Length of pipe with multiple connections for collecting or distributing drilling fluid.

3.1.47**Marsh funnel viscosity****funnel viscosity**

Viscosity measured with the instrument used to monitor drilling fluid (see API 13B-1 or API 13B-2).

NOTE A Marsh funnel is a tapered container with a fixed orifice at the bottom so that when filled with 1500 mL of fresh water, 946 mL (1 qt) will drain in 26 s. It is used for comparison values only and not to diagnose drilling-fluid problems.

3.1.48**mud**

Slurry of insoluble and soluble solids in either an aqueous or nonaqueous continuous-phase fluid.

NOTE See drilling fluid (3.1.31).

3.1.49**mud balance**

Beam-type balance used in determining drilling-fluid density (see API 13B-1 or API 13B-2).

3.1.50**mud cleaner**

Combination of hydrocyclones followed by screening equipment, where the screen separates out larger solids from the hydrocyclone underflow.

NOTE The hydrocyclone overflow returns to the drilling fluid, while the underflow of the hydrocyclones is processed through a vibrating screen. The screen is usually of size API 170 or finer. The screen solids discharge is discarded while the liquid and solids passing through the screen are returned to the drilling fluid.

3.1.51**mud compartment (or compartment)**

Subdivision of the removal, addition, or suction sections of a surface system.

3.1.52**mud gun**

Submerged nozzle used to stir drilling fluid with a high-velocity stream.

3.1.53**near-size particle**

Particle whose size is close to the size of the openings in the screen through which its passage is under evaluation.

3.1.54**Newtonian fluid**

A fluid such as water, oil, NAF, or brine that has a constant viscosity (at constant temperature) with a zero shear stress at zero shear rate; the shear stress is directly proportional to the shear rate.

3.1.55**nonaqueous drilling fluid****NADF**

Drilling fluid in which a NAF is the continuous phase, usually with calcium chloride brine as an emulsified internal phase. A NAF base fluid is not miscible with water.

3.1.56**particle**

Discrete unit of solid material that consists of a single grain or of any number of grains stuck together.

3.1.57**particle size distribution**

Mass or net volume classification of solid particles into each of the various size ranges, as a percentage of the total solids of all sizes in a fluid sample.

3.1.58**plugging**

Wedging or jamming of openings in a screening surface by near-size particles, which prevents the passage of undersize particles and leads to the blinding (see 3.1.11) of the screen.

3.1.59**possum belly**

Compartment or back tank on a shale shaker, into which the flow line discharges and from which drilling fluid is either fed to the screens or is bypassed, if necessary.

3.1.60**relative density**

Relative density is the ratio of the density (mass of a unit volume of a substance to the density of a given reference material. Most commonly, the reference material is water.

NOTE 1 Relative density is commonly named specific gravity.

NOTE 2 For the purposes of this recommended practice, the symbol for density, ρ , will be used for specific gravity.

3.1.61**removal section**

First section in the surface drilling-fluid system, consisting of a series of compartments where processing equipment is located to remove gas and undesirable solids.

3.1.62**retort**

Instrument used to distill NAF, water, and other volatile material in a drilling fluid to determine the volume fraction of NAF, water, and total solids (see API 13B-1 or API 13B-2).

3.1.63**sand trap**

First compartment in a surface system, generally located directly below or after the shale shakers. Usually unstirred or unagitated with a high weir so that it functions as a settling compartment where coarser solids that bypass the shakers accumulate.

3.1.64**screen cloth**

Type of screening surface woven in square, rectangular, or slotted openings.

3.1.65**screening**

Mechanical process that results in a division of particles on the basis of size, based on their passing through or being rejection by a screening surface.

3.1.66**shale shaker**

Mechanical device that separates drill cuttings and solids larger than the screen aperture from a drilling fluid.

NOTE The separation methods can include vibrating screens, rotating cylindrical screens, and screen cloth belts, etc.

3.1.67**sieve**

Laboratory screen with wire mesh or electronically punched holes of known dimensions mounted in a frame.

3.1.68**sieve analysis**

Classification (distribution) by size performed by measuring the mass of solid particles retained on a sequence of screens with decreasing aperture sizes.

NOTE Sieve analysis can be carried out by wet or dry methods (see Bibliography [2]).

3.1.69**slug tank**

Smaller volume compartment (relative to other surface system compartments), normally adjacent to the suction compartment, used to mix special fluids (such as spacers, pills, and spotting fluids) to pump downhole.

NOTE Slug tanks are most commonly used to prepare a small volume of weighted drilling fluid before a drill string trip out of the borehole. Also commonly called a pill pit.

3.1.70**suction section/compartment**

Last active section in the surface system that supplies drilling fluid to the suction of the drilling-fluid pumps.

NOTE In general terms, a suction compartment is any compartment from which a pump removes fluid.

3.1.71**tensioning**

Stretching of a screening surface of a shale shaker to the proper tension, while positioning it within the vibrating frame.

3.1.72**total non-blanked area**

Net unblocked area that permits the passage of fluid through a screen.

NOTE 1 Total non-blanked area is expressed in m² (ft²).

NOTE 2 Some screen designs can eliminate as much as 40 % of the gross screen panel area from fluid flow due to backing-plate and bonding-material blockage.

3.1.73**trip tank**

Gauged and calibrated vessel used to account for fill and displacement volumes as pipe is pulled from and run into the hole.

NOTE Close observation allows early detection of formation fluid entering a wellbore and of drilling fluid loss to a formation.

3.1.74**underflow****(centrifugal separator)**

Discharge stream from a centrifugal separator that contains a higher percentage of solids compared to the feed.

3.1.75**underflow****(screen separator)**

Discharge stream from a screen separator that contains a lower percentage of solids compared to the feed.

3.1.76**un-occluded**

Unobstructed area of a screen opening.

3.1.77**unweighted drilling fluid**

Drilling fluid that does not contain commercial suspended solids added for the purpose of increasing the density of the drilling fluid.

3.1.78**viscosity**

Ratio of shear stress to shear rate.

NOTE 1 In SI units, viscosity is expressed in pascal•seconds; in USC units, viscosity is expressed in centipoises.

NOTE 2 If the shear stress is expressed in the centimeter-gram-second (CGS) system of units (dynes per square centimeter) and the shear rate is expressed in reciprocal seconds, the viscosity is expressed in poises (P); $1 \text{ P} = 1 \text{ dyn}\cdot\text{s}/\text{cm}^2 = 1 \text{ g}\cdot\text{cm}^{-1}\cdot\text{s}^{-1} = 10^{-1} \text{ Pa}\cdot\text{s}$; and $1 \text{ cP} = 1 \text{ mPa}\cdot\text{s}$.

3.1.79**water-based drilling fluid**

Drilling fluid in which water is the base fluid for the formulation and is the continuous phase, whether oil is present or not.

3.1.80**weighted drilling fluid**

Drilling fluid to which solids have been added in order to increase its density.

3.1.81**weighting material**

High relative density solids added to a drilling fluid specifically to increase drilling-fluid density.

NOTE This material is commonly barite (relative density 4.1 or 4.2) or hematite (relative density 5.05); in special applications, it might be calcium carbonate.

3.2 Symbols, Acronyms, and Abbreviations**3.2.1 Symbols**

For the purposes of this document, the following symbols apply.

A	cross-sectional area, expressed in square centimeters (A_{SI}) or square inches (A_{USC})
C	conductance, expressed in kilodarcys per millimeter
D_{H}	hole diameter, expressed in millimeters ($D_{\text{H,SI}}$) or in inches ($D_{\text{H,USC}}$)
h	head, expressed in meters (h_{SI}) or in feet (h_{USC})
h_{T}	head for testing, expressed in millimeters ($h_{\text{T,SI}}$) or inches ($h_{\text{T,USC}}$)
K	permeability, expressed in darcys
L	length of the porous medium, expressed in centimeters
L_{H}	wellbore length, expressed in meters ($L_{\text{H,SI}}$) or feet ($L_{\text{H,USC}}$)
m_{C1}	mass of the weighing container and one liter of base fluid, either expressed in grams ($m_{\text{C1,SI}}$) or in pounds ($m_{\text{C1,USC}}$)
m_{C2}	final mass with one-half volume of the discarded wet drilled solids, the weighing container, and one-half volume of base fluid, expressed either in grams ($m_{\text{C2,SI}}$) or in pounds ($m_{\text{C2,USC}}$)

$m_{\text{DF-Dgas}}$	mass of the same volume sample than for $m_{\text{DF-Unpr}}$ of degassed drilling fluid, expressed in grams.
$m_{\text{DF-Unpr}}$	mass of a sample volume of unpressurized drilling fluid, expressed in grams
m_{LOST}	lost mass after retorting, expressed in grams
m_{R1}	mass of the empty retort sample cup, lid, and retort upper cell body packed with steel wool, expressed in grams
m_{R2}	mass of retort sample cup filled with wet drilled-solids sample, lid, and retort body packed with steel wool, expressed in grams
m_{R3}	mass of retort sample cup filled with wet drilled-solids sample and topping base fluid, lid, and retort body packed with steel wool, expressed in grams
m_{R4}	mass of empty, clean, dry liquid receiver, expressed in grams
m_{R5}	mass of liquid receiver and its condensed liquid content (oil and water), expressed in grams
m_{R6}	mass of cooled retort assembly (retort sample cup with retorted solids, lid, and retort body packed with steel wool), expressed in grams
m_{S}	retained sample mass, expressed in grams
m_1	mass of empty container, expressed in grams
m_2	mass of container plus sample, expressed in grams
m_3	mass of dried/retorted solids and container, expressed in grams
$\dot{m}_1$	feed mass flow rate, expressed in kilograms per minute (pounds per minute)
$\dot{m}_2$	overflow mass flow rate, expressed in kilograms per minute (pounds per minute)
$\dot{m}_3$	underflow mass flow rate, expressed in kilograms per minute (pounds per minute)
p	pressure, expressed in kilopascals (p_{SI}) or pounds-force per square inch (p_{USC})
Q_1	volumetric flow rate for discard 1, expressed in cubic meters per minute (barrels per minute)
Q_2	volumetric flow rate for discard 2, expressed in cubic meters per minute (barrels per minute)
q	flow rate through a porous medium, expressed in milliliters per second
q_{S}	flow rate through test screen, expressed in milliliters per minute ($q_{\text{S,SI}}$) or gallons per minute ($q_{\text{S,USC}}$)

$R_{\text{DF-DS}}$	drilling-fluid-to-wet-drilled-solids ratio (discarded solids), expressed as a volumetric ratio (v/v)
$R_{\text{DF-DS-Tot}}$	total (volume weighted) drilling-fluid-to-drilled-solids ratio for all waste stream discards expressed as a volumetric ratio (v/v)
$R_{\text{DF-DS1}}$	drilling-fluid-to-drilled-solids ratio of discard 1, expressed as a volumetric ratio (v/v)
$R_{\text{DF-DS2}}$	drilling-fluid-to-drilled-solids ratio of discard 2, expressed as a volumetric ratio (v/v)
R_{NAF}	ratio of the volume fraction of NAF to the sum of the volume fractions of NAF and pure water, from retort analysis, expressed as a percentage
R_{W}	ratio of the volume fraction of water to the sum of the volume fractions of NAF and condensed water from the retort analysis, expressed as a percentage
V_{BF}	volume of base fluid added to system for dilution, expressed in cubic meters (barrels)
V_{DDF}	volume of discarded drilling fluid in the discarded drilled solids, expressed in cubic meters (barrels)
V_{DDS}	volume of discarded wet drilled solids, expressed in cubic meters (barrels)
V_{DIL}	volume of clean drilling fluid (zero drilled solids) used for dilution to maintain the target drilled-solids concentration, expressed in cubic meters (barrels)
$\frac{V_{\text{DIL}}}{V_{\text{DS}}}$	dilution volume of clean drilling fluid (zero drilled solids) per unit volume of excavated drilled solids to maintain target concentration of drilled solids, dimensionless volumetric ratio (v/v) [i.e. cubic meters per cubic meter (barrels per barrel)]
$V_{\text{DIL-Exc}}$	volume of excess drilling fluid used for dilution, expressed in cubic meters (barrels)
$V_{\text{DIL-Itval}}$	total volume of clean fluid used for dilution for the interval, expressed in cubic meters (barrels)
V_{DIL_i}	volume of clean fluid used for dilution for each portion “i” of the interval (total n portions), usually daily, expressed in cubic meters (barrels)
$V_{\text{DIL+RDS}}$	volume of drilling fluid used for dilution including the retained drilled solids, expressed in cubic meters (barrels)
V_{DS}	excavated volume of drilled solids, expressed in cubic meters ($V_{\text{DS,SI}}$) or barrels ($V_{\text{DS,USC}}$)
V_{F}	final volume, expressed in liters ($V_{\text{F,SI}}$), as per recommended procedure 2 L, or quarts ($V_{\text{F,USC}}$), as per recommended procedure 2 qt
V_{R}	total volume of condensed liquid collected in the liquid receiver, expressed in milliliters
V_{RDS}	volume of retained drilled solids, expressed in cubic meters (barrels)

V_{TOP}	volume of topping fluid, expressed in milliliters
V_{W}	volume of condensed water collected in the liquid receiver, expressed in milliliters
V_{Waste}	overall waste volume of drilling fluid and drilled solids, expressed in cubic meters (barrels)
w	mass fraction of suspended solids, expressed as a decimal fraction
w_a	mass fraction of suspended solids removed (“capture”), expressed as a decimal fraction
$w_{\text{NAF-DS}}$	mass fraction of NAF for the wet drilled-solids sample, expressed as a decimal fraction
w_1	mass fraction of suspended solids in the feed to a piece of separator equipment, expressed as a decimal fraction
w_2	mass fraction of suspended solids in the overflow from a piece of separator equipment, expressed as a decimal fraction
w_3	mass fraction of suspended solids in the underflow from a piece of separator equipment, expressed as a decimal fraction
w_4	mass fraction of weighting material, expressed as a decimal fraction
w_5	mass fraction of low-gravity solids (LGS), expressed as a decimal fraction
Δp	pressure differential, expressed in atmospheres
η_{DSR}	drilled-solids removal system efficiency, expressed as a percentage
$\eta_{\text{DSR-Opt}}$	optimum drilled-solids system removal efficiency, expressed as a percentage
μ	fluid viscosity, expressed in centipoises (pascal•seconds)
ρ	density of NAF or oil, expressed in kilograms per cubic meter (ρ_{SI}) or pounds per gallon (ρ_{USC})
ρ_{BF}	density of the base NAF used for topping, expressed either in kilograms per cubic meter ($\rho_{\text{BF,SI}}$) or in pounds per gallon ($\rho_{\text{BF,USC}}$)
$\rho_{\text{BF-DS}}$	NAF density from retort procedure, expressed either in kilograms per cubic meter ($\rho_{\text{BF-DS,SI}}$) or in pounds per gallon ($\rho_{\text{BF-DS,USC}}$)
ρ_{DF}	density of the drilling fluid, expressed in kilograms per cubic meter ($\rho_{\text{DF,SI}}$) or pounds per gallon ($\rho_{\text{DF,USC}}$)
$\rho_{\text{DF-Pr}}$	pressurized drilling-fluid density, expressed in kilograms per cubic meter (pounds per gallon)

$\rho_{\text{DF-Unpr}}$	unpressurized drilling-fluid density, expressed in kilograms per cubic meter (pounds per gallon)
ρ_{DS}	density of the drilled solids, expressed in kilograms per cubic meter (pounds per gallon)
$\overline{(\rho_{\text{DS-D}})}$	uncorrected average density (volumic mass) of dry retorted drilled-solids sample, expressed in either in kilograms per cubic meter, $\overline{(\rho_{\text{DS-D,SI}})}$, or pounds per gallon $\overline{(\rho_{\text{DS-D,USC}})}$
$\rho_{\text{DS-W}}$	density of the wet drilled-solids sample, expressed in kilograms per cubic meter ($\rho_{\text{DS-W,SI}}$), or in pounds per gallon ($\rho_{\text{DS-W,USC}}$)
ρ_{LG}	density of the LGS, expressed in kilograms per cubic meter (pounds per gallon)
ρ_{WDS}	density of the discarded wet drilled solids, expressed either in kilograms per cubic meter ($\rho_{\text{WDS,SI}}$) or in pounds per gallon ($\rho_{\text{WDS,USC}}$)
ρ_{WM}	density of the weighting material, expressed in kilograms per cubic meter (pounds per gallon)
ρ_1	average relative density of all dried separated solids (see 6.7.3 and 6.8)
ρ_2	relative density of weighting material (see 6.7 and 6.8)
φ_{BDF}	base fluid volume fraction for the clean drilling fluid (zero drilled solids), expressed as a percentage
φ_{BF}	base fluid volume fraction for the drilling fluid with target (or average) drilled-solids concentration, expressed as a percentage
$\varphi_{\text{DF-DS}}$	volume fraction of drilling fluid of the wet drilled-solids sample, expressed as a percentage
φ_{DS}	target drilled-solids concentration of the drilling fluid, expressed as a percentage
$\varphi_{\text{DS-Tot}}$	volume fraction of total solids in the wet drilled-solids sample, expressed as a percentage
φ_{E}	volume fraction of wellbore enlargement, expressed as a percentage
$\varphi_{\text{G-DF}}$	volume fraction of gas or air in the drilling fluid, expressed as a percentage
$\varphi_{\text{G-DF-Gdis}}$	volume fraction of gas dissolved in the drilling fluid, expressed as a percentage
$\varphi_{\text{LG-DS}}$	volume fraction of LGS in the wet drilled-solids sample, expressed as a percentage
$\varphi_{\text{LG-Tot}}$	volume fraction of LGS for the total solids content, expressed as a percentage

$\phi_{\text{NAF-DF}}$	volume fraction of NAF of the whole NAF drilling fluid, expressed as a percentage
$\phi_{\text{NAF-DS}}$	volume fraction of NAF of the wet drilled-solids sample expressed as a percentage
$\phi_{\text{W-DS}}$	volume fraction of condensed water of the wet drilled-solids sample, expressed as a percentage
ϕ_{WM}	volume fraction of weighting-material solids of the whole drilling fluid, expressed as a percentage
$\phi_{\text{WM-DF}}$	volume fraction of weighting material associated with the drilling fluid in the wet drilled-solids sample, expressed as a percentage
$\phi_{\text{WM-DS}}$	volume fraction of weighting-material solids in the wet drilled-solids sample, expressed as a percentage
$\phi_{\text{WM-Ex}}$	excess volume fraction of weighting-material solids in the wet drilled-solids sample, expressed as a percentage
$\phi_{\text{WM-Tot}}$	volume fraction of weighting-material solids for the total solids content, expressed as a percentage

3.2.2 Acronyms and Abbreviations

For the purposes of this document, the following abbreviations apply.

AIO	aluminum oxide (Al_2O_3) with a specific gravity of 3.5 to 3.9
LGS	low-gravity solids
NADF	nonaqueous drilling fluid
NAF	nonaqueous fluid
PVC	polyvinyl chloride
ROC	retained oil (NAF) on cuttings
TC	to contain

4 Requirements

4.1 This recommended practice is organized such that a method of assessing the performance of an equipment set is presented first. A procedure for assessing the performance of individual equipment pieces is then presented. A collection of proven operating guidelines for the equipment and the overall system is then given. The principles shall be used to design a new system or to modify the operation of the equipment and removal system on an existing drilling rig and thereby conforms with this document.

4.2 Use of this practice allows direct comparison of the results achieved by modifications made to the system at the drill site. Improved drilled-solids removal performance can be recognized through lower trouble costs and improved drilling performance.

4.3 Shale shaker screen designations and labeling are included as a means for manufacturers to mark screens in a consistent manner. The screen identification tag describes the equivalent screen aperture opening, the conductance and the non-blanked area of the screen. Screen manufacturers shall use this designation to conform with this document.

5 System Performance of Drilling-fluid Processing Equipment

5.1 Principle

5.1.1 For any combination of drilling-fluid processing equipment, system performance can be evaluated by determining the drilled-solids removal system efficiency (η_{DSR}) and the drilling-fluid-to-drilled-solids ratio ($R_{\text{DF-DS}}$) of the discarded wet drilled solids (see Bibliography [3] to [6]).

Using the methods presented in this section allows the user to measure the performance in a way that will facilitate minimizing overall environmental implications, including reduced carbon footprints for the drilling-fluid and drilled-cuttings volumes.

NOTE The drilling-fluid-to-drilled-solids ratio ($R_{\text{DF-DS}}$) is often referred to as the mud-to-cuttings ratio and designated as MCR. The drilled-solids removal system efficiency (η_{DSR}) is often referred to as the solids removal efficiency and designated as SRE.

5.1.2 The purpose of drilling-fluid processing equipment is to minimize the volume of drilling fluid required for dilution and the volume of drilling related waste for a given well, while balancing a number of considerations. The term “drilling-fluid conservation” is used to mean the minimization of required drilling fluid. Drilling-fluid processing equipment is also an important factor for reducing the size of drilling locations by eliminating or minimizing the use of earthen settling basins.

In terms of reducing the volume of drilling fluid required to drill a well, two considerations are of overriding importance. The first is the target concentration of drilled solids to be maintained in the drilling fluid. The second is the drilled-solids removal efficiency of the drilling-fluid processing equipment. Figure 1 demonstrates how relatively small changes in the target drilled-solids concentration (x-axis) results in large changes in required dilution volumes, particularly for the lower range of values.

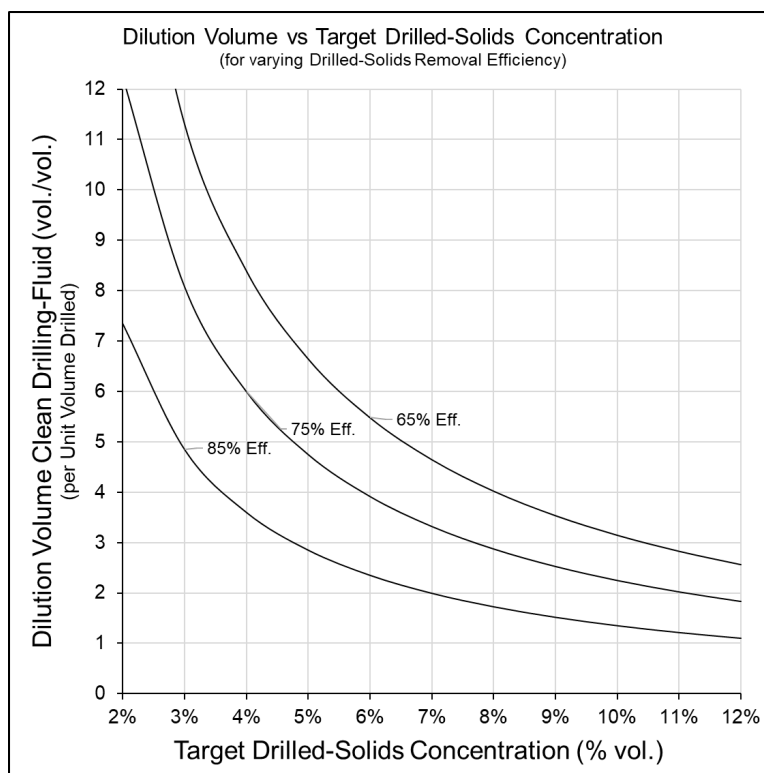


Figure 1—Dilution Volume Dependency on Target Drilled-solids Concentration

Figure 2 demonstrates how improvements in the drilled-solids removal system efficiency (x-axis) results in significant reductions in the required drilling-fluid dilution volume.

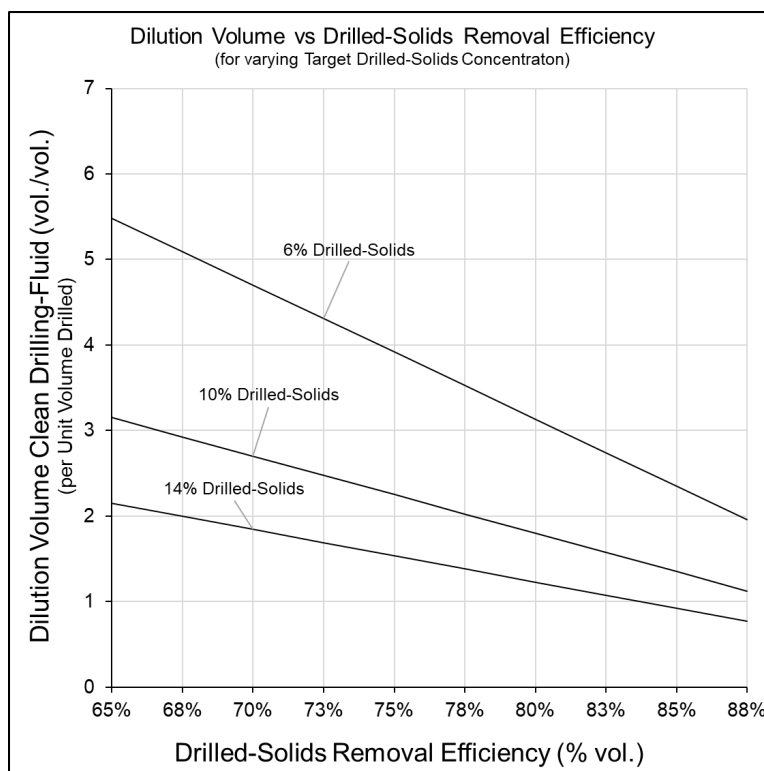


Figure 2—Dilution Volume Dependency on Drilled-solids Removal System Efficiency

5.1.3 The criteria used to select processing equipment include regulatory, logistical, cost, product supply, disposal, and other pragmatic considerations specific to a planned well or series of wells. All of these considerations fall outside the scope of this document. However, once drilling-fluid processing equipment is selected, it is always desirable to improve system performance by increasing drilled-solids removal and improving drilling-fluid conservation.

5.1.4 When additional mechanical processing equipment is used in an effort to increase drilled-solids removal efficiency, more drilling fluid is discarded and the drilling-fluid-to-drilled-solids ratio of the overall discard will increase such that drilling-fluid conservation will normally decrease. Conversely, methods used to increase drilling-fluid conservation by reducing the drilling-fluid-to-drilled-solids ratio of the combined discard will reduce drilled-solids removal system efficiency. This interdependency creates a practical maximum for drilled-solids removal system efficiency that can be achieved by mechanical processing equipment. An illustration of this interdependency is shown in Figure 3, with the combination of values closer to the origin being the easiest to achieve and those in the upper right quadrant being more difficult or technically not achievable. The objective for having the best system performance is to operate as far as possible into the upper right quadrant as is possible.

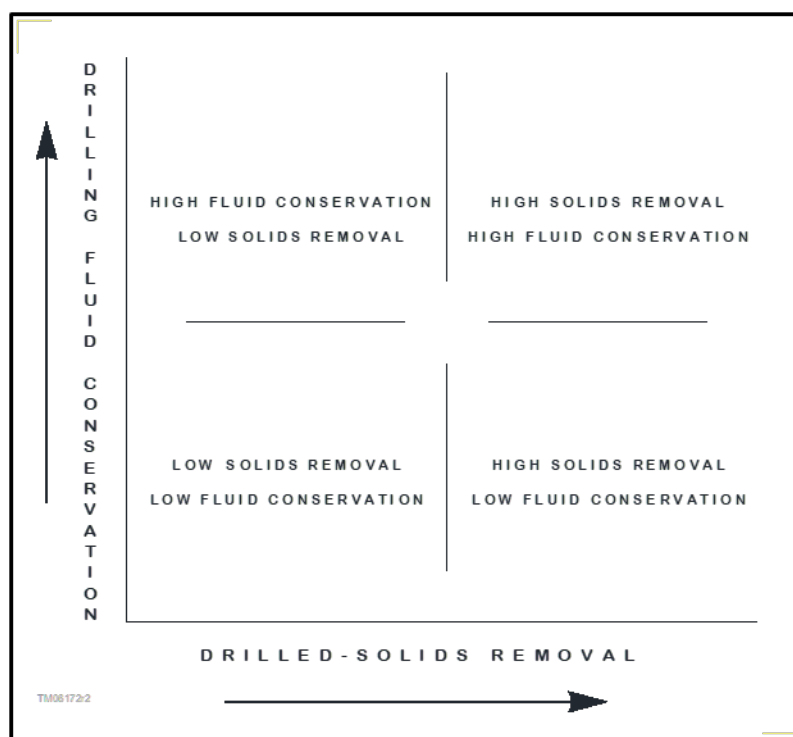


Figure 3—Interdependency of Drilled-solids Removal and Drilling-fluid Conservation

5.1.5 This section provides a procedure for determining:

- a) the overall drilled-solids removal system efficiency, η_{DSR} ;
- b) the drilling-fluid-to-drilled-solids ratio for discarded wet drilled solids $R_{\text{DF-DS}}$; and
- c) overall waste volumes for any combination of processing equipment, V_{Waste} .

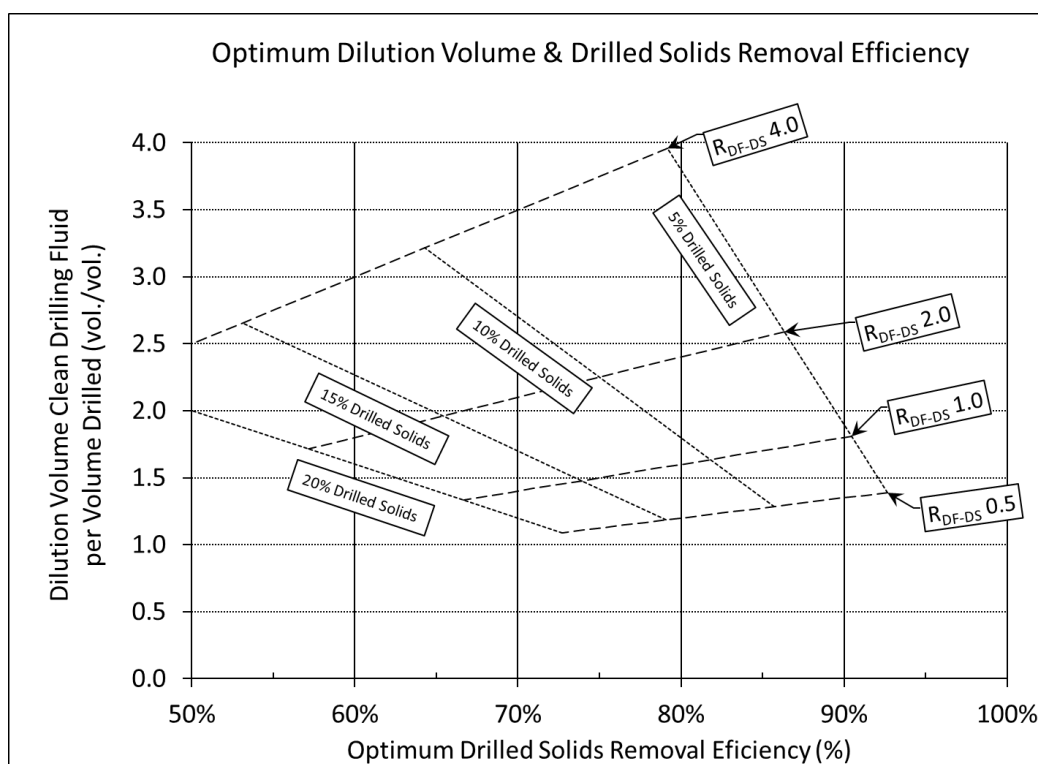
The drilled-solids removal system efficiency refers to the percent of excavated drilled solids that is discarded by the processing equipment. It can be determined from the volume of drilling fluid used for dilution by measuring the base fluid (water or NAF) added to the system or by using the actual volume of drilling fluid added to dilute the retained drilled solids (i.e. drilled solids not removed by the processing equipment).

5.1.6 Drilling-fluid conservation is important to the economics and environmental impact of most drilling programs. Strictly speaking, drilling-fluid conservation efficiency is the percentage of the drilling-fluid reporting to the processing equipment that returns to the surface pit system. Drilling-fluid conservation efficiency is difficult to measure directly in real-world drilling conditions. In this document, the drilling-fluid-to-drilled-solids ratio will be used to quantify drilling-fluid losses due to processing equipment and to evaluate system performance. The drilling-fluid-to-drilled-solids ratio indicates the volume of drilling fluid discarded when a “unit volume of drilled solids” is removed from the active drilling fluid by the processing equipment. A drilling-fluid-to-drilled-solids ratio of “2:1” means that a sample of discarded wet drilled solids is composed of 2 parts “drilling fluid” and 1 part “dry cuttings.” The drilling-fluid-to-drilled-solids ratio is 1:1 when a unit volume of drilling fluid is “retained on” or “commingled with” a unit volume of drilled solids discarded by processing equipment. Lower ratios indicate better drilling-fluid conservation by processing equipment as shown in Equation (13). When circulating drilling fluid is being dumped open ended to disposal with no drilling fluid being returned to the surface pit system, it would be the worst case for drilling-fluid conservation.

NOTE The term “discarded wet drilled solids” is used to mean the material is a combination of drilling fluid and drilled solids. This term applies universally to drilled solids from both water-based drilling fluid and NADF. All discarded drilled solids will contain some fraction of drilling fluid even if they look dry or dusty.

5.1.7 It is generally desirable to maintain constant surface pit volume while drilling and not build excess pit volume to control the target drilled-solids concentration. The optimum dilution ratio is defined as the dilution volume used to drill a unit volume of new hole while meeting two conditions. The first condition is maintaining a constant drilling-fluid volume in the surface pits. The second condition is maintaining the target drilled-solids concentration in the surface pits. The first condition is met when dilution volume built equals the new hole volume drilled plus the volume of drilling fluid lost with the discarded wet drilled solids. The second condition is met when the solids removal efficiency is sufficiently high to ensure that the dilution volume built is the exact volume needed to entrain those drilled solids (not removed by processing equipment) at the target drilled-solids concentration. Figure 4 shows the relationship between the drilling-fluid-to-drilled-solids ratio and the necessary drilled-solids removal system efficiency to maintain constant surface pit volume while drilling.

5.1.8 Drilled solids may be removed via any or all of the following: settling, screening, desanding, desilting, centrifuging, drilling fluid lost with the discarded waste from processing equipment, discarding whole drilling fluid, and/or losing drilling fluid to drilled formations. However, the drilled-solids removal system efficiency methods presented here are based solely on dilution volumes required to maintain a target drilled-solids concentration in the drilling fluid when volume built for downhole losses are excluded. Calculations for situations where the drilled-solids concentration changes or where volumes used due to lost circulation can easily be expanded are based on the concepts and definitions presented.

**Key**

R_{DF-DS} drilling-fluid-to-drilled-solids ratio of discard

**Figure 4—Optimum Dilution Volume and Drilled-solids Removal System Efficiency
(No Excess Drilling Fluid Built)**

5.2 Volume of Drilling Fluid Built for Dilution

5.2.1 The volume of drilling fluid built for dilution of retained drilled solids can be determined several ways. The preferred method is to calculate the dilution volume from the measured volume of base fluid used and the base fluid volume fraction for a drilled-solids-free (clean) drilling fluid. This volume is most accurate when done on a daily or more frequent basis and summed over a given interval since density, base fluid volume fractions, and system volumes change over an interval. Alternatively, the dilution volume can be calculated for the entire interval using a volume weighted average value for the base fluid volume fraction and drilled-solids concentration.

Regardless of how dilution volumes are determined, it is recommended that meters be used to measure volumes. Meters can be mechanical or electrical devices that measure and indicate the volume (or mass) flow rate. Meters should be used when measuring the volume of base fluid and other liquid additions to the circulating system. The fluids that require metering can be solids-free water, brine, NAF, solids laden premix or spike, or drilling fluid. The selection and the specification for a particular meter application is outside of the scope of this document.

5.2.2 The volume of clean drilling fluid used for dilution, V_{DIL} , expressed in cubic meters (barrels), shall be calculated using Equation (1).

$$V_{\text{DIL}} = \frac{100 \times V_{\text{BF}}}{\phi_{\text{BDF}}} \quad (1)$$

where

V_{BF} is the volume of base fluid added to system for dilution, expressed in cubic meters (barrels);

ϕ_{BDF} is the base fluid volume fraction for the clean drilling fluid (zero drilled solids), expressed as a percentage.

5.2.3 If the base fluid volume fraction, ϕ_{BDF} , for the clean drilling fluid (zero drilled solids) is not known, it shall be calculated using Equation (2), expressed as a percentage.

$$\phi_{\text{BDF}} = \phi_{\text{BF}} \times \left[\frac{100}{(100 - \phi_{\text{DS}})} \right] \quad (2)$$

where

ϕ_{BF} is the base fluid volume fraction for the drilling fluid with target (or average) drilled-solids concentration, expressed as a percentage;

ϕ_{DS} is the target concentration (volume fraction) of drilled-solids content in the drilling fluid, expressed as a percentage.

5.2.4 If the volume of drilling fluid built for dilution is tracked on a periodic basis over an interval, the total volume of fluid used for dilution for the interval is the summation of the periodic values and shall be calculated using Equation (3). For intermediate intervals, the cumulative volume to that point should be used.

$$V_{\text{DIL-Itval}} = \sum_{i=1}^n (V_{\text{DIL}_1} + V_{\text{DIL}_2} + V_{\text{DIL}_3} + \cdots + V_{\text{DIL}_n}) \quad (3)$$

where

$V_{\text{DIL-Itval}}$ is the total volume of clean fluid used for dilution for the interval, expressed in cubic meters (barrels);

V_{DIL_i} is the volume of clean fluid used for dilution for each portion “i” of the interval ($i = 1$ to n), usually daily, expressed in cubic meters (barrels).

NOTE The volume of clean drilling fluid built for dilution excludes drilled solids.

5.2.5 An alternative method to determine the dilution volume is to use accurate volumes of base fluid, products, and weight material added to the system. Extra effort should be made to ensure that these volumes are correct as measuring them accurately is often difficult and reported dilution volumes are often inaccurate. These volumes can be tracked daily or on a more frequent basis and summed over a given interval and totaled as described above and shown in Equation (3).

5.3 Volume of Excavated Drilled Solids

5.3.1 The volume of excavated drilled solids (i.e. drilled hole volume) should be calculated from the dimensions of the wellbore, i.e. length and diameter including any known enlargement. If caliper log data is available, the calculated volume from the caliper data shall be used for the excavated drilled-solids volume.

5.3.2 The excavated volume of drilled solids, V_{DS} , shall be calculated from Equation (4) or Equation (5).

a) Excavated volume $V_{DS,SI}$ expressed in cubic meters:

$$V_{DS,SI} = \frac{\pi}{4} \times \left(\frac{D_{H,SI}}{1000} \right)^2 \times L_{H,SI} \times \left(1 + \frac{\varphi_E}{100} \right) = 0.7854 \times 10^{-6} \times D_{H,SI}^2 \times \left(1 + \frac{\varphi_E}{100} \right) \quad (4)$$

where

$D_{H,SI}$ is the hole diameter, expressed in millimeters;

$L_{H,SI}$ is the wellbore length, expressed in meters;

φ_E is the volume fraction of wellbore enlargement, expressed as a percentage.

b) Excavated volume $V_{DS,USC}$ expressed in barrels:

$$V_{DS,USC} = 0.1781 \times \frac{\pi}{4} \times \left(\frac{D_{H,USC}}{12} \right)^2 \times L_{H,USC} \times \left(1 + \frac{\varphi_E}{100} \right) = \frac{D_{H,USC}^2}{1029.4} \times L_{H,USC} \times \left(1 + \frac{\varphi_E}{100} \right) \quad (5)$$

where

$D_{H,USC}$ is the hole diameter, expressed in inches;

$L_{H,USC}$ is the wellbore length, expressed in feet;

φ_E is the volume fraction of wellbore enlargement, expressed as a percentage.

5.3.3 If the system evaluation is being performed on a periodic basis over an interval, such as reporting daily data as shown in Annex D, the excavated volume of drilled solids, or daily drilled hole volume, should be summed to get a cumulative value such that interval intermediate values can be used to better determine performance. Although daily values may vary widely, generally drilled-solids removal system efficiency and the cumulative ratio of drilling fluid to drilled solids converge over just a few intervals or days.

5.4 Drilled-solids Removal System Efficiency

5.4.1 The drilled-solids removal system efficiency (η_{DSR}) is the percentage of excavated drilled solids that are discarded by processing equipment. It can be determined if the volume of drilling fluid (V_{DIL}) built to dilute retained drilled solids is known. Retained drilled solids are those drilled solids not discarded by the processing equipment. The volume of drilling fluid (V_{DIL}) used to calculate the drilled-solids removal system efficiency (η_{DSR}) is the volume of drilling fluid built and added while drilling, excluding volume built for lost circulation or other upset conditions. The preferred method to determine the volume of clean drilling fluid (V_{DIL}) built for dilution shall be from the volume of base fluid data as described in 5.2.1, using Equation (1). Alternatively, the drilling-fluid volume data may be used as described in 5.2.4. For drilling programs using NADF, drilled-solids

removal efficiencies will be in the range from 65 % to 85 %. Depending on reactivity of the formation drilled, drilled-solids removal efficiencies for drilling programs using water-based fluids may be lower.

NOTE The presence of wellbore strengthening material or lost circulation material in the circulating drilling-fluid system complicates the process of solids control and makes measurement of drilled solids concentration and measurement of drilling-fluid-to-drilled solids ratio difficult. Calculation of drilled solids removal system efficiency when drilling with high concentrations of these materials is outside the scope of this document.

5.4.2 The drilled-solids removal system efficiency, η_{DSR} , expressed as a percentage, shall be calculated from Equation (6).

$$\eta_{DSR} = \frac{\text{drilled-solids removed}}{\text{drilled-solids generated}} = 100 - \frac{(100 \times V_{DIL} \times \phi_{DS})}{[V_{DS} \times (100 - \phi_{DS})]} \quad (6)$$

where

V_{DIL} is the volume of clean drilling fluid (zero drilled solids) used for dilution to maintain the target drilled-solids concentration, expressed in cubic meters (barrels);

V_{DS} is the excavated volume of drilled solids, expressed in cubic meters ($V_{DS,SI}$) or barrels ($V_{DS,USC}$);

ϕ_{DS} is the target drilled-solids concentration of the drilling fluid, expressed as a percentage.

If the system evaluation is being performed on a periodic basis over an interval, such as reporting daily data as shown in D.3, the overall interval drilled-solids removal system efficiency should be calculated using cumulative values for V_{DIL} , volume of clean drilling fluid used for dilution, and V_{DS} , excavated volume of drilled solids (daily drilled hole volume).

5.4.3 The volume of retained drilled solids, V_{RDS} , expressed in cubic meters (barrels), shall be calculated using the drilled-solids removal system efficiency and the excavated volume of drilled solids, using Equation (7).

$$V_{RDS} = V_{DS} \times \left(1 - \frac{\eta_{DSR}}{100} \right) \quad (7)$$

where

η_{DSR} is the drilled-solids removal system efficiency, expressed as a percentage;

V_{DS} is the excavated volume of drilled solids, expressed in cubic meters ($V_{DS,SI}$) or barrels ($V_{DS,USC}$).

5.4.4 The volume of fluid used for dilution including the target retained drilled-solids percent, $V_{DIL+RDS}$, shall be the sum of the clean dilution drilling-fluid volume plus the retained drilled solids, as calculated using Equation (8), expressed in cubic meters (barrels)

$$V_{DIL+RDS} = V_{DIL} + V_{RDS} \quad (8)$$

where

V_{DIL} is the volume of clean drilling fluid used for dilution, expressed in cubic meters (barrels);

V_{RDS} is the volume of retained drilled solids incorporated into the clean drilling fluid.

5.4.5 Alternatively, if the volume of drilling fluid used for dilution with the retained drilled solids, $V_{\text{DIL+RDS}}$, is accurate and a preferred value to utilize, the drilled-solids removal system efficiency, η_{DSR} , may be calculated, expressed as a percentage, from Equation (9).

$$\eta_{\text{DSR}} = 100 - \left[\frac{\phi_{\text{DS}} \times V_{\text{DIL+RDS}}}{V_{\text{DS}}} \right] \quad (9)$$

where

$V_{\text{DIL+RDS}}$ is the volume of drilling fluid used for dilution with the retained drilled solids;

V_{DS} is the excavated volume of drilled solids;

ϕ_{DS} is the target drilled-solids concentration of the drilling fluid, expressed as a percentage.

5.4.6 The volume of discarded drilled solids, V_{DDS} , expressed in cubic meters (barrels), shall be calculated using the drilled-solids removal efficiency and the excavated volume of drilled solids, using Equation (10).

$$V_{\text{DDS}} = \frac{\eta_{\text{DSR}} \times V_{\text{DS}}}{100} \quad (10)$$

where

η_{DSR} is the drilled-solids removal system efficiency, expressed as a percentage;

V_{DS} is the excavated volume of drilled solids, expressed in cubic meters ($V_{\text{DS,SI}}$) or barrels ($V_{\text{DS,USC}}$).

5.5 Procedure for Measuring Drilling-fluid-to-Drilled-solids Ratio of Shale Shaker Discard

5.5.1 Principle

5.5.1.1 The drilling-fluid-to-drilled-solids ratio ($R_{\text{DF-DS}}$) for discarded wet drilled solids from shale shakers is an important metric for evaluating system performance and for calculating the volume of drilling fluid lost. Under normal drilling conditions, shale shakers will discard the majority of the drilled solids excavated. Shale shakers will also discard the majority of the lost drilling fluid attributable to processing equipment operation. Discarded wet drilled solids from shale shakers typically have drilling-fluid-to-drilled-solids ratios that range from 0.75 to 3.0. In the procedure described in this section, the drilling-fluid-to-drilled-solids ratio is calculated from the measured density of the discarded wet drilled solids, the measured drilling-fluid density, and the density of the formation being drilled. When applicable, this density-based procedure is easier to perform, less time consuming, and can be more accurate than retort-based procedures.

5.5.1.2 Drilling-fluid-to-drilled-solids ratios are highly dependent on the particle size of the drilled solids. As the particle size of the drilled solids decreases, the surface area increases and the drilling-fluid-to-drilled-solids ratio increases. Large-diameter fast-drilling intervals produce large-sized drilled solids that will have lower drilling-fluid-to-drilled-solids ratios due to the decreased surface area per mass of drilled solids when compared to smaller-sized drilled solids.

5.5.1.3 An accurate drilling-fluid-to-drilled-solids ratio can be determined from the density difference between the discarded wet drilled solids and the density of drilling fluid using the procedure in this section, and exceptions to the application of this procedure are noted below. The procedure works for both water-based

drilling fluids and NADF. When unweighted drilling fluids are used, it is applicable to all types of equipment, including shale shakers, centrifuges, and hydrocyclones.

When weighted drilling fluids are in use, the procedure can provide accurate results from shale shakers with screen sizes API 140 and below. However, this procedure should not be used for weighted drilling fluids when shakers screens API 170 and finer are used, because the wet drilled solids may have a higher concentration of weighting material than represented by the drilling fluid. Therefore, the retort procedure in Annex C shall be used to determine the drilling-fluid-to-drilled-solids ratio for weighted fluids with shaker screens API 170 and higher. Similarly, the procedure in Annex C shall be used to determine the drilling-fluid-to-drilled-solids ratio for discarded wet drilled solids from centrifuges or hydrocyclones when weighted drilling fluids are used. Figure 5 shows a graphic illustration of this method.

NOTE This procedure is also not applicable when significant quantities of lost circulation material are present in a drilling fluid because it will similarly be concentrated in the discarded wet drilled solids by the processing equipment.

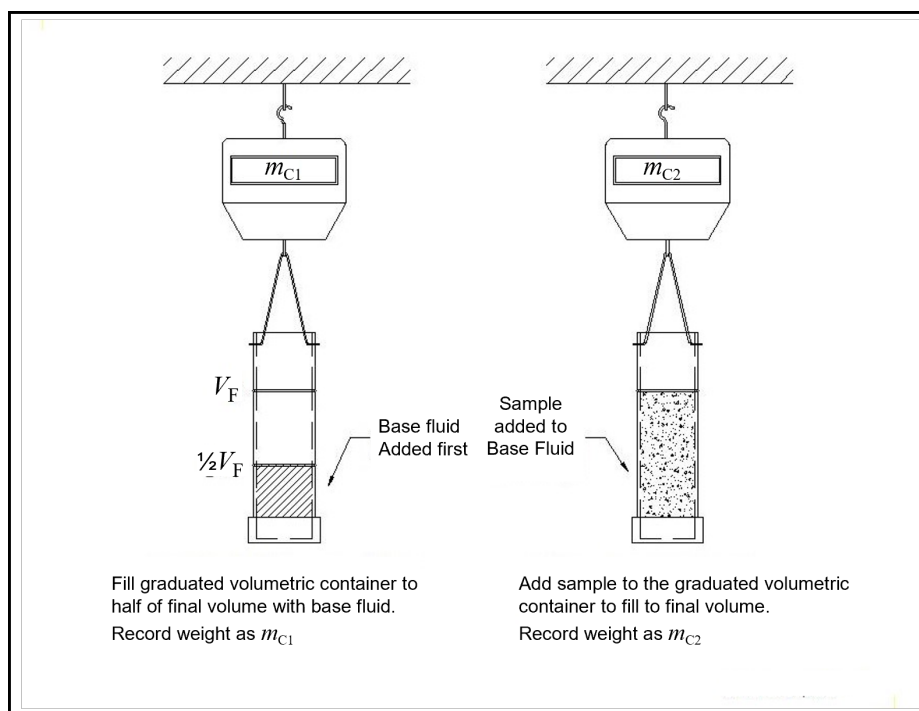


Figure 5—Density Method for Measuring Drilling-fluid-to-Drilled-solids Ratio

5.5.2 Apparatus

5.5.2.1 Open top weighing container, such as a pail, small bucket, can, or preferably a see-through, closed bottom plastic tube with a capacity of 2 to 5 L (0.5 to 1.0 gal).

When using handheld or hanging scales, it is recommended that the container have a handle.

5.5.2.2 Graduated cylinder or graduated volumetric container, with graduations of at least 10 mL (0.5 oz).

5.5.2.3 Scale or top-loading balance, capable of weighing 10 kg (22 lb) with an accuracy of ± 0.01 kg (± 0.02 lb).

5.5.2.4 Scoop or large spoon, suitable for transferring the discarded wet drilled solids into the open top weighing container.

5.5.2.5 Ruler.

5.5.2.6 Shaker discard sample collection container, such as a pail, small bucket, or can of sufficient size to collect a volume of shaker discard greater than the final volume of the procedure.

5.5.3 Procedure

The density of discarded wet drilled solids shall be determined applying the following procedure.

- Determine the final volume, V_F , to be used for the procedure. This volume should be at least 75 % of the capacity of the open top weighing container. The recommended final volume is 2 L (2 qt).
- Using the graduated cylinder or graduated volumetric container, measure V_F base fluid (water or NAF) volume equal to the final volume to be used for the procedure and pour into the open top weighing container. Use the ruler and measure and record the height of the liquid at the side of the weighing container.
- Empty the base fluid and clean and dry the weighing container. Mark the inside of the weighing container at the final volume liquid level height with an easy to see permanent marker or paint pen that is resistant to the base fluid.
- Using the graduated cylinder or graduated volumetric container, add one-half ($1/2 V_F$) of the final volume (water or NAF) to be used for the procedure. Using the scale, weigh the open top weighing container with one-half the final volume of base fluid, and record as $m_{C1,SI}$ in grams (or $m_{C1,USC}$ in pounds).
- Collect a representative sample of discarded wet drilled solids from the shale shaker(s) and homogenize. Using the scoop or large spoon, transfer the discarded wet drilled solids into the open top weighing container until the liquid level reaches the final volume V_F mark. Using the scale, weigh the container with base fluid and wet discarded solids, and record as $m_{C2,SI}$ in grams (or $m_{C1,USC}$ in pounds)
- When using a final volume of 2 L ($V_{F,SI} = 2$), the density of the discarded wet drilled solids, $\rho_{WDS,SI}$, expressed in kg/m^3 , shall be calculated using Equation (11).

$$\rho_{WDS,SI} = \frac{m_{C2,SI} - m_{C1,SI}}{0.5 \times V_{F,SI}} = m_{C2,SI} - m_{C1,SI} \quad (11)$$

where

$m_{C1,SI}$ is the weight of the weighing container and one-half volume ($1/2 V_F$) of base fluid (one liter recommended), expressed in grams;

$m_{C2,SI}$ is the final weight with one-half volume ($1/2 V_F$) of the discarded wet drilled solids, the weighing container, and one-half volume ($1/2 V_F$) of base fluid, expressed in grams;

$V_{F,SI}$ is the final volume, expressed in liters, as per recommended procedure $V_{F,SI} = 2$ L.

NOTE When using a scale or top-loading balance that has a tare feature, after taring per Item d), $m_{C1,SI} = 0$.

- g) When using a final volume of 2 qt ($V_{F,USC} = 2$), the density of the discarded wet drilled solids, $\rho_{WDS,USC}$, expressed in lb/gal shall be calculated using Equation (12).

$$\rho_{WDS,USC} = \frac{4 \times (m_{C2,USC} - m_{C1,USC})}{V_{F,USC}} = 2 \times (m_{C2,USC} - m_{C1,USC}) \quad (12)$$

where

$m_{C1,USC}$ is the mass of the weighing container and one-half volume ($1/2 V_F$) of base fluid (1 qt recommended), expressed in pounds;

$m_{C2,USC}$ is the final mass with one-half volume ($1/2 V_F$) of discarded wet drilled solids, the weighing container, and one-half volume ($1/2 V_F$) of base fluid, expressed in pounds;

$V_{F,USC}$ is the final volume, expressed in quarts, as per recommended procedure $V_{F,USC} = 2$ qt.

NOTE When using a scale or top-loading balance that has a tare feature, after taring per Item d), $m_{C1,USC} = 0$.

5.5.4 Drilling-fluid-to-Drilled-solids Ratios Calculations

5.5.4.1 The drilling-fluid-to-drilled-solids ratio (R_{DF-DS}) of the discarded wet drilled solids from shale shakers should be calculated from the density of the discarded wet drilled solids using Equation (13) with all density terms having the same units. This is the ratio expressed as a volumetric ratio (v/v) of the drilling-fluid content divided by the drilled-solids content for the discarded wet drilled solids.

$$R_{DF-DS} = \frac{\text{drilling-fluid content}}{\text{drilled-solids content}} = \frac{(\rho_{DS} - \rho_{WDS})}{(\rho_{WDS} - \rho_{DF})} \quad (13)$$

where

ρ_{DS} is the density of the drilled solids, expressed in kg/m³ (lb/gal);

ρ_{WDS} is the density of the discarded wet drilled solids, expressed in kg/m³ (lb/gal);

ρ_{DF} is the density of the drilling fluid, expressed in kg/m³ (lb/gal).

Drilling-fluid density (ρ_{DF}) shall be measured using a mud balance and the procedure described in API 13B-1 or API 13B-2.

If the system evaluation is being performed on a periodic basis over an interval, such as reporting daily data as shown in D.3, the overall interval drilling-fluid-to-drilled-solids ratio can be calculated by the ratio of cumulative volume of discarded drilling fluid with retained drilled solids to the volume of discarded drilled solids.

5.5.4.2 Each type of processing equipment discharging will have a different drilling-fluid-to-drilled-solids ratio of its discard. To calculate the total drilling-fluid-to-drilled-solids ratio, $R_{\text{DF-DS-Tot}}$, the individual streams of discarded wet drilled solids shall be measured and the values shall be volume weighted as shown in Equation (14) for two (2) discard streams.

$$R_{\text{DF-DS-Tot}} = \left[\left(\frac{Q_1}{Q_1 + Q_2} \right) \times R_{\text{DF-DS1}} \right] + \left[\left(\frac{Q_2}{Q_1 + Q_2} \right) \times R_{\text{DF-DS2}} \right] \quad (14)$$

where

$R_{\text{DF-DS-Tot}}$ is the total (volume weighted) drilling-fluid-to-drilled-solids ratio for all waste stream discards, expressed as a volumetric ratio (v/v);

Q_1 is the volumetric flow rate for discard 1, expressed in cubic meters per minute (barrels per minutes);

Q_2 is the volumetric flow rate for discard 2, expressed in cubic meters per minute (barrels per minutes);

$R_{\text{DF-DS1}}$ is the drilling-fluid-to-drilled-solids ratio of discard 1, expressed as a volumetric ratio (v/v);

$R_{\text{DF-DS2}}$ is the drilling-fluid-to-drilled-solids ratio of discard 2, expressed as a volumetric ratio (v/v).

5.6 Volume of Discarded Drilling Fluid

The volume of discarded drilling fluid in the discarded wet drilled solids, V_{DDF} , shall be calculated from the aggregate or total drilling-fluid-to-drilled-solids ratio and the volume of discarded drilled solids, expressed in cubic meters (barrels), using Equation (15).

$$V_{\text{DDF}} = R_{\text{DF-DS-Tot}} \times V_{\text{DDS}} \quad (15)$$

where

$R_{\text{DF-DS-Tot}}$ is the total (volume weighted) drilling-fluid-to-drilled-solids ratio for all waste stream discards, expressed a volumetric ratio (v/v);

V_{DDS} is the volume of discarded wet drilled solids, expressed in cubic meters (barrels).

5.7 Procedure for Calculating Drilling Waste Volumes

5.7.1 General

Due to the nature of drilling-fluid mechanical processing equipment and the difficulty with separating undesirable solids, waste volumes are an important metric for drilling operations. For many wells, handling wastes is a significant logistical challenge and cost. The three primary wastes are:

- drilled solids,
- drilling fluid commingled with the discarded wet drilled solids, and
- excess drilling-fluid volumes used for dilution.

System volume changes that occur at the end of an interval or the end of the well that result in an excess drilling-fluid volumes are not considered.

Determining the waste volume involves summing the active system addition and discard volumes and assumes the surface pits remain constant. The volume of discarded drilled solids (V_{DDS}) and drilling fluid (V_{DDF}) are calculated as described in 5.4.6 and 5.6.

5.7.2 Volume of Excess Drilling Fluid Used for Dilution

The volume of excess drilling fluid used for dilution, $V_{DIL-Exc}$, is the difference in the volume of drilling fluid used for dilution with the retained solids ($V_{DIL+RDS}$) from 5.4.4, less the volume of discarded drilling fluid in the discarded wet drilled solids from 5.6, less the excavated volume of drilled solids, from 5.3. The volume of excess drilling fluid used for dilution, ($V_{DIL-Exc}$), shall be calculated, expressed in cubic meters (barrels) using Equation (16).

$$V_{DIL-Exc} = V_{DIL+RDS} - V_{DDF} - V_{DS} \quad (16)$$

where

$V_{DIL+RDS}$ is the volume of drilling fluid used for dilution with the retained drilled solids, expressed in cubic meters (barrels);

V_{DDF} is the volume of discarded drilling fluid in the discarded wet drilled solids, expressed in cubic meters (barrels);

V_{DS} is the excavated volume of drilled solids, expressed in cubic meters ($V_{DS,SI}$) or barrels ($V_{DS,USC}$).

5.7.3 Overall Waste Volume

The overall waste volume of drilling fluid and drilled solids, V_{Waste} , including the excess drilling fluid over what is needed for dilution and for the surface pits to remain constant, expressed in cubic meters (barrels), shall be calculated with Equation (17).

$$V_{Waste} = V_{DDS} + V_{DDF} + V_{DIL-Exc} \quad (17)$$

where

V_{DDS} is the volume of discarded wet drilled solids, expressed in cubic meters (barrels);

V_{DDF} is the volume of discarded drilling fluid in the discarded wet drilled solids, expressed in cubic meters (barrels);

$V_{DIL-Exc}$ is the volume of excess drilling fluid used for dilution, expressed in cubic meters (barrels).

5.8 Procedure for Estimating Drilling-fluid Dilution and Waste Volumes

5.8.1 General

In addition to evaluating system performance for ongoing operations, it is important to estimate the volume of drilling fluid that will be needed for dilution and waste volumes when planning wells. This can be done by assuming values for the drilled-solids removal system efficiency (η_{DSR}), target drilled-solids concentration (ϕ_{DS}), and the drilling-fluid-to-drilled-solids ratio (V_{DIL} / V_{DS}). Once the dilution volume is calculated (V_{DIL}), the