Recommended Practice for Drilling Fluid Processing Systems Evaluation

API RECOMMENDED PRACTICE 13C
SECOND EDITION, MARCH 1996

American
Petroleum
Institute

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Exploration and Production Department

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FOREWORD

This recommended practice is under the jurisdiction of the API Committee on the Standardization of Drilling Fluid Materials. This edition of API Recommended Practice 13C includes revisions adopted at the 1994 Standardization Conference and subsequently approved by letter ballot as reported in Circ. PS-2054.

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CONTENTS

Drilling Fluid Processing Systems Evaluation

1 Scope

This recommended practice covers the standard procedure for assessing and modifying the performance of a solids control equipment system in the field. It is not intended as a procedure for the comparison of similar types of individual pieces of equipment.

2 References

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

ANSI[1]/AWWA[2]
- AS C705 *Standards for Water Meters*

API
- *Manual of Petroleum Measurement Standards,* Chapter 5 "Metering"
- Spec 13A *Specification for Drilling-Fluid Materials*
- RP 13B-1 *Recommended Practice Standard Procedure for Field Testing of Water-based Drilling Fluids*
- RP 13B-2 *Recommended Practice, Standard Procedure for Field Testing Oil-Based Drilling Fluids*
- RP 13E *Recommended Practice, for Shale Shaker Screen Cloth Designation*

ASTM[3]
- E-11 *Standard Specification for Wire-Cloth Sieves for Testing Purpose*
- E177 *Standard Practice for Use of the Terms Precision and Bias in ASTM Test Methods*

IADC[4]
- *Mud Equipment Manual, Handbook 2*

3 Definitions and Abbreviations

3.1 DEFINITIONS

3.1.1 addition section: A compartment(s) in the mud system between the removal section and the suction section which provides a well-agitated compartment(s) for the addition of chemicals, necessary solids, and liquids.

3.1.2 agitator: A mechanically driven mixer that stirs the mud by turning an impeller in the bottom of a mud compartment to maintain an even consistency in the mud.

3.1.3 air-locking: A condition causing a centrifugal pump to stop pumping due to bubbles of air or gas in the impeller center that will not let the liquid enter and which cannot itself pass through the pump.

3.1.4 aperture: The opening between the wires in a screen cloth.

3.1.5 apex: The opening at the bottom of a hydrocyclone.

3.1.6 API sand (physical description): The particles in a drilling fluid that are too large to pass through a U. S. Sieve No. 200 screen (74 micrometer equivalent).

3.1.7 backing plate: The plate attached to the back of screen cloth(s) for support.

3.1.8 baffles: The plates or obstructions built into a compartment to change the direction of fluid flow.

3.1.9 ball valve: A valve that uses a spherical closure with a hole through its center which rotates ninety (90) degrees to open and close.

3.1.10 barite, barytes: The natural barium sulfate ($BaSO_4$) used for increasing the weight of drilling fluids. API standards require a minimum of 4.20 specific gravity. API Specification 13A barite as commercial barium sulfate-containing ores, produced from a single ore or a blend or ores and may be a straight-mined product or processed by beneficiation methods. It may contain accessory minerals other than the barium sulfate ($BaSO_4$) mineral. Because of mineral impurities, commercial barite may vary in color from off-white to gray to red or brown. Common accessory minerals are silicates such as quartz and chert, carbonate compounds such as siderite and dolomite, and metallic oxide and sulfide compounds.

3.1.11 blinding: A reduction of open area in a screening surface caused by coating or plugging.

3.1.12 bonding material: The material used to secure screen cloth to a backing plate or support screen.

3.1.13 cascade shaker arrangement: A system that processes the mud through two or more shakers arranged in series.

[1]American National Standards Institute, 1430 Broadway, New York, New York 10018.
[2]American Water Works Association, 666 West Quincy Avenue, Denver Colorado 80235.
[3]American Society for Testing and Materials, 100 Bar Harbor Drive, West Conshohocken, Pennsylvania 19428.

3.1.14 centrifuge: A device rotated by an external force for the purpose of separating materials of various specific gravity and/or particle sizes or shapes from a slurry to which the rotation is imparted primarily by the rotating containing walls.

3.1.15 centrifugal pump: A machine for moving fluid by spinning it using a rotating impeller in a casing with a central inlet and a tangential outlet.

3.1.16 check/suction section: The last active section in the surface system which provides a location for rig pump and mud hopper suction, and should be large enough to check and adjust mud properties before the mud is pumped downhole.

3.1.17 clay (physical description): Solid particles of less than two micrometer equivalent spherical diameter.

3.1.18 coating (see related term: blinding): A condition where material forms a film that covers the apertures of the screening surface.

3.1.19 colloidal solids: See clay (3.1.17).

3.1.20 conductance: The ease with which a fluid can flow through a unit area of screen, measured in units of kilodarcies/millimeter.

3.1.21 cone: See hydrocyclone (3.1.53).

3.1.22 conveyor: A mechanical device for moving material from one place to another. In a decanting centrifuge, this is a hollow hub fitted with flights rotating in the same direction but at a different speed than the centrifuge bowl.

3.1.23 cuttings: The pieces of formation dislodged by the bit and brought to the surface in the drilling mud. Field practice is to call all solids removed by the shaker screen *cuttings*, although some can be sloughed material.

3.1.24 cut point: A general term for the effectiveness of a liquid-solids separation device expressed as the particle size that is removed from the feed stream at a given volume or weight percentage under specified operation conditions.

3.1.25 cutt point: The spherical diameters corresponding to the ellipsoidal volume distribution of a screen's opening sizes, as determined by image analysis. See API RP 13E.

3.1.26 cyclone: See hydrocyclone (3.1.53).

3.1.27 decanting centrifuge: A continuously conveying centrifuge which removes solids drained of their free liquid.

3.1.28 density: Mass per unit volume expressed in pounds per gallon (lb/gal); pounds per square inch per thousand feet of depth (psi/1000 ft); pounds per cubic feet (lb/ft3); and specific gravity.

3.1.29 desander: A hydrocyclone capable of removing a very high proportion of the 74 micrometer-size and larger particles from a mud. Generally, a desander has an inside diameter from 6 inches (15.2 cm) to 12 inches (30.3 cm).

3.1.30 desilter: A hydrocyclone capable of removing a very high proportion of the 2-74 micrometer-size particles from a mud. Generally, a desilter has an inside diameter from 2 inches (5.1 cm) to 5 inches (12.7 cm).

3.1.31 dilution: Decreasing the drilled solids content of a slurry by the addition of a material(s) other than drilled solids.

3.1.32 dilution factor: The ratio of the actual volume of mud required to drill a specified interval of footage with a solids removal system and at a calculated average drilled solids fraction to the volume of mud required to maintain the same drilled solids fraction over the same specified interval of footage with no solids removal system.

3.1.33 drilled solids: A formation of solids contained in the mud system.

3.1.34 drilled solids fraction: The average volume fraction of drilled solids maintained in the drilling fluid over a specified interval of footage.

3.1.35 drilled solids removal system: All processes used while drilling a well that remove the solids generated from the hole and carried by the drilling fluid, that is, settling, screening, desanding, desilting, centrifuging and dumping.

3.1.36 drilled solids removal system performance: A measure of the performance of a system to remove drilled solids from the drilling fluid.

3.1.37 drilling fluid: The term applied to any liquid or slurry pumped down the drill string and up the annulus of a hole to facilitate drilling.

3.1.38 eductor: A device consisting of a fluid stream that discharges under high pressure from a jet through an annular space to create a vacuum. When properly arranged, it can evacuate degassed mud from a vacuum-type degasser or pull solids through a hopper.

3.1.39 effluent: A discharge of liquid generally used to describe a stream of liquid after some attempt at separation or purification has been made.

3.1.40 equalizer: An opening for flow between compartments in a surface fluid holding system.

3.1.41 feed header: A pipe, tube, or conduit to which two or more hydrocyclones are connected and from which they receive their feed slurry.

3.1.42 flow capacity: The rate at which a shaker can process mud and solids. It is a function of many variables including shaker configuration, design and motion, mud rheology, solids loading, and blinding by near size particles.

3.1.43 flowline: The piping or trough that directs the mud from the wellhead to the first downstream process component.

3.1.44 flow rate: The amount of liquid or slurry moved through a pipe in one unit of time, that is, gallons per minute, barrels per minute, and so forth.

3.1.45 foam: The bubbles floating on the surface of the mud. The bubbles are usually air but can be gas.

3.1.46 foot valve: A check valve installed at the end of a suction line.

3.1.47 funnel viscosity: See marsh funnel viscosity (3.1.57).

3.1.48 gumbo: The cuttings that agglomerate and form a sticky mass as they are circulated up the wellbore.

3.1.49 head: The height of a column of liquid or slurry measured above a point in a pipe or at a pump.

3.1.50 high specific gravity solids: The solids added to a drilling fluid specifically to increase mud density. Barite is the most common, but others are used, that is, iron oxides.

3.1.51 hook strips: The hooks on the edges of a screen section of a shale shaker that accepts the tension member for screen mounting.

3.1.52 hopper: A large funnel- or coned-shaped device into which dry components can be poured to uniformly mix the components with liquids or slurries.

3.1.53 hydrocyclone: A liquid-solids separation device utilizing centrifugal force for settling. Fluid enters tangentially and spins inside the cone. The heavier solids settle to the walls of the cone and move downward until they are discharged at the cone apex. The spinning fluid travels part way down the cone and back up to exit out the top of the cone through the vortex finder.

3.1.54 impeller: A spinning disc in a centrifugal pump with protruding vanes used to accelerate the fluid in the casing.

3.1.55 low specific gravity solids: All solids in a drilling fluid, except barite or other commercial weighting materials, that is, salts, drilled solids of every size, commercial colloids, lost circulation materials, and so forth.

3.1.56 manifold: A length of pipe with multiple connections for collecting or distributing.

3.1.57 marsh funnel viscosity: The time in seconds required for a measured volume of mud to flow out of a marsh funnel. See API RP 13B-1 or RP 13B-2.

3.1.58 martin's radii: The distance from the centroid of an object to its outer boundary. The direction of this measurement is specified by the azimuth orientation of the line (the radii in the 0°, 90°, 180°, 270° angle from horizontal).

3.1.59 mechanical stirrer: See agitator (3.1.2).

3.1.60 mesh: The number of openings (and fraction thereof) per linear inch in a screen, counted in both directions from the center of a wire.

3.1.61 mesh count: The count is the term most often used to describe a square or rectangular mesh screen cloth. A mesh count, such as 30 × 30 or often 30 mesh, indicates a square mesh, while a designation such as 70 × 30 mesh clearly indicates rectangular mesh.

3.1.62 micron: A metric unit of linear measure, denoted as μ. Equivalent term in API standards is micrometer. 1000 microns or micrometers equals 1 millimeter; 25,400 microns = 1 inch.

3.1.63 mud: See drilling fluid (3.1.37).

3.1.64 mud balance: A beam-type balance used in determining mud weight. Refer to API RP 13B-1 or API RP 13B-2, Section 2.

3.1.65 mud cleaner: A generic term used for a combination of hydrocyclones and screens in series. The hydrocyclone overflow is returned to the mud, while the underflow of the hydrocyclones is processed through a fine-mesh vibrating screen. The screen solids discharge is discarded while the liquid and solids passing through the screen are returned to the mud.

3.1.66 mud gun: A submerged nozzle used to stir the mud with a high-velocity stream.

3.1.67 mud hopper: See Hopper (3.1.52).

3.1.68 mud compartment: A subdivision of the removal, addition or check/suction sections of a surface system.

3.1.69 mud ditch: A trough built along the upper edge of many surface systems that is used to direct flow to selected compartments of the surface system.

3.1.70 mud weight: A measurement of specific weight of a slurry usually reported in lb/gal, lb/cu ft., psi/1000 ft. or specific gravity.

3.1.71 near size: A term used in describing screen plugging and refers to particles with a dimension only slightly larger than the screen opening.

3.1.72 oil-based mud: A special type of drilling fluid where oil is the continuous phase and water or brine is the dispersed phase.

3.1.73 overflow: The discharge stream from a centrifugal separation that contains a higher percentage of liquids than does the feed.

3.1.74 overflow header: A pipe into which two or more hydrocyclones discharge their overflow.

3.1.75 particle: A discrete unit of solid material that may consist of a single grain or of any number of grains stuck together.

3.1.76 particle size distribution: The weight, 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.

3.1.77 perforated rotor centrifugal separator: A mechanical centrifugal separator in which the rotating element is a perforated cylinder (the rotor) inside of and concentric with an outer stationary cylindrical case.

3.1.78 perforated panel screen: A screen in which the backing plate used to provide support to the screen cloths is a metal sheet with openings.

3.1.79 plastic viscosity: A measure of the internal resistance to fluid flow attributable to the amount, type, and size of solids and the viscosity of the liquid phase of a given fluid. Refer to API RP 13B-1 or API RP 13B-2.

3.1.80 plugging: The wedging or jamming of openings in a screening surface by near-size particles, preventing passage of undersize particles and leading to the blinding of the screen. See blinding.

3.1.81 possum belly: The compartment on a shale shaker into which the flow line discharges, and from which the mud is either fed to the screens or is bypassed, if necessary.

3.1.82 premix system: A compartment used to mix materials (such as bentonite, polymers, and so forth) that require time to hydrate or disperse fully before they are added to the mud.

3.1.83 pretensioned screen: A screen cloth that is bonded to a frame or backing plate with proper tension applied prior to its installation on a shaker.

3.1.84 reduced port: A valve whose bore size is less than the area of the pipe to which it is attached.

3.1.85 reserve pit: (a) An earthen pit used to store drilling waste in land drilling operations. (b) A section of the surface system used to store drilling fluid.

3.1.86 removal section: The first section in the mud system consisting of a series of compartments to remove gas and undesirable solids.

3.1.87 retort: An instrument used to distill oil, water, and other volatile material in a drilling fluid to determine oil, water, and total solids contents in volume-percent. See API RP 13B-1 or RP 13B-2, Section 4.

3.1.88 rope discharge: The characteristic underflow of a hydrocyclone so viscous and overloaded with separable solids that not all the solids reporting to the underflow can crowd through the apex.

3.1.89 sand content (API sand content): The mud particles that are larger than 74 micrometers (200 mesh screen) expressed as a volume percent of mud. These particles can be of any mineral or chemical composition and characteristic, for example: barite, shale, mica, silica, steel, chert, and so forth. See API RP 13B-1, Section 5.

3.1.90 sand trap: The first compartment in a surface system intended as a settling compartment. It is the only unstirred compartment.

3.1.91 screen cloth: A type of screening surface, woven in square, rectangular, or slotted openings.

3.1.92 screening: A mechanical process resulting in a division of particles on the basis of size by their acceptance or rejection by a screening surface.

3.1.93 separation potential: The relative potential grade efficiency of a screen composition as defined by the ellipsoidal volume distribution of its openings as a function of spherical diameter, also called the *cutt* point distributions.

3.1.94 settling velocity: The velocity a particle achieves in a given fluid when gravity forces equal friction forces of the moving particle; that is, when the particle achieves its maximum velocity.

3.1.95 shale shaker: The general term for a mechanical device that removes solids from a drilling fluid using screens and a vibrating mechanism.

3.1.96 shute: In a woven cloth, the direction of the wires running perpendicular to the loom. See also warp.

3.1.97 sieve: A cylindrical or tray-like container with a screening surface bottom of standardized apertures.

3.1.98 sieve analysis: Determination of the relative percentages of substances, passing through or retained on a sequence of screens of increasing mesh count. Analysis may be by wet or dry methods.

3.1.99 silt (physical description): Particles of a size between clay (less that 2 micrometers) and API sand (greater than 74 micrometers).

3.1.100 slug tank: A small compartment (normally adjacent to the suction compartment) used to mix special fluids to pump downhole. The most common use is to prepare a small volume of weighted mud before a trip.

3.1.101 solids concentration or content: The total amount of solids in a drilling fluid as determined by distillation includes both the dissolved and the undissolved solids.

3.1.102 solids separation equipment: Any and all of the devices used to remove solids from liquids in drilling, that is, shale shaker, desander, desilter, mud cleaner, centrifuge, and so forth.

3.1.103 spray discharge: The characteristic underflow of certain hydrocyclones discharging to the atmosphere and not overloaded with separated solids.

3.1.104 square mesh: A screen cloth with the same mesh count in both directions.

3.1.105 suction compartment: The area of the check/suction section from which mud is picked up by the suction of the mud pumps.

3.1.106 sump: A disposal compartment or earthen pit for holding discarded liquids and solids.

3.1.107 tensioning: The stretching to the proper tension of a shale shaker's screening surface within the vibrating frame.

3.1.108 total dilution: The volume of mud that would be built to maintain a specified fraction of drilled solids over a specified interval of footage if there was no solids removal system.

3.1.109 total nonblanked area: The net unblocked area, in square feet, that will permit the passage of fluid through a screen. Some screen designs can eliminate as much as 40 percent of the gross screen panel area from fluid flow due to backing plate and bonding material blockage.

3.1.110 trip tank: A gauged and calibrated vessel used to account for fill and displacement volumes as pipe is pulled from and run into the hole.

3.1.111 underflow: The discharge stream from centrifugal separators that contains a higher percentage of solids than does the feed.

3.1.112 unoccluded: Unobstructed area of a screen opening.

3.1.113 unweighted mud: A mud that does not contain high specific gravity suspended solids added for the purpose of increasing the density of the mud.

3.1.114 venturi: Streamlining up to given pipe size following a restriction (as in a hopper) to minimize turbulence and pressure drop.

3.1.115 viscosity: A characteristic property of a fluid, liquid, or slurry crudely defined as resistance to flow. A specific definition is the ratio of shear-stress to shear-rate.

3.1.116 volume of mud built: The volume of mud built over a specified interval of drilled footage.

3.1.117 volume of solids drilled: The volume of solids drilled over a specified interval of drilled footage.

3.1.118 vortex (air): A cylindrical or conical shaped core of air or vapor lying along the central axis of the rotating slurry inside a hydrocyclone.

3.1.119 warp: In a woven cloth, the direction of the wires running parallel with the loom. See also shute.

3.1.120 water-based mud: A drilling fluid where water is the suspending medium for solids and is the continuous phase.

3.1.121 weighted mud: A drilling fluid to which high specific gravity solids have been added to increase its density.

3.1.122 weight material: Any high specific gravity solids used to increase the density of drilling fluids.

3.1.123 wire cloth: See screen cloth. (3.1.91)

3.1.124 working pressure (wp): The maximum pressure to which the valve should be exposed in order to comply with the manufacturer's warranty and to be within industry codes and safety standards.

3.2 ABBREVIATIONS

3.2.1 ACS: American Chemical Society.

3.2.2 API: American Petroleum Institute.

3.2.3 ASTM: American Society for Testing and Materials.

3.2.4 CAS: Chemical Abstract Service.

3.2.5 TC: To contain.

3.2.6 TD: To deliver.

4 Requirements

4.1 This document 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 guidelines can be used to modify the operation of the equipment and the removal system, and thus improve the efficiency of whatever equipment set is in use.

4.2 Use of this practice will allow direction comparison of the results achieved by modifications made to the system at the drill site. Improved removal performance can be recognized and monitored and the benefits of improved solids removal realized.

5 Drilled Solids Removal—System Performance

5.1 DESCRIPTION

5.1.1 This procedure gives a method to determine the drilled solids removal efficiency by a set of drilling fluid processing equipment.

5.1.2 The efficiency of a drilled solids removal system was previously reported as the percentage of the drilled rock that was removed by the equipment and did not take into account the amount of fluid lost in the process.

5.1.3 By the above definition, simply jetting the mud would give 100 percent removal efficiency, but would not be a desirable method due to the amount of mud lost. Thus, to more accurately describe the performance of a system, a term is needed that will take into account the percentage removed and the wetness of the drilled solids.

5.1.4 The *dilution factor* is a term created to describe the drilled solids removal system performance. The *drilled solids removal system* is defined as all processes used while drilling a well that remove the wellbore solids generated from the active fluid. These processes consist of dumping of whole mud (including lost circulation), settling, screening, desanding, desilting, and centrifuging. The dilution factor is calculated by monitoring the amount of base fluid (oil or water) added to the system.

5.2 EQUIPMENT

5.2.1 Meters: Water meters shall comply with American Water Works Association Standard C705 as referenced in ANSI/AWWA C700-77 and has been approved by the American National Standards Institute, Inc. on January 19, 1978.

Metering of oils shall be done in accordance with the API *Manual of Petroleum Measurement Standards*, Chapter 5. Turbine meter operation is contained in Section 3.

5.2.2 Mud Weight (density) determination: Any instrument of sufficient accuracy to permit measurement within ±0.1 lb/gal (or 0.5 lb/ft^3, 0.01 g/cm^3, 10 kg/m^3) may be used. The mud balance is the instrument generally used for mud weight determinations. The mud balance is designed such that the mud 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. Refer to API RP 13B-1 or RP 13B-2, Section 2.

5.2.3 Water, oil and solids determination: Refer to API RP 13B-2, Section 4.

a. Retort instrument.
b. Liquid receiver.
c. Fine steel wool.
d. High temperature silicone grease.
e. Pipe cleaners.
f. Putty knife or spatula.
g. Defoaming agent.

5.2.4 Chloride determination: Refer to API RP 13B-1, Section 8 or RP 13B-2, Section 5 as appropriate for water- or oil-based fluids.

a. Silver nitrate solution as appropriate.
b. Potassium chromate indicator solution: 5 g/100 cm^3 of water.
c. Sulfuric or nitric acid solution: standardized 0.02 normal (N/50).
d. Phenolphthalein indicator solution: 1 g/100 cm^3 of 50 percent alcohol/water solution.
e. Calcium carbonate: precipitated, chemically pure grade.
f. Distilled water.
g. Serological (graduated) pipettes (TD): one 1-cm^3 and one 10 cm^3.
h. Titrating vessel: 100-150 cm^3, preferably white.
i. Stirring rod.

5.3 PROCEDURE /CALCULATIONS

5.3.1 Suction Pit Mud Weight, Salinity, and Solids (Retort) Data

Measure and record all suction pit mud weight, salinity, and solids (retort) data for the subject interval.

5.3.2 Measure and Record Base Fluid Additions to the Mud (V_{bf})

Metering devices can provide the actual volume of base fluid used within the accuracy of the equipment. The most commonly used meters for measuring base fluid consumption are the mechanical turbine, propeller, and compound types. Magnetic and Doppler meters are more dependent on suspended solids in fluid streams to provide volume measurements. The sizing of the meter is critical for accuracy. Tables of acceptable line sizes per volume throughput is included in the AWWA C700 series standards. The test for all meters should be volumetric or by weight if accurate scales are available. The recorded volume shall be within 0.25 percent of the actual volume. Use strainers upstream of the meter and check frequently for clogging.

5.3.3 Determine the Base Fluid Fraction (F_{bf})

The base fluid fraction is the average value for the interval in question. The averaging method is critical and it is important to use the same method to enable interval and well comparisons. Using different averaging methods can result in inaccurate comparisons. The base fluid fraction can be calculated from solids analysis methods using retort and salt measurements.

5.3.4 Determine the Drilled Solids Fraction (F_{ds})

The drilled solids fraction can be calculated by several methods from simple solids analysis which correct for salt and bentonite concentrations to complex material balance methods which correct for additional components such as commercial additives. The drilled solids fraction is the average for the interval, therefore, the averaging method is again critical. Sensitivity studies of the effect of the drilled solids fraction on the final dilution factor show that a significant variance is possible when using different methods of averaging. Comparisons are valid only when using identical averaging methods.

5.4 CALCULATION

5.4.1 Calculate the Volume of Mud Built (V_{mb})

The volume of mud built is determined from the base fluid fraction.

$$V_{mb} = V_{bf} F_{bf} \quad (1)$$

Where:

V_{mb} = volume of mud built.
V_{bf} = volume of base fluid added to drilling fluid system.
F_{bf} = base fluid fraction.

5.4.2 Calculate the Excavated Volume of Solids Drilled (V_{ds})

This value can be calculated from the dimensions of the wellbore, that is, length and diameter.

5.4.3 Calculate the Total Dilution (D_t)

Total dilution is as the volume of mud that would be built if there was no solids removal system. In this case, all drilled solids would be incorporated into the mud system with dilution being the only form of solids control. The mud quality and drilling performance would remain equal whether using dilution exclusively or a solids removal system.

$$D_t = V_{ds} / F_{ds} \quad (2)$$

Where:

D_t = total dilution.
V_{ds} = volume of solids drilled.
F_{ds} = drilled solids fraction.

5.4.4 Calculate the Dilution Factor (*DF*)

The dilution factor is the ratio of the volume of mud built to total dilution. It is the ratio of mud used to actually drill an interval using a solids removal system as compared to only using dilution. In both cases, the level of drilled solids in the mud remains constant and appears in both calculations. The lower the factor, the more efficient the system.

$$DF = V_{mb} / D_t \quad (3)$$

Where:

D_F = dilution factor.
V_{mb} = volume of mud built.
D_t = total dilution.

5.4.5 Calculate the Drilled Solids Removal System Performance (*SP*)

$$SP = (1 - DF)(100) \quad (4)$$

Where:

SP = drilled solids removal system performance.
DF = dilution factor.

5.6 EXAMPLE—METRIC UNITS CALCULATION

Mud Report Data:

Base fluid added (V_{bf}):	2000 m³
Average base fluid fraction (F_{bf}):	0.80
Initial depth:	5000 meters
Final depth:	6714 meters
Average hole diameter:	12.25 inches
Volume of solids drilled (V_{ds}):	250 m³
Average drilled solids fraction (F_{ds}):	0.05

Using Equation 1—volume of mud built (V_{mb}):

$$Vmb = V_{bf} / F_{bf} = 2000/0.80 = 2500 \text{ m}^3$$

Using Equation 2—total dilution (D_t):

$$D_t = Vds / Fds = 250/0.05 = 5000 \text{ m}^3$$

Using Equation 3—dilution factor (*DF*):

$$DF = V_{mb} / D_t = 2500/5000 = 0.50$$

Using Equation 4—drilled solids removal system performance (*SP*):

$$SP = (1 - DF)(100) = (1 - 0.50)(100) = 50\%$$

6 Rigsite Evaluation of Drilled Solids Management Equipment

6.1 DESCRIPTION

6.1.1 This section presents a rigsite method for determining the cost-effectiveness of individual pieces of solids control equipment when using a water-base mud. If the equipment and system arrangement meets the operating guidelines described in Section 7, the operational performance is assumed to be adequate and correct. The question remains as to whether each piece of mechanical solids removal equipment is cost-effective as applied.

6.1.2 Shale shakers, hydrocyclones, and mud cleaners treat the active drilling fluid system. They can be evaluated by comparing the cost to remove drill solids with mechanical equipment with an equivalent drill solids reduction against the cost of using dilution to remove drill solids.

6.1.3 A centrifuge processing an unweighted drilling fluid and discarding the heavy (or underflow) slurry may also be evaluated with this technique.

6.1.4 A centrifuge processing a weighted drilling fluid is used to adjust the *viscosity* of the drilling fluid by removal of colloidal solids. The quantity of colloidal solids permissible in the drilling fluid is controlled by the rheological properties and is not easily determined. This procedure does not currently apply to weighted mud processing by a centrifuge.

6.1.5 Drilled solids concentrations can be maintained with either mechanical equipment or dilution. Dilution is used for the cost comparison, even though the resulting drilling fluid will not have exactly the same solids composition and particle size distribution as if solids removal equipment were used. Once the operating range of satisfactory drilled solids concentration has been established, the cost of operating the equipment can be compared with the cost of dilution to reach the same concentration.

6.1.6 The cost of operating the equipment includes the rental cost, the cost of mud products discarded (liquid and solid), disposal costs, and the cost of replacing the volume discarded from the system. The dilution cost includes disposal costs for the volume of drilling fluid discarded and cost of replacement fluid to maintain an equal volume in the system.

6.1.7 The procedure calculates solids removal rates by mechanical equipment but does not attempt to compare the removal rate with that at which the drill solids are generated downhole and arrive at the surface.

6.1.8 The procedure does not prescribe the acceptable level of drilled solids for the fluid system. This decision must be made before the analysis is made.

6.1.9 As written the procedure applies only to water-based muds, however, it can be adapted to oil-based muds as well.

6.2 EQUIPMENT

6.2.1 Mud balance, pressurized preferred (API RP 13B-1, Section 1).

6.2.2 Mud retort instrument (API RP 13B-1 or RP 13B-2, Section 4).

6.2.3 Bentonite determination: Refer to API RP 13B-1, Section 6 (Methylene Blue Capacity) for procedure.

6.2.4 Chloride determination: Refer to API RP 13B-1, Section 8 for procedure.

6.3 PROCEDURE

6.3.1 Determine the daily operating time of the piece of equipment. Record as A, hr/day.

6.3.2 Measure the equipment discard flow rate. Record as B, gal/min.

Note: Various types of equipment will require different methods to determine the discard rate. As no specific methods are given here, the user must devise a procedure that is applicable to the solids removal system being evaluated.

6.3.3 Measure the discard density with the pressurized mud balance. Record as C, lb/gal.

6.3.4 Determine the volume percent solids in the discard stream with the retort. Record as D, %.

6.3.5 Determine the equivalent bentonite content in the drilling fluid from the mud report or measure using the Methylene Blue Capacity procedure in API RP 13B-1, Section 6. Record as E, lb/bbl.

6.3.6 Determine the chloride ion content of the drilling fluid from the mud report or measure using the chloride ion test in API RP 13B-1, Section 8. Record as F, mg/L.

6.3.7 Obtain the desired volume percent drilled solids content of the drilling fluid. Record as G, %.

6.3.8 Obtain the drilled solids density from the mud report or measure with a retort. Record as a, g/cm^3.

6.3.9 Obtain the density of the weighting material. Record as b, g/cm^3.

6.3.10 Obtain the drilling fluid cost. Record as H, $/bbl, £/m^3, ¥/m^3, DM/m^3, Ffr/m^3, NK/m^3, and so forth, or currency of choice.

6.3.11 Obtain the drilling fluid liquid phase cost. Record as H', in currency of choice/bbl or m^3.

6.3.12 Obtain the weighting material cost. Record as I, in currency of choice/bbl or m^3.

Note: This is the cost of a barrel of weighting material not the cost of the weighting material contained in one barrel of drilling fluid.

6.3.13 Obtain the cost of the chemicals in the drilling fluid. Record as J, in currency of choice/bbl or m^3.

6.3.14 Obtain the rental cost of the equipment. Record as K, in currency of choice/day.

6.3.15 Obtain the cost of waste disposal. Record as c, in currency of choice/bbl or m^3.

Note: The costs to dispose of excess drilling fluid and the discard stream may be different.

6.4 CALCULATION—DISCARD STREAM COMPOSITION

6.4.1 The corrected liquid content of the discard stream is calculated as follows:

$$L(\%) = (100 - D)\,(1 + 5.88 \times 10^{-8} \times F^{1.2}) \quad (5)$$

Where:

L = corrected liquid content in the discard stream.

Note: The following equation corrects the solids content of the discard stream for salt in the form of sodium chloride only. If other salts are present as the dominant salt, different equations must be used to compensate for their presence.

6.4.2 The corrected solids content of the discard stream is calculated as follows:

$$M(\%) = 100 - L \quad (6)$$

Where:

M = corrected solids content of the discard stream.

6.4.3 The density of the liquid phase in the discard stream is calculated as follows:

$$N\,(\text{g/cm}^3) = 1 + 1.94 \times 10^{-5} \times F^{0.95} \quad (7)$$

Where:

N = density of the liquid phase in the discard stream.

6.4.4 The density of solids in the discard stream is calculated as follows:

$$O\,(\text{g/cm}^3) = (12 \times C - L \times N) / M \quad (8)$$

Where:

O = density of solids in the discard stream.

6.4.5 The weighting material content of the discard stream is calculated as follows:

$$P\,(\text{lb / bbl}) = 3.5 \times b \times M \times (O - a) / (b - a) \quad (8)$$

Where:

P = weighting material content of the discard stream.

$$Q\,(\%) = P / (3.5 \times b) \quad (9)$$

Where:

Q = percentage of weighting material content of the discard stream.

6.4.6 The low gravity solids content of the discard stream is calculated as follows:

$$R\,(\%) = M - Q \quad (10)$$

Where:

R = percentage of low gravity solids content of the discard stream.

6.4.7 The drill solids content of the discard stream adjusted for the bentonite content is calculated as follows:

$$S\,(\%) = R - E / 9.1 \quad (11)$$

Where:

S = drill solids content of the discard stream, adjusted for the bentonite content.

$$T\,(\text{lb / bbl}) = 3.5 \times S \times a \quad (12)$$

Where:

T = drill solids content of the discard stream.

Note: This estimation is used as a substitute for a measurement of the bentonite content of the discard stream. Since its impact on total cost is small, it is considered sufficiently accurate for field evaluations.

6.5 CALCULATION—COST COMPARISON

6.5.1 The total volume discarded per day by the piece of equipment being evaluated is calculated as follows:

$$U\,(\text{bbl / day}) = A \times B \times (60 / 42) \quad (13)$$

Where:

U = total volume discarded per day (by each piece of equipment).

6.5.2 The volume of liquid in the discard stream is calculated as follows:

$$V\,(\text{bbl/day}) = U \times [(100 - M) / 100] \quad (14)$$

Where:

V = volume of liquid in the discard stream.

6.5.3 The volume of drilled solids in the discard stream is calculated as follows:

$$W\,(\text{bbl / day}) = U \times S / 100 \quad (15)$$

Where:

W = volume of drilled solids in the discard stream.

6.5.4 The volume of weighting material in the discard stream is calculated as follows:

$$X\,(\text{bbl / day}) = U \times Q / 100 \quad (16)$$

Where:

X = volume of weighting material in the discard stream.

6.5.5 The cost of the weighting material in the discard stream is calculated as follows:

$$Y = X \times I \quad (17)$$

Where:

Y = cost of weighting material.

6.5.6 The cost of the chemicals in the discard stream is calculated as follows:

$$Z = V \times J \quad (18)$$

Where:

Z = cost of chemical in the discard stream.

6.5.7 The cost of the liquid in the discard stream is calculated as follows:

$$Z''' = V \times H' \quad (19)$$

Where:

Z''' = cost of liquid in the discard stream.

6.5.8 The cost to dispose of the discard stream is calculated as follows:

$$Z'' = U \times c \quad (20)$$

Where:

Z'' = cost to dispose of the discard stream.

6.5.9 The total cost of using the piece of equipment being evaluated is calculated as follows:

$$A = K + Y + Z + Z'' + Z''' \quad (21)$$

Where:

A = total cost of using the piece of equipment.

6.5.10 The dilution volume required to *dilute out* an equivalent volume of drilled solids is calculated as follows:

$$B'(\text{bbl} = (100W / G) - W \quad (22)$$

Where:

B' = dilution volume required to dilute an equivalent volume of drilled solids.

6.5.11 The cost to implement this dilution, including the cost to dispose of the excess fluid is calculated as follows:

$$C = B \times (H + c) \quad (23)$$

Where:

C = cost to implement this dilution.

6.5.12 The operation of the equipment can be considered cost-effective in the currency of choice, if

$$A < C \quad (24)$$

7 Practical Operational Guidelines

7.1 DESCRIPTION

The benefits of effective solids control are well known. These benefits include increased drilling rates, reduced mud costs, reduced hole problems, reduced abrasion and wear, and reduced disposal costs. Disposal costs are reduced because good solids control practices minimize the total volume of waste generated by a drilling operation. For the above benefits to be realized, solids control equipment must be properly sized, properly installed, and properly operated. All too often the benefits of effective solids control are not obtained in the field because of improper sizing, improper installation, or improper operation. The following equipment operational guidelines are the result of years of experience and are the best current recommended practices. Following the recommended guidelines should result in better solids control systems and in more of the associated benefits being realized.

7.2 SURFACE SYSTEMS

7.2.1 The surface system should be divided into three sections, each having a distinct function: (a) removal section, (b) addition section, and (c) check/suction section. Undesirable drilled solids should be removed in the removal section. All mud material and liquid additions should be made in the addition section. The check/suction section provides volume for blending of new mud materials and verification of desired mud properties.

7.2.2 Minimum recommended *useable* surface mud volume is 100 barrels (less for slim hole) plus enough to fill the hole when the largest drill string the rig can handle is pulled wet and all the mud inside the string is lost. In order to maintain fluid properties in large diameter, soft, fast-drilling holes, the minimum surface volume should be at least five to six times the volume of hole drilled per day.

7.2.3 Based on experience, a rule of thumb for the minimum square feet of compartment horizontal surface area (CHSA) is as follows:

$$\text{CHSA, ft}^2 = \frac{\text{maximum circulating rate, gpm}}{40} \quad (25)$$

It has been found from experience that this rule of thumb provides fluid velocities low enough to allow entrained air bubbles to rise to the surface and break out.

Note: This rule of thumb was developed by Ormsby and is included in the IADC *Mud Equipment Manual, Handbook 2*; "Mud System Arrangements", pg. 2-17.

7.2.4 The ideal tank depth would be approximately equal to the width, or the diameter, of the tanks. If deeper, special consideration can be necessary for stirring; if shallower, adequate stirring without vortexing will be difficult or impossible.

7.2.5 Use top equalization for the sand trap.

7.2.6 Use top equalization between the degasser suction and discharge compartments.

7.2.7 Use bottom equalization between the suction and discharge compartments of desanders, desilters, mud cleaners, and centrifuges.

7.2.8 Use an adjustable equalizer between the removal and addition sections when the cyclones and/or centrifuges are being used. Run with the high position on the downstream side.

7.2.9 Use bottom equalization in the addition section and in the check/suction section.

7.2.10 For removal devices processing flow rates greater than the rig circulating rate, equalizing flows should always be in the reverse (or upstream) direction.

7.2.11 All removal compartments, except the sand trap, should be well-stirred or agitated to ensure even loading on solids removal equipment.

7.2.12 Mechanical stirrers are preferred for stirring removal compartments.

7.2.13 Mechanical stirrers should be properly sized and installed according to the manufacturer's recommendations.

7.2.14 Baffles may be installed around each mechanical stirrer to prevent air vortices and settling. A typical baffle can be 1 inch thick × 12 inches wide (2.5 cm thick × 30.5 cm wide) and extend from the tank bottom to 6 inches (15.2 cm) above the top agitator blade. Four baffles are usually installed around each agitator. They are installed 6 inches (15.2 cm) past the tips of the agitator blades along lines connecting the center of the agitator blade with the four actual corners of a square pit or compartment. For a long rectangular pit, with two or more agitators, the tank is divided into imaginary square compartments and a baffle is pointed at each corner (either actual or imaginary).

7.2.15 Mud guns should not be used in the removal section except where the feed mud to the mud gun(s) comes from the compartment being stirred by the mud gun(s).

7.2.16 Mud guns can be used in the addition and check/suction sections of the surface system and to provide the benefits of shear and dividing and blending of newly-added mud materials.

7.2.17 The sand trap is the only settling compartment in the surface mud system. It should not be stirred nor should any pump take its suction from the sand trap. See 7.2.48 of surface systems for an exception to this rule.

7.2.18 If a sand trap is used, the sand trap should be large enough to allow proper solids settling. The bottom should slope to its outlet at 45 degrees or steeper. The outlet valve should be large, non-plugging, and quick opening and closing.

7.2.19 The degasser (if needed) should be installed immediately downstream of the shaker and upstream of any piece of equipment requiring feed from a centrifugal pump.

7.2.20 The solids removal equipment should be arranged sequentially so that each piece of equipment removes successively finer solids. Although every piece of equipment can not be used or needed, general arrangements are as follows:

Unweighted Mud	Weighted Mud
Shale shaker	Shale shaker
Degasser	Degasser
Desander	Mud cleaner
Desilter	Centrifuge
Centrifuge	

7.2.21 The overflow for each piece of solids control equipment should discharge to the compartment downstream from the suction compartment for that piece of equipment. This is termed proper piping, plumbing, or fluid routing.

7.2.22 Improper fluid routing always leads to solids-laden fluid bypassing the removal device.

7.2.23 Two different pieces of solids equipment should not simultaneously operate out of the same suction compartment.

Note: Different means, for example, degasser and desander or desander and desilter.

7.2.24 Two different pieces of solids control equipment should not simultaneously discharge into the same compartment.

Note: Different means, for example, degasser and desander or desander and desilter.

7.2.25 If two of the same piece of solids control equipment are used simultaneously, the same suction and discharge compartment should be used for both.

Note: As an example, if two desilter units are used, both should be properly rigged up and have the same suction and discharge compartments.

7.2.26 The degassers, desanders, desilters, and mud cleaners should process 100 percent of the mud entering their individual suction compartments. In a properly designed system the processing rate should be at least 10-25 percent more than the rig circulating rate. (See 7.8 for hydrocyclones.)

7.2.27 If 7.2.21, 7.2.25, and 7.2.26 are applicable and are followed, the equalizing flow between compartments will be in the reverse (or upstream) direction. The back flow confirms that all mud entering the compartment is being processed.

7.2.28 Mud should never be pumped from one removal compartment to another compartment except through solids removal devices.

7.2.29 Mud should never enter any removal compartment from outside the removal section to feed mud guns, mixers, or the eductor jet of a vacuum degasser.

7.2.30 The power mud for the eductor jet for a vacuum degasser should come from the degasser discharge compartment.

7.2.31 Single purpose pumps are necessary in the removal section to ensure proper fluid routing. One suction and one discharge should be used. Suctions and discharges should not be manifolded.

7.2.32 In a properly designed system, solids control devices should not overflow into mud ditches.

7.2.33 Exception to 7.2.32: Based on field experience, mud foaming problems can be reduced by routing the overflow of a desander or desilter into a mud ditch for a horizontal distance of about ten feet before the fluid enters its discharge compartment to allow entrained air to break out. If this is done, ensure that the fluid routing is correct.

7.2.34 All mud material additions should be made after the removal section. All removal, including all centrifuging, must be finished before the mud material addition begins.

7.2.35 Mud foaming problems can also be reduced by using a non-air-entraining mud mixing hopper. Jet and venturi hoppers suck air into the mud during mixing.

7.2.36 Jet hoppers should include a venturi for better mixing.

7.2.37 The check/suction section of the surface system should contain a 20-50 barrel slugging tank which includes a mud gun system for stirring and mixing.

7.2.38 Mud premix systems should be used on any mud system whose additives require time and shear for proper mixing. Premix systems should especially be used on systems requiring the addition of bentonite, or hard-to-mix polymers, such as CMC, PHPA, XC, and so forth.

7.2.39 Special shear and mixing devices are recommended for premix systems for mixing polymers (especially PHPA), spotting fluids, specialized coring fluids, and for hydrating bentonite.

7.2.40 High-shear devices should not be used on the active system because the high shear will rapidly reduce mud solids to the colloidal range.

7.2.41 The surface system should include a trip tank.

7.3 OPEN SYSTEMS—ONSHORE OPERATIONS

7.3.1 Sections 7.2.1–7.2.41 from surface systems apply to open systems. In addition for onshore operations, the following also apply for open systems.

7.3.2 The waste pit (also called reserve pit or sump) should be large enough to accommodate the solid and liquid waste from the drilling operation.

7.3.3 If base fluid from the waste pit is reused, the waste pit should be constructed with dikes to maximize settling time. Depending on the clarity of the base fluid, it may be reused as wash base fluid for solids discards from removal devices, dilution base fluid for centrifuges treating weighted muds, rig washdown, and as makeup base fluid for the mud.

7.4 CLOSED SYSTEMS

7.4.1 With the exception of 7.2.5, 7.2.16, 7.2.18, and 7.2.20–7.2.41 from surface systems apply to closed systems as well as the following:

7.4.2 Preplanning is a must for implementing a successful closed system.

7.4.3 Drilled solids removed from the mud system as waste will occupy about three times the volume they did down hole prior to drilling.

7.4.4 Inspect the existing rig for proper installation, sufficient fluid capacity, and solids removal capability to close the system.

7.4.5 Modify existing rig equipment as necessary and supplement with additional equipment to meet the standards set forth in the operational guidelines for that piece of equipment.

7.4.6 The sand trap should be either eliminated or converted to a well-stirred compartment with bottom equalization.

7.4.7 Install sufficient shakers to permit screening unweighted drilling fluid through 74 micrometer or smaller screens or a weighted drilling fluid through 105 micrometer screens with the highest penetration rates in the largest hole size using the maximum rig circulating rate.

7.4.8 Never bypass the shaker. Leave the shaker running on trips into the hole.

7.4.9 On unweighted muds run properly rigged desanders and desilters. If screens with openings larger than 74 micrometers are being run on the shakers, then screen the desander/desilter underflow through 74 micrometer or smaller mud cleaner screens and collect in a small well-stirred catch tank which is equalized with the desilter discharge compartment. Use a decanting centrifuge to process the fluid in the catch tank at a slightly higher feed rate than the combined underflow rate from the hydrocyclones. The solids removed are discarded and the centrifuge effluent (light slurry) is returned to the next compartment downstream. If screens with openings smaller than 74 micrometers are being run on the shakers, it is usually not necessary to screen the hydrocyclone underflow prior to centrifuging. In cases where the drilled solids are extremely abrasive, it can be necessary to screen the centrifuge feed through a 44 micrometer or smaller screen to prevent excessive conveyor wear.

7.4.10 If the colloidal solids content of the unweighted base fluid-base mud exceeds acceptable limits as reflected by mud plastic viscosity and solids content, the centrifuge effluent (light slurry) from the centrifuge in 7.4.9 should be run through a flocculation unit (also called mud processor or debase fluiding unit) which may also include a decanting centrifuge. Additional mud may need to be centrifuged to provide sufficient feed to the flocculation unit. The cleaned liquid is returned to the active system.

7.4.11 On unweighted or weighted muds the API sand content of the mud being pumped down the hole should be a trace or less.

7.4.12 On weighted base fluid-base muds, use a centrifuge for viscosity control.

7.4.13 On weighted base fluid-base muds, the centrifuge effluent (light slurry) should be either treated through a flocculation unit (which may include a decanting centrifuge) to remove colloidal particles and the liquid returned to the active system or hauled to a disposal site—whichever is more economical.

7.5 SHALE SHAKERS

7.5.1 Treat 100 percent of the mud circulating volume through the available units. No whole mud or other recycled fluids should enter the active system without first passing through the screens.

7.5.2 Run finest mesh screens practical considering economics. If economical, run screens having an image analyzer D50 of 140 micrometers or less (refer to API RP 13E). Replace or patch torn screens at once.

7.5.3 For double-deck shakers, run a coarser screen on top and a finer screen on bottom. The coarser screen should be at least two mesh sizes (screen designations) coarser. Watch for a torn bottom screen. Cover 75 to 80 percent of the bottom screen with mud to maximize utilization of the available screen area. Flow back pans improve coverage and throughput.

7.5.4 For a single-deck shaker with parallel screens, run all the same mesh screens. If coarser screens are necessary to prevent mud loss, no more than two different mesh sizes should be on the shaker at one time. Install the finer mesh screen closest to the possum belly. The two mesh sizes should have approximately the same size opening. For example, use a combination of screens with openings of 140 micrometers (100 mesh) and 178 micrometers (80 mesh) not 140 microns (100 mesh) and 279 micrometers (50 mesh). Cover 75 percent to 80 percent of the screen area with mud to properly utilize the screen surface area.

7.5.5 Use spray bars only when needed for sticky clays, gumbo, and so forth. The spray bar should be located toward the discharge end of the screening surface and should create a mist and not a continuous stream. Using a mist will cause less damage to the screen and will wash fewer solids through the screen than a continuous stream.

7.5.6 Do not bypass the screens or operate the shaker with torn screens; these are the main causes of plugged hydrocyclones. Fine mesh screens constructed with coarse mesh backing cloth have the advantage of providing some screening even when the fine mesh tears.

7.5.7 For improved life with hook-strip-type screens, make sure the components of the screen tensioning system, including any rubber supports, nuts, bolts, springs, and so forth, are in place, clean, and in good shape. Periodically rubber supports should be removed, inspected, and cleaned inside and out. Install screens according to the manufacturer's recommended installation procedure.

7.5.8 Hook-strip-type screens should be installed by gradually tensioning from the center to the end. Repeat this procedure until proper tension is achieved. Recheck tension after 15-30 minutes of operation and hourly thereafter.

7.5.9 Check the bearing lubrication every 100 hours of operation or according to manufacturer's maintenance schedule. Lubricate and maintain the unit according to manufacturer's instructions.

7.5.10 Rig up with sufficient space and walkways with handrails around the shaker skid to permit easy service. The shaker skid should be level.

7.5.11 Check for correct direction of rotation of the shaker motors. Follow manufacturer's guidelines.

7.5.12 The flow line should enter the bottom of the possum belly to minimize solids settling and buildup in the possum belly. If the flow line must enter over the top of the possum belly, it should extend downward into the possum belly leaving only enough clearance for gumbo to exit from the flow line.

7.5.13 Rig up for equal fluid and solids distribution when more than one shaker is used.

7.5.14 An upstream bypass is desirable and should only be used to permit separation of cement, spotting fluids, and so forth.

7.5.15 Consider a cascade shaker arrangement if drilled solids are very abrasive, significant amounts of gumbo are present, or drilling rate is extremely fast.

7.5.16 When using a shaker with an adjustable deck angle, watch for solids degradation or grinding at positive uphill deck angles, especially above +3 degrees uphill. If stationary piles or lumps of solids are found in the pool, excessive grinding will occur, especially with softer solids. If grinding is suspected, the deck angle should be decreased.

7.5.17 Check weight material losses. Weight material losses for the same mud and mesh screens are often lower on linear motion flow line shakers than on downstream mud cleaners. Weight material losses over the shaker can be significant and therefore should be checked periodically. See 7.9 for mud cleaners.

7.5.18 Reducing weight material losses can also reduce the amount of drilled solids discarded.

7.5.19 Following the above guidelines promotes better performance by any shaker, which in turn contributes to better performance by other downstream solids equipment. Solids management begins at the shale shaker but the shaker should be regarded as just one part of a total processing system.

7.6 CENTRIFUGAL PUMPS

7.6.1 Select a pump to handle the highest anticipated flow rate. Select the drive motor size to handle the highest anticipated drilling fluid density at that flow rate and head. Select an impeller size to provide sufficient discharge head to overcome friction in the lines, lift the fluid as required, and have sufficient head remaining to operate the equipment being fed.

7.6.2 Install the centrifugal pump with a flooded suction which is sufficient submergence to prevent vortexing or airlocking. Foot valves are not needed or recommended with flooded suctions.

7.6.3 Only if plugging of hydrocyclones and nozzles is a problem, install a removable screen over the suction to keep out large solids and trash. It can be made out of $^1/_2$-inch expanded metal and should have a total screen area at least five times the cross-sectional area of the suction line so it will not restrict flow. A handle extending above the tank surface is necessary to allow the screen to be pulled during service and cleaned.

7.6.4 Suction and discharge lines should be properly sized and as short as practical. Flow velocities should be in the range of 5 to 10 feet per second. Less then 5 feet per second causes solids to form a tight layer obstructing the bottom of horizontal lines. At velocities at or exceeding 10 feet per second pipe-turns tend to erode, headers do not distribute properly, and there will be cavitation in the pump suction. To calculate velocity inside the pipe, use the following equation:

$$\text{velocity, ft/sec} = \frac{\text{gpm}}{3.48 \times (\text{I.D. inches})^2} \qquad (26)$$

The suction line should contain no elbows, swages, or reducers closer than 3 pipe diameters to the pump suction flange.

7.6.5 Eliminate manifolding. One suction and one discharge per pump is most cost effective over time. Do not manifold two pumps on the same suction line. Do not pump into the same discharge line with two or more pumps.

7.6.6 Make sure the impeller rotation is correct.

7.6.7 Keep air out of the pump by degassing the mud, having adequate suction line submergence, and installing baffles to break mixer vortices. Properly sized, baffled and agitated compartments will not vortex unless the mud level becomes extremely low.

7.6.8 Do not restrict the flow to the suction side of the pump. Starving the pump suction causes cavitation and this will damage the pump very rapidly.

7.6.9 Install a pressure gauge between the pump discharge and first valve. When the valve is closed briefly, the pressure reading may be used for diagnostic evaluation of the pump performance. To convert head to pressure or pressure to head use the following equations:

$$\text{pressure (psi)} = 0.052 \times (\text{mud weight, lb/gal}) \times (\text{head, ft}) \qquad (27)$$

or:

$$\text{head, ft} = \frac{\text{pressure, psi}}{0.052 \times \text{mud weight, lb/gal}} \qquad (28)$$

7.6.10 Do not completely close off the discharge for more than 3 minutes or overheating and seal damage could occur.

7.6.11 The recommended startup procedure for an electric motor-driven centrifugal pump with a valve between the pump and the equipment being operated is to start the pump with the valve just slightly open. Once the pump is up to speed, open the valve slowly to full open. This approach will reduce the startup load on the electric motor and will reduce the shock loading on equipment such as pressure gauges and hydrocyclones. An alternate startup procedure is to completely close the valve before startup and open the valve slowly immediately after startup to prevent overheating and possible damage as discussed in 7.6.10.

7.6.12 Following these simple, practical guidelines will prevent many of the common problems associated with centrifugal pump installations.

7.7 DEGASSERS

7.7.1 Degassers should be located downstream from the shale shakers and prior to any equipment requiring a centrifugal feed pump. The degasser suction should be installed downstream of the sand trap and upstream of any centrifugal pump in the system.

7.7.2 The degasser suction should be located about 1 foot off bottom in a well-agitated compartment.

7.7.3 Use top equalization between the degasser suction and discharge compartments.

7.7.4 The power mud for the eductor jet for a vacuum degasser should come from the degasser discharge compartment.

7.7.5 The power mud centrifugal pump must provide the required feed head. Install a pressure or head gauge to monitor the feed head at the eductor. (For conversion formulas see 7.6 for centrifugal pumps.)

7.7.6 Ensure that degasser capacity exceeds rig circulating rate with gas cut mud.

7.7.7 Periodically check degasser components (for example, 3-way valves, vacuum pumps, vacuum blowers) for proper operation. Follow the manufacturer's recommended lubrication and maintenance schedule.

7.7.8 Follow all of the manufacturer's recommended guidelines for rig-up, operation, and service to ensure optimum performance.

7.8 HYDROCYCLONES

7.8.1 Oil field hydrocyclones are available in sizes ranging from 1 inch to 12 inches (2.5 cm to 30.5 cm). Cones equal to or larger than 6 inches (15.2 cm) are called desanders while cones smaller than 6 inches (15.2 cm) are termed desilters. Hydrocyclones can be used on either weighted or unweighted drilling fluids. The underflow can be discarded, screened, centrifuged, or screened/centrifuged depending upon the application, the value of the liquid phase, and environmental considerations.

7.8.2 Install enough hydrocyclones to process 100 percent of the mud volume entering the hydrocyclone suction compartment or to handle the maximum solids loading, whichever is larger.

7.8.3 Use correct fluid routing with bottom equalization. The hydrocyclone overflow should be returned to the next compartment downstream from the hydrocyclone suction compartment. The hydrocyclone discharge compartment must back flow to the hydrocyclone pump suction compartment. This should be accomplished by an opening at the bottom of the partition between the two compartments. The opening should be sized for 5 to 8 ft/sec maximum fluid velocity with no way to shut it off.

7.8.4 Mechanically stir all hydrocyclone removal and discharge compartments for more uniform feed to the cyclones. Mud guns are not recommended for stirring because they can cause bypassing of the hydrocyclones. Properly sized agitators give much better results.

7.8.5 Operate hydrocyclones in spray discharge, not rope discharge. Rope discharge is less effective at drilled solids removal and causes more wear and plugging problems. Roping cones can be corrected by opening up the cone apexes, adding more cones, or running finer shaker screens.

7.8.6 Clean hydrocyclones with plugged inlets and apexes immediately.

7.8.7 Smaller hydrocyclones are much more susceptible to plugging. To prevent severe plugging problems with 2-inch hydrocyclones, make sure most of the API sand-size particles (greater than 74 micrometers) and the larger of the API silt-sized particles (74 to 2 micrometers) are removed by some combination of fine mesh screens, desanders, and desilters.

7.8.8 Quick-connect type hydrocyclones are easier to service than flanged type hydrocyclones. Quick-connects make it much easier to clean out plugged hydrocyclone inlets and inspect and replace worn parts.

7.8.9 The feed inlet to hydrocyclones should be above the highest mud level in the active mud tanks to prevent accidental loss of whole mud by gravity drainage when the hydrocyclones are not in operation.

7.8.10 Provide space and walkways around the equipment to encourage proper service.

7.8.11 Maintain a working pressure or head gauge with gauge protection such as a ball valve and/or diaphragm on the hydrocyclone feed header.

7.8.12 Install a siphon breaker on the overflow header.

7.8.13 Do not bypass the shale shaker or operate with torn screens. When large solids plug the hydrocyclone underflow, this indicates some of the drilling fluid did not pass through a shaker screen.

7.8.14 Install centrifugal feed pumps with flooded suctions.

7.8.15 If needed, install centrifugal pump suction screens to keep out trash and large solids (see 7.6).

7.8.16 Size the pump impeller and motor RPM to give the recommended head at the hydrocyclone feed header (usually 75 ft (22.9 m) of head, or pressure in psi approximately 4 times the mud weight) (see 7.6).

7.8.17 Size suction and discharge piping so that flow velocities are in the 5 to 10 ft/sec range.

7.8.18 Eliminate manifolding. Use single purpose pumps, preferably one pump per hydrocyclone unit.

7.8.19 The basics of efficient hydrocyclone installations are really quite simple. Adherence to these practical operating guidelines will dramatically improve the efficiency of many installations.

7.9 MUD CLEANERS

7.9.1 Since the mud cleaner is a combination of hydrocyclones and a shaker, many of the guidelines given for shakers and hydrocyclones apply to mud cleaners. Always follow specific manufacturer's recommended maintenance practice.

7.9.2 Unweighted Muds

7.9.2.1 Use the mud cleaner only as a desilter (blank off screen) unless environmental constraints or economics dictate the use of screens.

7.9.2.2 If screens are used, run the finest screen practical.

7.9.2.3 Centrifuging the cone/screen underflow can result in better solids removal.

7.9.3 Weighted Muds

7.9.3.1 Use mud cleaners when the shale shakers do not reduce the API sand content (total material in the sand test tube) to $^1/_2$ percent or less.

7.9.3.2 Check weight material losses. Measured barite contents have ranged from 28 to 95 percent by weight of total solids discarded over the mud cleaner screens, with the average loss of barite being 40 to 50 percent by weight. When comparing weight material losses for the same mesh screens and same mud, losses are often higher for a mud cleaner than for a shaker on the flow line. For example, if weight material losses on the same mud are compared for a 150 mesh (105 micrometer opening) mud cleaner screen versus a 150 mesh (105 micrometer opening) shaker screen, the mud cleaner barite losses will probably be higher.

7.9.3.3 For base fluid-based muds, weight material losses can be reduced by adding dilution base fluid to the hydrocyclone underflow ahead of the screen, running more mud onto the screen from either the hydrocyclone underflow or a reflux mud connection on the overflow manifold.

7.9.3.4 For oil-based muds, weight material losses can be reduced by adding dilution oil to the hydrocyclone underflow ahead of the screen, or running more mud onto the screen from either the hydrocyclone underflow or a reflux mud connection on the overflow manifold.

7.9.3.5 Reducing weight material losses can also reduce the amount of drilled solids discarded.

7.9.3.6 Weight material additions should be made downstream of the removal section.

7.9.3.7 When the mud weight is being increased by 1 lb/gal or more during one or two circulations, barite losses can be reduced by turning off the mud cleaner. As an alternative, coarser mesh screens could be used during this rapid weight-up period.

7.10 CENTRIFUGE

7.10.1 Weighted Base Fluid Base Muds (Active System)

7.10.1.1 The primary use of the decanting centrifuge on active base fluid base muds is the control of viscosity while drilling by reducing the clay content of the mud. It has also proved quite valuable for concentrating mud from the active system for storage on location when the size of the system is to be reduced (for example, at a casing set point); for speeding weight-up when needed (for example, when a kick is encountered); to salvage weight material; or to reduce contamination of the liquid phase (for example when a salt base fluid flow has entered the borehole).

7.10.1.2 The RMS perforated rotor machine also can perform each of those functions except the last two, with less efficiency as weight increases above about 15 lb/gal.

7.10.1.3 The following guidelines apply primarily to the use of a centrifuge to control viscosity in a weighted base fluid base mud.

7.10.1.3.1 A centrifuge is used on the active weighted base fluid-base muds to control the mud viscosity while drilling.

7.10.1.3.2 Have adequate centrifuge capacity to process 5 percent to 15 percent of the rig circulation rate. Reduce feed rates in harder, less mud-making formations.

7.10.1.3.3 Do not exceed the manufacturer's maximum recommended feed rate for a given mud weight or the recommended rotational speed.

7.10.1.3.4 Follow the manufacturer's recommended lubrication and maintenance schedules.

7.10.1.3.5 Run the centrifuge constantly on the active system to control mud viscosity. It is better to run the unit continually at lower feed rates while drilling than to feed high volumes to the centrifuge over short time intervals. For example, if the centrifuge is run 8 hours per day at 12 gpm, it can be run constantly for 24 hours at a rate of 4 gpm and process the same volume of mud. A feed rate less than the recommended maximum can produce better results.

7.10.1.3.6 If the centrifuge is run all the time, be sure the feed is shut off while tripping.

7.10.1.3.7 Add sufficient base fluid and mud additives to maintain a constant surface volume and desired mud properties. Be sure a viscosity problem is not created by excessive addition of commercial clays.

7.10.1.3.8 Add sufficient dilution base fluid to the decanting centrifuge feed to reduce the API funnel viscosity of the centrifuge effluent to 37 sec/qt.

7.10.1.3.9 Have an adequate supply of clean base fluid.

7.10.1.3.10 Take the centrifuge feed from a well-agitated spot upstream from the centrifuge discharge compartment.

7.10.1.3.11 Return the solids to the active system at a well-agitated spot downstream of the centrifuge suction compartment.

7.10.1.3.12 Return the solids underflow upstream of the mud mixing section of the surface system.

7.10.1.3.13 For better mixing, be sure a high mud level is maintained in the tank where the underflow solids return.

7.10.1.3.14 Always wash out the unit on shutdown to prevent possible problems when the unit is restarted.

7.10.1.3.15 If the centrifuge is to be run on both unweighted and weighted muds, rig up to allow either option. Both the liquid effluent and the solids underflow should be rigged up to allow each to be discarded or returned to the active system, depending on the application.

7.10.1.3.16 In a weighted mud, both underflow and overflow discharge streams will contain low specific gravity solids and weight materials.

7.10.2 Unweighted Muds (Active System)

7.10.2.1 For unweighted base fluid muds, the user has to decide whether to run the centrifuge on the active system or on hydrocyclone or mud cleaner underflow or some combination of both. Running the centrifuge on either hydrocyclone underflow or mud cleaner underflow is considered to be the optimum choice because more separable solids are presented to the centrifuge. This is true only if the characteristics of the underflow slurry do not force the centrifuge to prematurely exceed its torque limit.

7.10.2.2 A high volume unit with a high solids capacity is usually required to process a significant amount of the rig circulation rate unless the machine is processing hydrocyclone underflow.

7.10.2.3 Do not exceed the manufacturer's maximum recommended rotational speed or feed rate.

7.10.2.4 Follow the manufacturer's recommended lubrication and maintenance schedule.

7.10.2.5 Feed rates 30 to 70 percent of the manufacturer's claimed maximum can give the most solids removal. For a given mud system and solids distribution, field experimentation must be used to determine the feed rate which gives the maximum total solids removed.

7.10.2.6 If the centrifuge is to be run on both unweighted and weighted muds, rig up to allow either option. Both the liquid effluent and the solids underflow should be rigged up to allow each to be discarded or returned to the active system.

7.10.3 Unweighted Muds—Hydrocyclone Underflow

7.10.3.1 Be sure there is enough centrifuge capacity to handle the solids and the liquid underflow from the hydrocylones. Screen as required to prevent excessive conveyor wear.

7.10.3.2 Do not exceed the manufacturer's maximum safe rotational speed or feed rate.

7.10.3.3 Follow the manufacturer's recommended lubrication and maintenance schedule.

7.10.3.4 Feed rates 30 percent to 70 percent of the manufacturer's claimed maximums can give the most solids removal. For a given mud system and solids distribution, field experimentation must be used to determine the feed rate which gives the maximum total solids removed.

7.10.3.5 Collect hydrocyclone underflow into a small well-agitated catch tank that is equalized with the active system downstream of the last hydrocyclone suction compartment. The feed rate to the centrifuge should be slightly more than the hydrocyclone underflow volume so there is always a small flow from the active system through the equalizer line to the small catch tank. Equalization with the active system prevents the catch tank from overflowing should the centrifuge shut down automatically.

7.10.3.6 Open up any adjustable hydrocyclone apexes for maximum underflow liquid volumes and solids removal but do not exceed the maximum centrifuge solids removal capacity or optimum total centrifuge feed rate. See 7.10.3.4 above.

7.10.3.7 An increase in centrifuge feed rate does not necessarily result in an increased solids removal rate.

APPENDIX A—PARTICLE SIZE DISTRIBUTION BY WET SIEVE ANALYSIS

A.1 Description

A.1.1 This procedure can be used to determine the particle size distribution of solids contained in both water-based and oil-based drilling fluids which are larger than 45 micrometers. The size distribution of smaller particles can be determined by diffraction analysis.

A.1.2 The wet sieve analysis is best suited for determining the size distribution of particles carried in the drilling fluid from the flowline to the desander discharge. The size distribution is determined by measuring the amount of solids retained on sieves of various opening sizes.

A.1.3 Two procedures are included: a volumetric method for a relative determination of the particle size distribution, and a gravimetric method for a more quantitative analysis is also desired. Both methods could give similar results assuming the solids separated by sieving are all of the same specific gravity, that is, mostly drill solids.

A.2 Volumetric Method

A.2.1 EQUIPMENT

A.2.1.1 Glass or plastic container: one 1 quart (0.9 L).

A.2.1.2 Sieves: set of 7 to 8 of increasing mesh count (decreasing opening size) with the coarsest being U.S. Sieve No. 40 mesh (425 micrometer openings) and the finest being U.S. Sieve No. 400 mesh (38 micrometer openings).

Note: A set of eight sieves consisting of U.S. 40 (425 micrometers), 50 (300 micrometers), 70 (212 micrometers), 100 (150 micrometers), 140 (106 micrometers), 200 (75 micrometers), 270 (53 micrometers) and 400 (38 micrometers) mesh gives a linear distribution of opening sizes on a log scale (adjacent sieve openings differ by a factor of the square root of 2) and should give the best results.

A.2.1.3 Glass sand content tube, 10 cm^3 capacity graduated for 0 to 20 percent sand.

A.2.1.4 Pump-up liquid sprayer, with a volume of approximately $^1/_2$ gallon (1.9 L), a trigger type control valve and a hose to an adjustable spray nozzle.

A.2.1.5 Wash liquid, water for water base muds or the base oil for oil muds.

Note: For best results the wash water should have a salinity and pH similar to that of the drilling fluid to minimize size degradation of the solids being collected.

A.2.1.6 Glass or plastic funnel about 4 inches (10.2 cm^3) in diameter with a short, wide stem.

A.2.2 PROCEDURE

A.2.2.1 Collect a 1 quart (0.9 L) sample of the fluid to be tested.

A.2.2.2 Pour sample through a 400 mesh (38 micrometer) sieve using the pump-up sprayer filled with the wash liquid to wash all of the drilling fluid out of the container and through the sieve, retaining only the solids larger than the sieve opening.

A.2.2.3 Wash the solids retained on the 400 mesh sieve through the stack of sieves with the coarsest sieve on top and the finest sieve (400 mesh) on the bottom.

A.2.2.4 Wash the contents of each sieve into a sand content tube using the funnel and record the volume of solids retained on each sieve.

A.2.3 CALCULATION

A.2.3.1 Add the volumes measured for each of the sieve sizes.

A2.3.2 Calculate the percent retained on each sieve.

A.2.3.3 Plot the percent retained on each sieve versus the opening size of the sieve to give a frequency distribution.

A.2.3.4 Add the volumes successively from the finest to the coarsest sieve and plot versus the logarithm of the opening size of the sieve to give a cumulative distribution as percent finer than the finest sieve.

Note: This procedure yields a distribution only of the coarser particles in the drilling fluid and is not representative of the total amount of solids present.

A.3 Gravametric Method

A.3.1 EQUIPMENT

A.3.1.1 Glass or plastic container: one 1 quart (0.9 L).

A.3.1.2 Sieves: set of 7 to 8 of increasing mesh count (decreasing opening size) with the coarsest being U.S. Sieve No. 40 mesh (425 micrometer openings) and the finest being U.S. Sieve No. 400 mesh (38 micrometer openings).

Note: A set of eight sieves consisting of U.S. 40 (425 micrometers), 50 (300 micrometers), 70 (212 micrometers), 100 (150 micrometers), 140 (106 micrometers), 200 (75 micrometers), 270 (53 micrometers) and 400 (38 micrometers) mesh gives a linear distribution of opening sizes on a log scale (adjacent sieve openings differ by a factor of the square root of 2) and will give the best results.

A.3.1.3 Pump-up liquid sprayer, with a volume of approximately $^1/_2$ gallon (1.9 L), a trigger type control valve and a hose to an adjustable spray nozzle.

A.3.1.4 Wash liquid, water for water base muds or the base oil for oil muds.

Note: For best results the wash water should have a salinity and pH similar to that of the drilling fluid to minimize size degradation of the solids being collected.

A.3.1.5 Low boiling solvent such as isopropyl alcohol (for use only when testing oil muds).

A.3.1.6 Drying oven with a large enough capacity to hold the sieves.

A.3.1.7 Balance: precision of 0.01 g.

A.3.2 PROCEDURE

A.3.2.1 Collect a 1 quart (0.9 L) sample of the fluid to be tested.

A.3.2.2 Pour sample through the 400 mesh (38 micrometer) sieve using the pump-up sprayer filled with the wash liquid to wash all of the drilling fluid out of the container and through the screen.

A.3.2.3 Clean and dry at 200° F (93°C) each sieve. Weigh each sieve and record each weight.

A.3.2.4 Wash the solids retained on the 400 mesh sieve through the stack of sieves with the coarsest sieve on top and the finest sieve (400 mesh) on the bottom.

A.3.2.5 If an oil-based mud is being used, the sieves should be rinsed with a low boiling solvent such as isopropyl alcohol before drying.

A.3.2.6 Dry each sieve with its retained solids at 200° F (93°C) in the drying oven.

A.3.2.7 Cool each sieve. Reweigh each sieve with its retained solids and record each weight.

A.3.3 CALCULATION

A.3.3.1 Determine the weight of the retained solids on each screen by subtracting the weight of the sieve from the weight of the dried sieve plus the retained solids.

A.3.3.2 Add the retained solids weights together to give a total weight of solids larger than 400 mesh (38 micrometer).

A.3.3.3 Calculate the weight percent retained on each sieve.

A.3.3.4 Plot the percent retained on each sieve versus the opening size of the sieve to give a frequency distribution.

A.3.3.5 Add the weight percents successively from the finest to the coarsest sieve and plot versus the logarithm of the opening size of the sieve to give a cumulative distribution as percent finer than the finest sieve.

Note: This procedure yields a distribution only of the coarser particles in the drilling fluid and is not representative of the total amount of solids present.

APPENDIX B—PARTICLE SIZE DISTRIBUTION BY DIFFRACTION ANALYSIS

B.1 Description

B.1.1 This procedure can be used to determine the particle size distribution of the solids contained in a base fluid-base drilling fluid which are smaller than those determined by wet sieve analysis. The procedure is suited for samples taken from downstream of the shale shaker to the pump suction.

B.1.2 The diffraction technique (so-called Fraunhofer diffraction) is based on measuring the angle and intensity of light that is scattered by particles in the path of a laser beam which passes through a diluted sample of the drilling fluid. The intensity versus scattering angle data is processed via an algorithm to yield the concentration of particles within a set of fixed size ranges. Different manufacturers use different algorithms and different measurement methods but the end results are generally similar.

B.1.3 The technique yields acceptable results for particles ranging in size from approximately 1 micrometer up to 700 micrometers. Different instruments may cover different ranges, but the range of most interest for drilling fluids is usually from 2 to 200 micrometers. Larger particles can also be measured by wet sieve analysis. Smaller particles, such as well dispersed clays and polymers, require more sophisticated techniques.

B.1.4 Particle size distribution as determined by light diffraction, by wet sieve analysis and by other techniques will generally not be in complete agreement. Each of these methods *look* at the particles in different ways and will generate different distributions. However, all give results in terms of the volume or mass distribution of equivalent spherical particles.

B.2 Equipment

B.2.1 A computerized laser light diffraction analyzer (preferably portable) with a size range of at least 2 to 200 micrometers.

B.2.2 Plastic hypodermic syringe: one 2- or 5-cm³.

B.2.3 Dilution base fluid in a quantity sufficient to operate the light scattering instrument as per the manufacturer's instructions.

Note: For best results, the chemistry of the dilution base fluid should be similar to that of the mud filtrate. Base fluid of lower salinity can reduce the particle size by dispersion. Base fluid of higher salinity can increase particle size by flocculation/aggregation.

B.3 Procedure

B.3.1 Set up and calibrate the particle size analyzer as per the manufacturer's instructions.

B.3.2 Collect a 1 to 2 cm³ sample of well stirred drilling fluid in the syringe and mix with the dilution base fluid in the particle size analyzer.

Note: The sample size will depend on the specific instrument and should be based on the manufacturer's recommendation if different from B3.2.

B.3.3 Allow the diluted sample to reach a uniform concentration throughout the circulating system of the analyzer and start the analysis.

B.3.4 It is best to conduct multiple runs with the same sample to insure consistent results. The timing and number of runs to average will depend on the specific instrument.

B.4 Calculation

Particle size results will generally be presented by the apparatus as a cumulative distribution (volume percent finer than), as a frequency distribution (volume percent within a given size range), or both.

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