

Semi-Automatic Drilling Fluid Property Measurement Device

Jovani Contreras, Katherine P. Hoelscher and Colin Stewart, M-I SWACO, a Schlumberger Company

Copyright 2019, AADE

This paper was prepared for presentation at the 2019 AADE National Technical Conference and Exhibition held at the Hilton Denver City Center, Denver, Colorado, April 9-10, 2019. This conference is sponsored by the American Association of Drilling Engineers. The information presented in this paper does not reflect any position, claim or endorsement made or implied by the American Association of Drilling Engineers, their officers or members. Questions concerning the content of this paper should be directed to the individual(s) listed as author(s) of this work.

Abstract

M-I SWACO developed a device for basic semi-automatic drilling fluid property measurements. The unit has been designed to increase the efficiency of the on-site drilling fluid specialist and generate real-time data by measuring the drilling fluid's rheology profile over various temperatures (4-65 °C), including gels (up to 30 minutes), and density up to 21 lbm/gal.

The unit is highly mobile, with a small 2 ft x 2 ft x 1ft footprint and it weigh only 75 pounds. No rigging up is required, only an electrical outlet and ethernet cable are needed. The device is controlled by a user-friendly touchscreen and is self-cleaning. It is designed for use on land or offshore rigs anywhere in the world and increases the level of visibility of the drilling fluid properties data.

The rheology, gel strengths, and density measurements are timestamped and stored on the unit and Schlumberger's data server where the data can be accessed by computer or smartphone anytime. The Semi-automatic Rheology and Density Device (SRDD) will reduce HSE risk and enhance operations.

Introduction

Drilling fluid is an essential component of the well construction cycle and in a world moving towards a digital era, automation and digitalization of drilling fluid rheology and density measurements play an important roll not only in decision making but also in well integrity management and performance improvement of critical operations. It is well known that during a 24-hour period, the drilling fluid properties may change as the fluid circulates through the drilling system. These changes can't always be tracked or noticed over the usual measurement cycle of 4 manual measurements per day. Density and rheology are certainly the most critical properties to evaluate and manage during the well construction process, Failure to do so may lead to a potential well-control events or significant non-productive time event (NPT).

Manual rheology testing as dictated by API RP 13 B1 and API RP 13 B2 procedures require sample heating, or cooling for deepwater operations, before reading the values from the rheometer. Accurate rheology measurements require that the temperature remains stable for the duration of the measurement. The SRDD unit eliminates potential manual discrepancies created by the users and it has a temperature control capability to within ± 2 degF while the testing is being performed.

The device been designed to increase the reliability and

accuracy of drilling fluids data and to increase the time efficiency of the drilling fluids engineer by allowing personnel to focus in fluid engineering aspects in both conventional and demanding critical operations. It also offers broad temperature rheology testing, addressing operator's concerns to control specific rheology readings at a desired temperature (i.e. 600 r/min @ 40 degF), so that corresponding hydraulic simulations are more accurate especially in deepwater operations. These rheology and density measurements are used by real-time hydraulics monitoring software in order to improve and enhance ECD and hole-cleaning predictions, thus giving confidence for real-time decision making.

The unit has the capability to measure rheology and density of any drilling fluid sample fed to it, due to flexibility in fluid sample collection, this is important when different fluids are pumped into the well. Moreover, due to easy handling and a small footprint the SRDD unit is highly mobile, so that it can be deployed in locations where non-continuous testing is required such as mud plants or a laboratory if required. Other design features include the ability to self-clean after each test and maintenance requirements are low.

Design Features

The semi-automatic rheology and density measurement device is an affordable-robust-low maintenance unit, which is highly mobile due to its small footprint. The unit consist of an automatic co-axial viscometer which is API RP 13B R1 B1 compliant and a Coriolis mass flowmeter among other internal/external components such as feeding pump, chiller and firewall for communication.

Operation is easy and simple. The fluid is manually collected in a bottle container that is screwed onto the unit. The unit has a filter so that LCM (Lost Circulation Material) or other large particles are not pumped into the device that may interfere with the geometry of the co-axial viscometer inside the unit (**Fig.1**). Once the sample is fed, the fluid is pumped into the viscometer which has a temperature control device to warm up or cool down the sample as per the user requirements.

The unit is controlled by a user-friendly touchscreen user interface which has large buttons for easy use, it contains functions such as run rheology, clean, reports, trends, help, settings, network and diagnostics. In the user touchscreen, the sample tests needed are programmed and results are displayed as they are obtained. No manual cleaning is required as it has a self-cleaning cycle that insures the viscometer is cleaned out

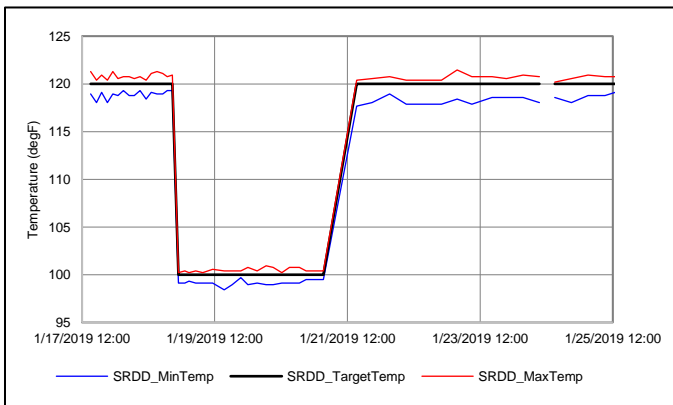
after the test is run. Frequent flushing of the unit is recommended, if a different fluid type will be tested it is advised to completely flush the system. In case the unit fails, the touch screen has a diagnostics module, where the user can see what specific part of the device is failing. If low maintenance is required, the unit is supplied and fully equipped with a spare parts kit to make any necessary repair on location.



Fig. 1. Outside view of the Semi-automatic rheology and density device. The sample container is on the right side and the touchscreen at the front.

Rheological Measurements

The unit measures API recommended rheological sets at 600, 300, 200, 100, 6, 3 r/min (60 & 30 r/min as needed in specific locations) as well as 10-sec, 10-min and 30-min gel strengths. The temperature range for each rheology set varies from 4.4 to 65.5 degC (40 to 150 degF). The temperature setpoint for rheology measurements is selected directly from the touchscreen While performing the test, the unit keeps the temperature setpoint within ± 2 degF average as per API RP 13B and displays the maximum and minimum temperature recorded during the entire test (**Graph 1**).



Graph 1. Temperature control while measuring rheology at two different temperatures.

The time demand for performing the testing depends on the temperature selected by the user. For example, it takes 10 minutes for set of rheology measurements from 600 to 3 r/min at one temperature. A full rheology measurement including 30-min gels it may take up to 60 minutes. If rheology results are desired at three different temperatures, the unit uses the same fluid sample to perform the whole test and starts ramping up from the colder temperature so that energy is efficiently used (**Fig 2**).

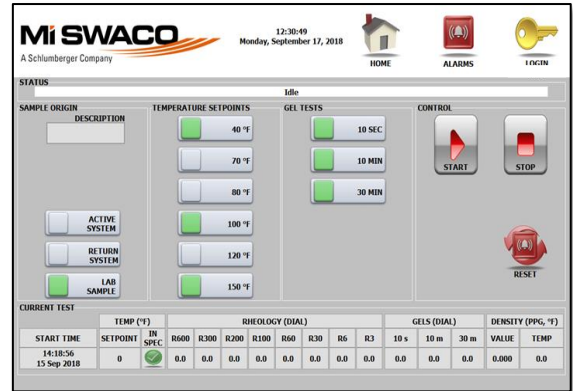
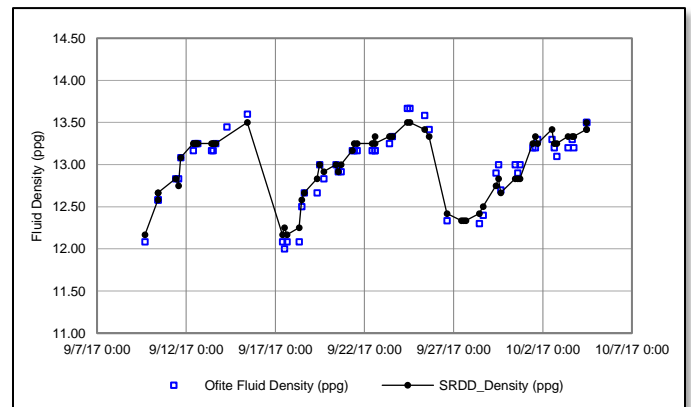


Fig. 2. User interface screen where Rheology test to be performed is selected.

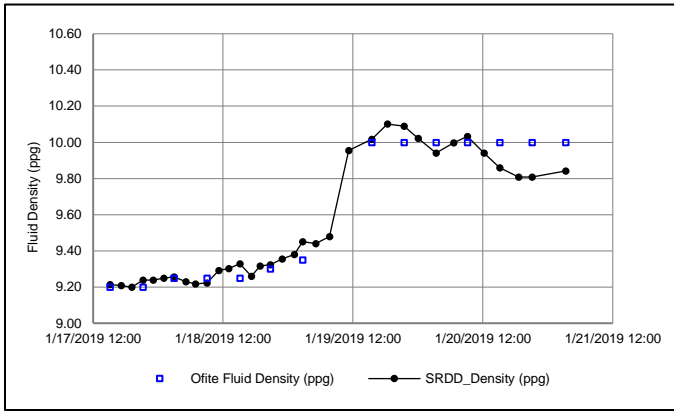
Density and Temperature Measurements

Reliable and consistent density measurements immensely enhance real-time hydraulic modeling calculations not only while drilling, but also in other activities such as fluid displacements. Accurately knowing the density of all fluids pumped during displacements allows more precise hydraulic simulations to be performed and more accurate predictions of Equivalent Circulating Density (ECD) and Standpipe Pressure (SPP).

The SRDD measures density at a reference temperature for the sample with an industry-recognized mass flowmeter that has been used in the oilfield industry for several years. This instrument provides accurate readings as shown in **Table 1**.



Graph 2. NADF density measurements comparison between SRDD and API scale.



Graph 3. WBM density measurements comparison between SRDD and API scale.

Data Accessibility

Semi-automatic measurements of rheology and density allow operators to gather data close to real time for hydraulic modeling and for service companies to maintain drilling fluid properties within pre-defined specifications.

A history of previous data measured at the wellsite can be accessed through the user interface in a report format (**Fig. 3**). The unit has the capability to display trends, so results can be checked at any time. The data gathered on location can be also displayed in an online viewer.

The data collected is transmitted via WITS 0 protocol to any acquisition system. Data can be timestamped to a WITSML server where the data can be displayed and viewed in remote location, or on mobile devices. Real-time hydraulic modeling software supporting WITS 0 or WITSML v1.3.1.1 and v1.4.1.1 can connect directly to the SRDD fed.

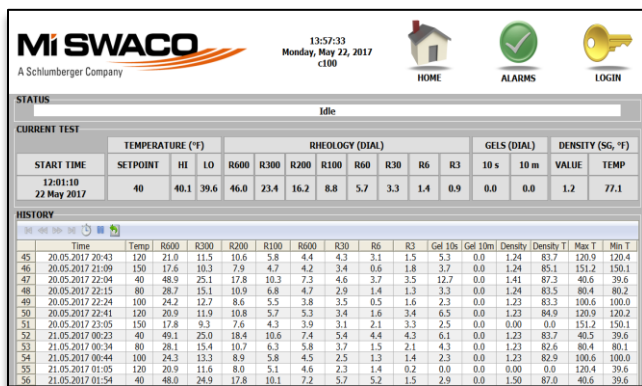


Fig. 3. User interface screen displaying rheology and density measured.

Real-time monitoring

The data transmitted via WITS 0 or WITSML protocols is used by a proprietary real-time hydraulics modeling software (**Fig. 4**). The device allows more frequent rheology and density measurements, instead of the more usual 6 intervals, ECD and hole-cleaning simulations are more completely optimized. This

allows drilling teams to make decisions in real-time, or with a faster response to changes in drilling fluid properties so that the performance of the well can be improved, and NPT can be avoided.



Fig. 4. Onshore SLB online viewer with Semi-automatic rheology, density and drilling parameters integration.

Results and Analysis

The unit has been in field trials where water, non-aqueous and synthetic drilling fluid systems have been used. The unit have been run continuously with a high degree of confidence and with very little maintenance.

In order to evaluate the accuracy of the unit, rheology and density values measured by the device were compared to the API rheology test performed by the drilling fluid specialist at the location. The sample analyzed by the drilling fluid specialist was introduced to the device at the same time in order to do a side-by-side validation. Calibration and validation processes were performed before the job so that a fair comparison is assured (**Table 2**).

Table 2 – Calibration Record for NADF

	R1 B1 Viscometer		Semi-automatic Device	
Speed	Theoretical / Dial		Theoretical / Dial	
600	204.93	201	187.7	187.4
300	103.50	102	94.8	95.4
200	69.00	68	62.6	63.8
100	34.50	34	31.6	31.7
6	2.07	2	1.9	2.0
3	1.04	1	0.9	1.0

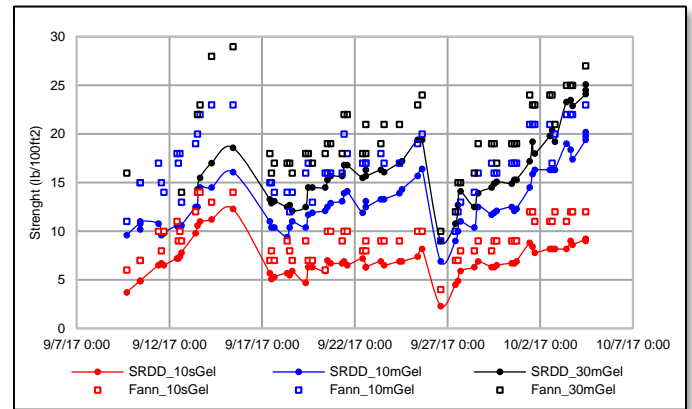
The results from three wells show that the unit was used to measure fluids with different densities and rheology which provided a wide range for validation, the ranges and accuracy of the measurements for density and rheology are shown in **Table 1** and **Table 3**.

Table 1 – Density measurements accuracy and ranges

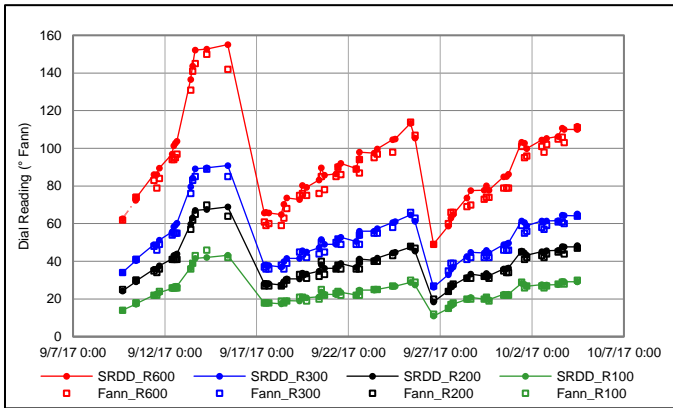
Reference (lbm/gal)	OBM	SBM	WBM
Avg. density delta	0.02	0.02	0.01
SRDD Dens. range	12.2-13.5	11.21-12.48	9.2-11.2
Fluid Scale range	12.0-13.7	11.20-12.40	9.2-11.3

Reference	NADF	SBM	WBM
Plastic Viscosity (cps)	23-64	15-25	9-15
Yield Point (lb/100ft ²)	3-26	9-26	14-34
LSYP (lb/100ft ²)	1-12	4-14	3-9

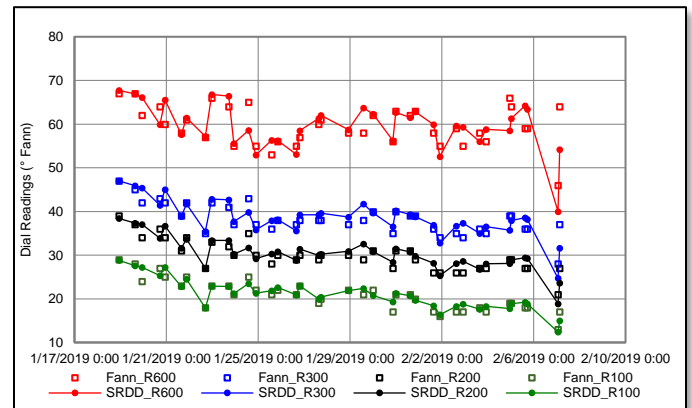
Graphs 4 to 7 show high-end, low-end rheology and gel strengths measurements of non-aqueous drilling fluids (NADF) environment. Graph 8 and 9 show the agreement in SBM, meanwhile Graph 10 shows the comparison in a WBM scenario. The accuracy of the measurements is shown in the Table 1 and Table 3.



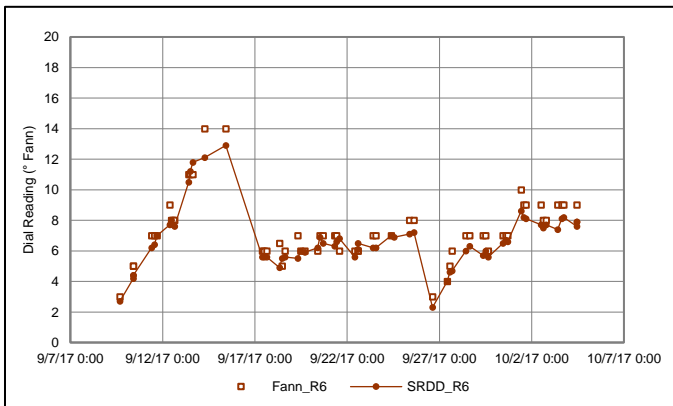
Graph 7 – 10-sec, 10-min and 30-min Gel Strengths in NADF obtained from the SRDD and compared to API readings obtained by the drilling fluid specialist on location.



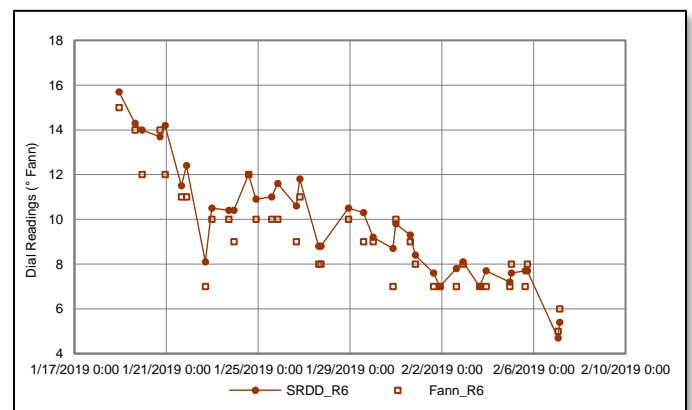
Graph 4 – High-end rheology in NADF obtained from the SRDD and compared to API readings obtained by the drilling fluid specialist on location.



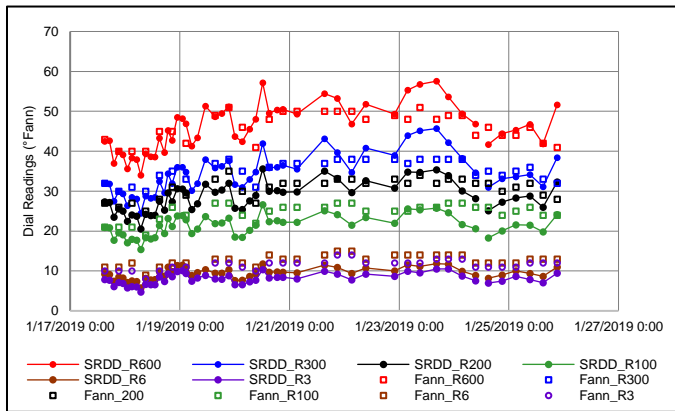
Graph 8 – High-end rheology in SBM obtained from the SRDD and compared to API readings obtained by the drilling fluid specialist on location.



Graph 5 – 6-rpm dial readings in NADF obtained from the SRDD and compared to API readings obtained by the drilling fluid specialist on location.



Graph 9 – 6-rpm dial readings in SBM obtained from the SRDD and compared to API readings obtained by the drilling fluid specialist on location.



Graph 10 – Rheology readings in WBM obtained from the SRDD and compared to API readings obtained by the drilling fluid specialist on location.

Overall rheology and gel strengths in all three environments show a good agreement compared to Fann viscometer readings with maximum standard deviation of 3.5 for the high-end rheology and no higher than 1.2 for low-end rheology; complete statistics are shown in tables **Table 4**, **5** and **6**.

Table 4 – Fitting statistics for NADF

Reference	Stand. Dev.	Stand. Error %
R600	3.28	0.42
R300	2.13	0.27
R200	1.53	0.20
R100	0.99	0.13
R6	0.58	0.08
R3	0.56	0.07
10s Gel	1.27	0.16
10m Gel	2.60	0.33
30m Gel	2.48	0.35

Table 5 – Fitting statistics for SBM

Reference	Stand. Dev.	Stand. Error %
R600	3.49	0.57
R300	2.00	0.33
R200	1.62	0.26
R100	1.13	0.18
R6	0.69	0.11
R3	0.74	0.12
10s Gel	1.08	0.14
10m Gel	5.12	0.66

Table 6 – Fitting statistics for WBM

Reference	Stand. Dev.	Stand. Error %
R600	3.39	0.62
R300	3.29	0.60
R200	2.46	0.45
R100	2.05	0.37
R6	1.15	0.21
R3	1.14	0.21

10s Gel	1.71	0.31
10m Gel	2.51	0.46

Conclusions

The semi-automatic rheology and density device requires the sample to be introduced to the unit, the measuring process and cleaning are automatic. Results show the following benefits:

- Good agreement between the semi-automatic measuring device and manual API measurements with high confidence levels.
- Improved and semi-continuous measurement of rheology and density provides enhanced quality assurance of measurements over a range of temperatures for critical operations such as deepwater.
- The unit offers flexibility in sample collection points, especially for knowing fluids pumped into the well during displacements.
- The unit is highly mobile due to its small footprint, it is easy to install and to operate.
- Industry standard communication protocols allow the unit to stream data without any human interaction, so that information can be easily accessed in remote locations.
- Efficient spending; less labor; lower cost; better product usage are additional benefits that provide an affordable option for land fast-drilling operations where cost-effective solutions are required.
- Improves and enhances hydraulics modeling and allows faster response to changes in drilling fluids.
- Reduces contact with drilling fluids hence decreased exposure to harmful chemical risk.

Acknowledgments

The authors thank both M-I SWACO for supporting the efforts and for giving permission to publish this work. They also thank the engineering team and field personnel who contributed to the development and deployment of the device.

Nomenclature

API	= American Petroleum Institute
cps	= Centipoises
ECD	= Equivalent Circulating Density
lb/100ft ²	= Pounds per square foot
lbm/gal	= Pounds per gallon
HSE	= Health, safety and environment
LCM	= Lost Circulation Material
LSYP	= Low-shear Yield Point
NADF	= Non-aqueous Drilling Fluid
OBM	= Oil-based Mud
NPT	= Non-productive time
PV	= Plastic Viscosity
r/min	= revolutions per minute
SBM	= Synthetic-based Mud
sg	= Specific gravity
SLB	= Schlumberger

SPP = *Standpipe Pressure*
WBM = *Water-based Mud*
WITS = *Wellsite Information Transfer Specification*
WITSML = *WITS Markup Language*
YP = *Yield Point*

References

1. API RP 13B-1: “Recommended Practice for Field Testing Water-based Drilling Fluids”, American Petroleum Institute, fourth edition, March, 2009.
2. API RP 13B-2: “Recommended Practice for Field Testing Oil-based Drilling Fluids”, American Petroleum Institute, fifth edition, April 2014.
3. Ronaes, E., Fossdal, T. and Stock, T.: “Real-Time Drilling Fluid Monitoring Analysis – Adding to Integrated Drilling Operations” IADC/SPE 151459, IADC/SPE Drilling Conference and Exhibition, San Diego, California, USA, March 6-8, 2012.
4. Dotson, A., Mahajan L., Sandeep D., K., Landry, A. and Eiland, E.: “Improvements in Automatic Continuous Measurement of Drilling Fluid Properties” SPE-188022-MS, Society of Petroleum Engineers, Dammam, Saudi Arabia, April 24-27, 2017.
5. Vajargah, A. K., Sullivan, G. and Van Oort, E.: “Automatic Fluid Rheology and ECD Magament”, SPE-180331-MS, Society of Petroleum Engineers, Galveston, Texas, USA, September 14-15, 2016.
6. Saasen, A., Omland, T.H., Ekrene, S.J. et al.: “Automatic Measurement of Drilling Fluid and Drill-Cuttings Properties, SPE-112687-MS, Society of Petroleum Engineers, Orlando, Florida, USA, December 2009.