

New Industry Standards Simplify Drilling Fluid Processing System Evaluation

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Abstract

API RP13C Recommended Practice titled *Drilling-fluid Processing Systems Evaluation* has been significantly revised and updated to be more applicable to current industry practices. The American Petroleum Institute (API) recently published the 6th Edition. It provides methods for assessing performance of fluids processing equipment and evaluating the impact of processing efficiency on drilling fluid consumption and overall waste. New calculations for solids removal efficiency, required dilution volumes, and optimum dilution volume have been added and are discussed in this paper.

Additionally, two new procedures added to the 6th Edition are discussed. The first is a simple gravimetric method to measure mud-to-cuttings ratio (MCR) without using a retort. The second is a retort procedure that similarly quantifies the volume of mud lost with cuttings but also gives the concentration of low gravity solids (LGS) and high gravity solids (HGS) in shale shaker overflows, centrifuge underflows, and other semi-liquid drilling wastes with high solids content. The data is useful in determining cost savings from equipment operation and to determine if weighting agents are being disproportionately discarded with cuttings. Comprehensive examples using these metrics are provided.

Introduction

For the past 20 years, the drilling industry has relied on a limited method for determining drilling fluids processing efficiency. The API Subcommittee 13 has recently developed a non-biased and comprehensive method for determining an overall drilling fluids system performance. Subcommittee 13 consists of drilling fluid specialists, drilling fluid companies, fluids processing equipment service companies, and operators that were all contributors to the 6th Edition of the API RP 13C document.

A significant portion of Operators' costs when drilling an oil and gas well is attributed to drilling fluid and drilling fluid related costs such as dilution, fluids processing services and expendables, haul off, disposal, and Non-Productive Time (NPT) particularly when drilling with environmentally sensitive drilling fluids. These fluids' related costs are reported to be in the 8 to 20 percent range of the overall drilling cost.

In today's push for lowering emissions and reducing the carbon footprint during drilling operations, Operators are seeking methods for accurately measuring and improving drilling efficiency. The 6th Edition of the API RP 13C: Drilling Fluid Processing Systems Evaluation that was published in December 2023 addresses several factors that directly pertain to quantifying drilling fluid processing efficiency, drilling fluid conservation, and the balance between the two.

Figure 1 and Figure 5 illustrate the interdependency between solids removal efficiency and fluid conservation where values on the lower left indicate inefficiencies and values in the upper right are more desirable but difficult to achieve. This balance between performance metrics is poorly understood by the industry in general, including that after a certain point as more processing equipment or increasingly finer shaker screens are used, fluids conservation will decrease as more mud is discarded. It is recommended for all to study and understand the more comprehensive concepts presented in RP 13C Section 5.1.

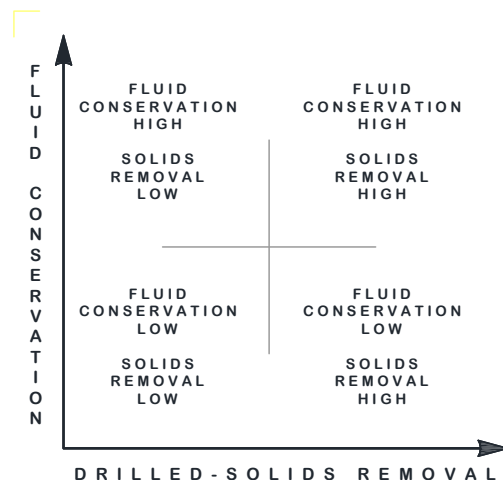


Figure 1: Solids Removal Efficiency and Fluid Conservation Interdependency

Why was Change Needed

The 4th and 5th editions of API RP 13C (and the identical ISO 13501 versions) used a solids removal efficiency metric named “drilled-solids removal system performance (efficiency)” that was based on a fluid conservation metric named the “dilution factor”. The dilution factor was defined as the ratio of actual dilution volume divided by the hypothetical dilution volume if no solids removal equipment was used and all drill solids were incorporated into the active volume. Both operators and service providers never widely adopted the use of these two previous API 13C metrics and few drilling fluids or fluids processing professionals knew or understood the calculations or concepts. Instead, solids removal efficiency became the de facto industry standard and appeared in numerous industry publications.

During the 6th edition revision, it was recognized that this lack of adoption left the industry in a state where metrics for solids removal efficient and fluids conservation were not standardized, measured, or routinely reported. Daily reports and end of well reports (recaps) from both drilling fluids and solids control equipment service providers typically lacked any metrics for these interdependent concerns. This realization that “if you don’t measure it, you can’t improve it” was obvious and the reason for making the changes discussed in this paper.

Previous editions of 13C did not contain the calculations needed to determine dilution volumes in a standard way or practical methods for measuring the quantity of mud retained on drilled-solids removed by shakers or other solids removal equipment where an excess quantity of barite is often discarded. For these reasons industry practices varied widely to the point where comparing reported data between companies was suspect.

Also missing were methods for determining and reporting; a) the quantity of excess dilution volume (measure of drilling fluid conservation), b) the optimum solids removal efficiency (for no excess dilution volume), and c) the quantity of overall waste (discarded drilled solids, mud retained on drill solids, plus excess dilution volume).

Clearly these deficiencies were an impediment to the industry measuring and reporting data in a standardized way that would allow solids removal equipment efficiencies to be evaluated concurrently with metrics for fluids conservation.

System for Measuring Solids Control Performance

The new and revised metrics in API RP 13C provide methods to improve operational data and to analyze solids control effectiveness. The updates and new metrics are summarized below.

Note that symbols used to denote variables in the equations in API RP 13C have been changed in this document to either “plain language” or abbreviations of the plain language. The terms “cuttings” and “drilled-solids” are used interchangeably to describe formation solids. The term “wet cuttings” means the mixture of cuttings and drilling fluid discarded by a shale

shaker or other solids control component. For example, “shale shaker screen overflow” is a type of “wet cuttings.”

Solids Removal Efficiency

The revision to RP 13C replaces the aforementioned “system performance” with the more widely used industry metric “solids removal efficiency”. SRE is the volume of drilled-solids removed from the active circulating system divided by the hole volume as shown in in Equation 1. In real-time drilling operations, solids removal efficiency (SRE) is difficult to measure directly because the volume of drilled solids removed is obscured by the wet cuttings volume which includes drilling fluid retained on the cuttings.

$$SRE = \frac{\text{Volume of Drilled-solids Removed}}{\text{Volume of Hole Drilled}} \times 100 \quad (1)$$

As in earlier editions, RP 13C focuses on the “volume of drilling fluid built and added while drilling” rather than on the volume of cuttings removed. The reason for this is purely practical. It is much easier to determine the volume of cuttings not removed by the solids control process from mud report data and volume balance information. As shown in Equation 2 and Equation 3, SRE can be calculated if the volume of dilution mud built and the drilled solids concentration in the active circulating system are known. Equation 2 is on a “clean mud” basis, as if, mud was built at a mud plant with no drilled solids and used for dilution. Equation 3 is on a “dirty mud” basis and applies when the volume of mud built for dilution includes volume from drilled-solids. The LGS concentration in the active circulating system (%LGS) is assumed to equal the drilled-solids concentration in the active system in the equations in this paper.

$$SRE = 100 - \frac{(100 \times V_{\text{mud built}} \times \%LGS)}{V_{\text{hole}} \times (100 - \%LGS)} \quad (2)$$

$$SRE = 100 - \frac{(100 \times V_{\text{dirty mud built}} \times \%LGS)}{V_{\text{hole}}} \quad (3)$$

SRE data can be generated on a near real-time basis, daily basis, or at the end of an interval. When base fluid usage is metered or closely tracked, the base fluid volume usage can be used to determine the “clean mud dilution volume built” as shown in Equation 4 below for a nonaqueous based drilling fluid (NADF) where the %NAF is the percent nonaqueous fluid from a formulation or retort of a zero drilled solids fluid.

$$V_{\text{mud built}} = \frac{(100 \times V_{\text{NAF}})}{\%NAF} \quad (4)$$

The SRE calculation assumes that “dilution volume built” was used to entrain drilled solids not removed by the solids control process. Drilling fluid volume found in daily mud reports may include volume built for other reasons. For example, a lost circulation event may require drilling fluid volume be built, but the volume built would be unrelated to diluting drilled-solids. Mud report data can be scrubbed by backing out any drilling fluid volume built for reasons other than dilution so that calculated SRE reflects the performance of the solids control process.

New Metric and Two New Procedures

The revision to RP 13C includes a new metric called the Mud to Cuttings Ratio (MCR) and two new procedures for measuring the quantity of mud lost with cuttings. The first procedure is a “Density Method” wherein MCR is determined by using a quick and simple weight measurement. The second procedure is called a “Topped-up Retort Procedure”, where the retort cell is partially filled with wet cuttings then “topped-up” with base fluid. This allows the quantity of wet cuttings to be determined. Additional gravimetric and volumetric data allows mud lost with cuttings to be calculated as well as a complete solids analysis of the wet cuttings sample, including any excess barite over the amount from the retained mud.

Mud to Cuttings Ratio

MCR is the volume/volume ratio of drilling fluid to cuttings in a discard stream or sample. MCR can be written as a ratio or as a fraction and is always simplified to be per “unit volume of cuttings”. Interpreting MCR data is a relatively straightforward process. If a shale shaker overflow has MCR of 1.5:1, then 1.5 barrels of mud is lost with each barrel of cuttings discarded by the shaker. Equation 5 shows MCR written as fraction.

$$\text{MCR} = \frac{\text{Volume of Drilling Fluid}}{\text{Volume of Cuttings}} \quad (5)$$

Mud to cuttings ratio can be determined empirically by either the Density Method or the Topped-up Retort Procedure.

The Density Method in RP 13C Section 5.5 is the simplest method for collecting MCR data but may have limitations, as discussed later. The density difference between suction pit mud and the wet cuttings discard is used to calculate MCR. The wet cuttings density can be quickly measured for shale shaker overflows or other solids removal equipment discharges using the weight-based method shown in Figure 2.

The Topped-up Retort Procedure found in RP 13C Annex C is recommended for situations where the density method may have limitations, discussed later, or for validating the use of the Density Method. These situations are where weighting material is likely to be concentrated in the wet cuttings by the solids removal equipment.

The two new procedures in 13C offer several advantages over the commonly used retained oil on cuttings (ROC) retort procedure from API RP 13B-2 Annex B for determining the quantity of mud lost with cuttings. The Density method is more accurate, faster and easier to use, and does not require the use of a retort. The Topped-up retort method is also more accurate and generates considerably more information that is useful in evaluating processing equipment performance.

Optimum Solids Removal Efficiency

Optimum Solids Removal Efficiency is the removal efficiency that results in drilling an interval during which (a) the mud volume in the surface pits remains constant, (b) sufficient volume is built to fill the new hole drilled, and (c) drilled solids concentration in the active mud system is maintained as specified by the mud program or drilling management. When the above conditions are met, no excess drilling fluid will be built while drilling the interval.

Equation 6 gives the calculation for optimum solids removal efficiency. It demonstrates that SRE, MCR and target LGS concentration are interlinked. If mud lost with cuttings is high, then a lower SRE will keep the surface pit level constant by making dilution volume equal to that required fill the hole drilled plus the volume required to replace mud lost with cuttings. If mud lost with cuttings is low, then a higher SRE is necessary to ensure that pit level will remain constant at any given LGS concentration. Similarly, when the target for LGS concentration is high, lower SRE is optimum and vice versa.

$$\text{SRE}_{\text{OPT}} = 100 \times \frac{(100 - \% \text{LGS})}{(100 + (\% \text{LGS} \times \text{MCR}))} \quad (6)$$

The use of the word optimum may be somewhat misleading as the most desirable performance is to have the lowest achievable MCR and highest SRE. However, this is limited by a practical minimum MCR due to fact that after a certain point, adding additional mechanical processing equipment or using increasingly finer shaker screens to increase SRE, will discard more mud, increasing MCR.

The utility of monitoring these performance measures is to manage overall fluid volumes required for dilution so that excess unwanted volume is not generated.

Waste Volume generated due to Solids Control

The new metrics in API RP 13C are simply calculations for waste volume discarded by the solids control process. The calculations are useful for evaluating a current well or planning a future well. The volume of dry cuttings in the discard stream going to waste is calculated in Equation 7. The volume of mud lost with the cuttings is given by Equation 8. The volume of wet cuttings is the sum of the two equations.

$$\text{Waste Volume}_{\text{drilled-solids}} = \frac{V_{\text{hole}} \times \text{SRE}}{100} \quad (7)$$

$$\text{Waste Volume}_{\text{mud losses}} = \frac{V_{\text{hole}} \times \text{SRE} \times \text{MCR}}{100} \quad (8)$$

Excess Drilling Fluid Built

When an interval or well is drilled with a solids removal efficiency lower than the optimum solids removal efficiency, the surface mud pit volume will increase. Excess drilling fluid will be transferred to reserve, to storage tanks, or to a disposal site. The drilling fluid volume sent to reserve or to disposal can be calculated using Equation 9

$$V_{\text{excess mud}} = \left[\frac{(100 - \text{SRE})}{\% \text{LGS}} - \frac{(\text{MCR} \times \text{SRE})}{100} - 1 \right] \times V_{\text{hole}} \quad (9)$$

Overall Waste Volume

Overall drilling waste is a summation of the cuttings waste, the mud lost with cuttings, and the excess drilling fluid built as shown in Equation 10. The drilling fluid volume in the active mud system is not included in the calculation for excess drilling fluid built.

$$V_{\text{overall waste}} = V_{\text{hole}} \times \frac{\text{SRE}}{100} \times (1 + \text{MCR}) + V_{\text{excess mud}} \quad (10)$$

Density Method for MCR

Analyzing cuttings samples using the Density Method in RP 13C increases the safety, frequency, and quality of MCR data. The Density Method is recommended for all types of drilling fluids and for all types of solids control equipment even hydrocyclones and centrifuges when unweighted drilling fluids are in use. It can also be used in weighted fluids provided that weighting material is not being classified and concentrated in the sample tested.

Tried and true “weight-up formulas” found in most mud engineering handbooks form the basis for the procedure. Wet cuttings discard from solids control equipment will be denser than the drilling fluid pumped downhole unless the equipment is flooding. Based on the assumption that formation density is 2.6 specific gravity, a “weight-up formula” can be applied to calculate MCR from the density difference between suction pit mud weight and the wet cuttings sample.

The procedure relies on an indirect measurement of wet cuttings volume which is accomplished by displacing base fluid in a graduated volumetric container. See illustration of the apparatus and steps in Figure 2. An indirect volume measurement is necessary because wet cuttings are not free-

flowing or self-leveling and they may contain large size cuttings or entrap air.

The procedure requires a scale and a graduated volumetric container. After pre-filling a graduated volumetric container with base fluid and weighing (or taring) the container with base fluid, wet cuttings are then added to the container slowly using a spoon or spatula. When the added cuttings have displaced the base fluid from one graduation mark to another, a fixed volume of cuttings will have been added to the container. The base fluid is usually the same as that in the drilling fluid. Typically, the sample size of wet cuttings is one quart. The net weight of the wet cuttings is measured by placing the container back on the tared scale. If the sample size is one quart, the scale reading is density in lb/quart. Once the density of cuttings is calculated, Equation 11 is used to calculate MCR. All values plugged into the equation must be in the same units. Units of lb/gallon are used in the example. Other units, namely, specific gravity or kg/m³ also work.

$$\text{MCR} = \left(\frac{(21.68 - \text{Wet Cuttings Density})}{(\text{Wet Cuttings Density} - \text{Mud Weight})} \right) : 1 \quad (11)$$

For an example, if suction pit mud weight is 10 lb/gallon and shaker overflow density is 16 lb/gallon, then MCR for the shaker overflow would be calculated as shown in Equation 12.

$$\text{MCR} = \left(\frac{21.68 \text{ ppg} - 16.0 \text{ ppg}}{16.0 \text{ ppg} - 10.0 \text{ ppg}} \right) : 1 = 0.94:1 \text{ or } \frac{0.94}{1} \quad (12)$$

Field Measurement of Drilled-solids Density

Although not covered in RP 13C, the density of drilled-solids can be measured in the field rather than relying upon the assumption of 2.6 specific gravity (21.68 lb/gallon). This can be done using gravimetric methods and a volumetric flask or pycnometer (Robinson, et al., 1991), or mud balance (Bourgoyne, et al., 1986, Chapter 6 equation 6.22).

Limitations of the Density Method

When drilling with weighted fluids, the Density Method gives excellent results for overflow samples from shale shakers with screens up to and including API Number 140. API Number 170 or higher screens concentrate weighting material, like barite, in the wet cuttings. This happens when there is a significant quantity of weighting material in the drilling fluid and when the shaker screen opening size is close to the upper bounds of the grind size for the barite or other weighting material. API barite specifications allow 3% larger than an API 200 screen (75 microns). Due to piggybacking and particle aggregation in the solids screening process over shale shakers, the Density Method is an inefficient process in determining the MCR when the discarded solids include a significant amount of near size fines.

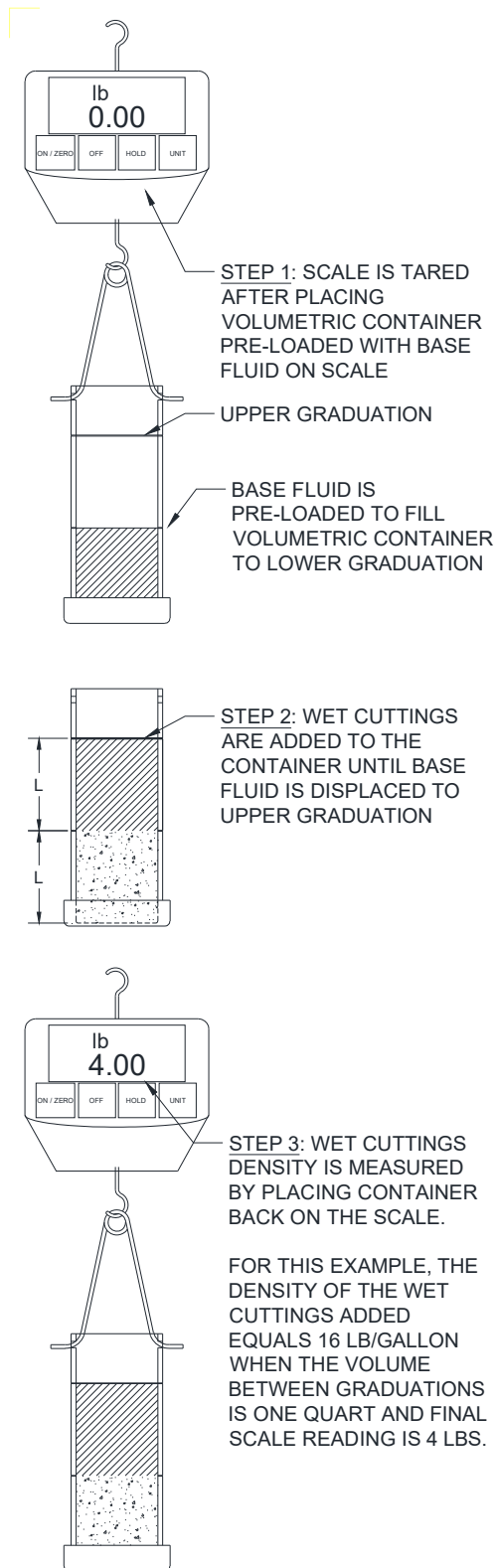


Figure 2: Apparatus for Weighing Wet Cuttings for Measuring MCR by Density Method

When drilling with weighted fluids, the Density Method cannot be used for hydrocyclones or centrifuge discard streams because both are centrifugal separators and will preferentially concentrate weighting material in the underflow (heavy phase) stream. The Density Method under reports mud lost with cuttings if weighting material is disproportionately concentrated in wet cuttings.

The 6th Edition of the API RP 13C recommends that the new “topped-up” retort procedure in Annex C be used for MCR analysis on samples from shale shakers with API 170 and finer screens and other solids removal equipment when weighted drilling fluids are in use. The retort procedure can also be used to confirm results from the Density Method. In some cases, the Density Method will give good results with API 170’s in weighted muds and can be used once confirmed with the retort method discussed below.

Although not covered in 13C, MCR values can be converted to the often used “mud on cuttings” value that is reported as a percent. For example, suppose a shale shaker sample has an MCR of 1.5:1 meaning it is discarding 1.5 barrels of mud with each barrel of cuttings. The MOC for the same sample is 60% as shown in Figure 3.

$$\text{MOC} = \frac{\text{Volume of Drilling Fluid}}{\text{Volume of Wet Cuttings}} \times 100$$

$$\text{MOC} = \frac{\text{Volume of Drilling Fluid}}{\text{Volume Cuttings} + \text{Volume Drilling Fluid}} \times 100$$

$$\text{MOC} = \frac{1.5 \text{ bbl}}{1 \text{ bbl} + 1.5 \text{ bbl}} \times 100 = 60\%$$

$$\text{MOC} = \frac{\text{MCR}}{1 + \text{MCR}} \times 100 = \frac{1.5}{1 + 1.5} \times 100 = 60\%$$

Figure 3: Converting MCR Data into MOC Data

Topped-up Retort Procedure

The Topped-up Retort Procedure is the second new procedure added to API RP 13C. It extends the use of a standard oilfield 50 ml retort and enables the analysis of wet cutting samples from the discard or recovery streams. The calculations in API RP 13C yield a complete breakdown of the solid and liquid constituents including:

- Wet cuttings density
- MCR (mud lost with cuttings)
- Excess weight material losses (barite stripping)
- Average Specific Gravity of Dry Solids
- Specific Gravity of Condensed NAF
- Concentration of low gravity solids
- Concentration of high gravity solids
- Missing mass from non-condensable constituents
- Oil/Water Ratio

Solids-laden pastes from shale shakers and centrifuges contain large particles and are often too viscous to self-level when added to a retort mud cup. For this reason, the Topped-up Retort Procedure relies on an indirect volume measurement like that used in the Density Method. The procedure differs from the ROC procedure in API RP 13B-2 annex B because the mud cup cell is topped off with base fluid after partially filling cell with sample. The vented mud cup cap is then installed to express excess base fluid for a final volume (wet cuttings plus topping fluid) fixed at 50 ml before heating. The volume of topping fluid added is given by Equation 13.

$$\text{Volume of Topping Fluid Added} = \frac{W_3 - W_2}{\text{Sp.Gr.}_{\text{topping fluid}}} = V_{\text{top}} \quad (13)$$

API RP 13C describes the Topped-up Retort procedure fully and is not belabored here. Figure 4 summarizes the eight measurements required to calculate results. There are four weight measurements made before the heat cycle in the retort oven. There are two weight measurements and two volume measurements made post-cooling. The calculations used to check validity and to report MCR data are discussed below.

Data Validity

Gravimetric measurements quantify the mass of the wet cuttings sample before heating, the mass of the residual solids post-heating, and the mass of the condensate. Typically, mass is missing when “weight before” is compared to the combined weights after heating. All weights are measured in grams. API RP 13C stipulates a maximum allowable “lost mass” of 1.5 grams for the test to be valid. Lost or missing mass can lead to significant errors in retort analysis. (Morgenthaler, et al, 2016)

The oil/water ratio of the wet cuttings in comparison to oil/water ratio in the drilling fluid is an indicator of process conditions like water wet barite or NAF dilution upstream of processing equipment. See RP 13C for Calculations

The density of condensed NAF serves as a quality control check. The volume of condensed NAF includes the topping fluid added. API RP 13C requires a plus or minus 5% tolerance on NAF density. Equation 14 gives NAF density in units of lb/gallon.

$$\text{Density of Condensed NAF} = \left[\frac{(W_{\text{full}} - W_{\text{mt}} - V_{\text{wtr}})}{(V_{\text{total}} - V_{\text{wtr}})} \right] \times 8.34 \quad (14)$$

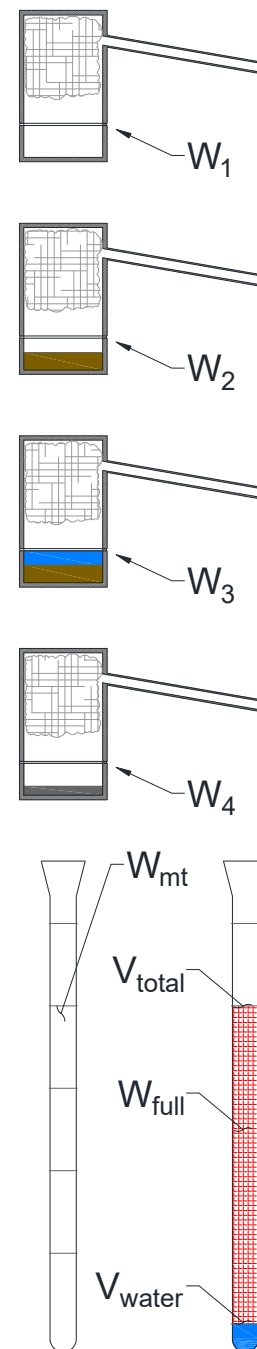


Figure 4: Measurements and Symbols for Topped-up Retort Procedure

Wet Cuttings Density and ROC

The density of the wet cuttings sample is measured in the retort cell when using the Topped-up Retort procedure. The known density combined with MCR data serves to determine if excess weighting agents are present in the wet cuttings sample. Equation 15 gives wet cuttings density in lb/gallon (Mud Weight of Wet Cuttings). ROC is the weight fraction of NAF in a wet cuttings sample as calculated in Equation 16.

$$\text{Density of Wet Cuttings} = \left[\frac{(W_2 - W_1)}{50 - [(W_3 - W_2) / (\text{Sp.Gr.}_{\text{topping fluid}})]} \right] \times 8.34 \quad (15)$$

$$\text{Weight Percent NAF in Wet Cuttings} = \frac{[(W_{\text{full}} - W_{\text{mt}}) - (W_3 - W_2) - V_{\text{wtr}}]}{(W_2 - W_1)} \times 100 \quad (16)$$

Calculation of MCR from Topped-up Retort Data

Mud lost with cuttings is easily calculated from Topped-up Retort data. Two different calculations are shown below for converting retort data to mud to cuttings ratio (MCR) when cuttings are drilled with NADF.

Equation 17 calculates MCR based on two assumptions:

- Source of NAF in wet cuttings is the drilling fluid
- Weighting agents are not concentrated in the sample

$$\text{MCR} = \left(\frac{\% \text{NAF}_{\text{wet cuttings}}}{(\% \text{NAF}_{\text{in drilling fluid}} - \% \text{NAF}_{\text{wet cuttings}})} \right) : 1 \quad (17)$$

Equation 18 calculates MCR when weighting material is concentrated in the wet cuttings sampled.

$$\text{MCR} = \left(\frac{\% \text{MUD}_{\text{wet cuttings}} + \% \text{ExWM}_{\text{wet cuttings}}}{(100 - (\% \text{MUD}_{\text{wet cuttings}} + \% \text{ExWM}_{\text{wet cuttings}}))} \right) : 1 \quad (18)$$

The concentration of NAF (v%) in the drilling fluid is found on every mud report which means, in most cases, the Topped-up Retort procedure needs to be run only on the wet cuttings sample. Referring to Figure 4, the concentration of NAF (v%) in the wet cuttings is calculated by Equation 19 and results are applied in Equation 17 and/or Equation 18.

$$\text{Volume Percent NAF in Wet Cuttings} = \frac{(V_{\text{total}} - W_{\text{wtr}} - V_{\text{top}})}{(50 - V_{\text{top}})} \times 100 = \% \text{NAF}_{\text{wet cuttings}} \quad (19)$$

$$\text{Volume Percent Drilling Fluid in Wet Cuttings} = \frac{\% \text{NAF}_{\text{wet cuttings}}}{\% \text{NAF}_{\text{in drilling fluid}}} = \% \text{MUD}_{\text{wet cuttings}} \quad (20)$$

Checking if Weighting Material is Concentrated

Equation 21 “reverse calculates” the wet cuttings density using the MCR value calculated in Equation 17. If the calculated density closely agrees with the measured Wet Cuttings Density calculated with the density measured in the

Topped-up Retort procedure and calculated in Equation 15, then the solids removal equipment is not stripping weighting material from the drilling fluid and the Density Method can be used to measure MCR.

$$\text{Wet Cuttings Density from MCR Data} = \frac{(\text{MW}_{\text{drilling fluid}} \times \text{MCR}) + 21.68}{(\text{MCR} + 1)} = \text{MW}_{\text{wet cuttings}} \quad (21)$$

If the Wet Cuttings Density calculated using Equation 21 is greater than the measured wet cuttings density, then the solids removal equipment is disproportionately concentrating weighting material. In this case Equation 17 applies and the concentration of excess weighting material in the wet cuttings will need to be determined so that Equation 18 can be used to calculate MCR.

The “concentration of excess weighting material” is determined by comparing the measured “concentration of weighting material in the wet cuttings” to the expected concentration if drilling fluid containing weighting material was mixed with dry cuttings in proportions to equal to the mud to cuttings ratio. Equation 22 calculates the volume fraction of excess weighting material as a volume percentage. The calculated value in equation below is applied in Equation 18.

$$\text{Volume Percent Excess WM} = \% \text{HG}_{\text{in wet cuttings}} - \left[\% \text{HG}_{\text{in mud}} \times \frac{\% \text{NAF}_{\text{wet cuttings}}}{\% \text{NAF}_{\text{in drilling fluid}}} \right] \quad (22)$$

Effect of Barite Concentration on MCR Calculations

The Topped-up Retort Procedure was used to determine the MCR from the rig owned shakers while drilling with a synthetic oil base mud in North Louisiana. API 170 screens were installed on all three shakers. A composite sample was collected from all three while drilling at 18,500 feet with 6-3/4” bit.

Mud report data at time sample collected:

- Mud weight.....15.1 ppg
- NAF concentration in mud.....52.4%
- HGS concentration in mud.....23.3%

Topped-up Retort data for sample of shaker overflow:

- Wet Cuttings Density18.0 ppg
- NAF concentration in cuttings...34.4%
- HGS concentration in mud.....20.1%

The MCR is first calculated using Equation 17 which assumes no excess weighting material is present. The results are:

$$\text{MCR} = \left(\frac{34.4}{(52.4 - 34.4)} \right) : 1 = \frac{1.91}{1}$$

The results from above are then used to reverse calculate the wet cuttings density using Equation 21.

$$MW_{\text{wet cuttings}} = \frac{(15.1 \times 1.91) + 21.68}{(1.91 + 1)} = 17.4 \text{ ppg}$$

The wet cuttings density (mud weight of the wet cuttings) is less than that empirically determined in the Topped-up Retort procedure. The volume percentage of excess weighting material can be calculated using Equation 22.

$$\%ExWM_{\text{wet cuttings}} = 20.1\% - \left[23.3\% \times \frac{34.4\%}{52.4\%} \right] = 4.7\%$$

The MCR including the excess weighting material can be calculated using Equation 18.

$$MCR = \left(\frac{65.6\% + 4.7\%}{(100 - (65.6 + 4.7))} \right) : 1 = \frac{2.36}{1}$$

Application of the Revised RP 13C

RP 13C Annex D gives example calculations for; D.2 (an entire interval), D.3 (daily and cumulative total), and D.4 (a single daily example) of combined equipment discharges using the topped-up retort method. The daily and cumulative example utilizes data normally reported on a daily mud report with only an additional input for MCR and is well suited to spreadsheet or daily reporting software applications.

Conclusions

The 6th Edition of RP13C provides standardized methods for assessing performance of fluids processing equipment and evaluating the impact of processing efficiency on drilling fluid consumption and overall waste. These new calculations are more in line with current industry practices and allow for the calculation of solids removal efficiency, required dilution volumes, and optimum dilution volume.

The two new procedures for MCR are improvements to what is commonly performed today and allow more accurate values to be measured and reported. These metrics allow solids removal performance to be evaluated and balanced against its impact on fluid conservation such that cost savings from equipment operation can be quantified.

These standardized methods for monitoring and reporting SRE, MCR, and dilution volumes will allow the industry to compare performance between rigs and between various equipment alternatives so that unbiased evaluations can be made for both solids removal efficiency and fluid conservation. This will allow operators to identify the most desirable level of equipment application and minimize overall environmental implications. An illustration of this is shown in Figure 5.

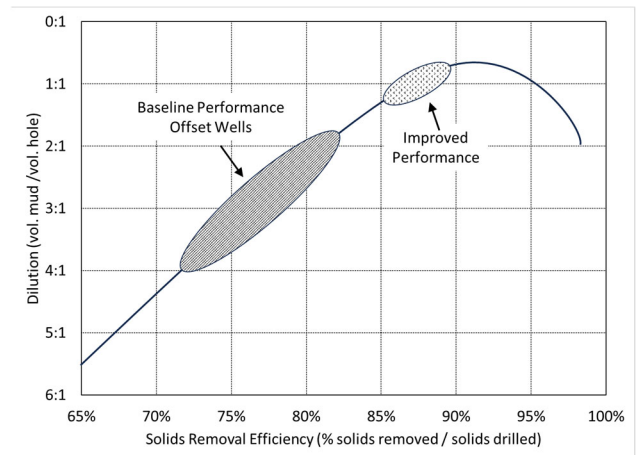


Figure 5 Monitoring SRE & Fluid Conservation

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Nomenclature

Description	Symbol
Concentration of Drilled-Solids in the Active Circulating System expressed as a volume percentage	%LGS
Concentration of Drilling Fluid in Wet Cutting expressed as a volume percentage	%MUD _{wet cuttings}
Concentration of High Gravity Solids in a Drilling Fluid expressed as a volume percentage	%HG _{drilling fluid}
Concentration of High Gravity Solids in Wet Cuttings expressed a volume percentage	%HG _{wet cuttings}
Concentration of NAF base fluid in a drilling fluid including drilled- solids expressed as a volume percentage (as if built in the active circulating system)	%NAF _{dirty}
Concentration of NAF base fluid in a drilling fluid with zero drilled- solids expressed as a volume percentage (as if built in a mud plant)	%NAF _{clean}

Description	Symbol
Concentration of NAF in Wet Cuttings expressed as a volume percentage	$\%NAF_{\text{wet cuttings}}$
Density (mud weight) of Wet Cuttings	$MW_{\text{wet cuttings}}$
Mud on Cuttings	MOC
Mud to Cuttings Ratio	MCR
Optimum Solids Removal Efficiency	SRE_{OPT}
Retained Oil on Cuttings (normally expressed as a percentage by weight)	ROC
Solids Removal Efficiency	SRE
Volume of condensate (NAF and water) in the graduated cylinder after retort distillation	V_{total}
Volume of Dilution Mud built including drilled- solids (as if built in circulating active system)	$V_{\text{dirty mud built}}$
Volume of Dilution Mud built with zero drilled- solids (as if built in mud plant)	$V_{\text{clean mud built}}$
Volume of Hole Drilled	V_{hole}
Volume of Water in the graduated cylinder after retort distillation	V_{wtr}
Weight of clean retort cell assembly packed with steel wool	W_1
Weight of retort cell assembly partially filled with cuttings sample	W_2

Description	Symbol
Weight of retort cell assembly after topping-off the cuttings with base fluid	W_3
Weight of retort cell assembly after retort distillation	W_4
Weight of graduated cylinder and condensed fluid after retort distillation	W_{full}
Weight of empty graduated cylinder before retort distillation	W_{mt}

References

1. Robinson, L. H., Elward-Berry, J., Annis, M. R. 1991. Pycnometer Accurately Determines Low-Gravity Solids. PETROLEUM ENGINEER International, JUNE 1991.
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3. Morgenthaler, M., Hinton W.B., Nace C.L. 2016. Are we over reporting LGS content in non-aqueous fluids? Paper AADE-16-FTCE-36 Proceedings of AADE Fluids Technical Conference and Exhibition, Houston (USA).
4. Bridges, S. D., Robinson, L.H. A Practical Handbook for Drilling Fluids Processing. Gulf Drilling Guides, First Edition, February 2020

Appendix 1: API RP 13C Contents

1. Scope
2. Normative References
3. Terms, Definitions, Symbols, Acronyms, and Abbreviations
4. Requirements
5. System Performance of Drilling-fluid Processing Equipment
6. Rigsite Evaluation of Drilled-solids Management
7. Practical Operational Guidelines
8. Conductance of Shale Shaker Screens
9. Shale Shaker Screen Designation
10. Non-blanked Area of Shale Shaker Screen Panel
11. Shale Shaker Screen Labeling
- Annex A. Derivation of Capture Equation
- Annex B. Finder's Method
- Annex C. 50 mL Retort Procedure for Wet Drilled-solids Samples
- Annex D. Example Calculations System Performance of Drilling-fluid Processing Equipment

13C Figures related to this AADE paper:

1. Dilution Volume Dependency on Target Drilled-solids Concentration
2. Dilution Volume Dependency on Drilled-solids Removal System Efficiency
3. Interdependency of Drilled-solids Removal and Drilling-fluid Conservation
4. Optimum Dilution Volume and Drilled-solids Removal System Efficiency
5. Density Method for Measuring Drilling-fluid-to-Drilled-solids Ratio