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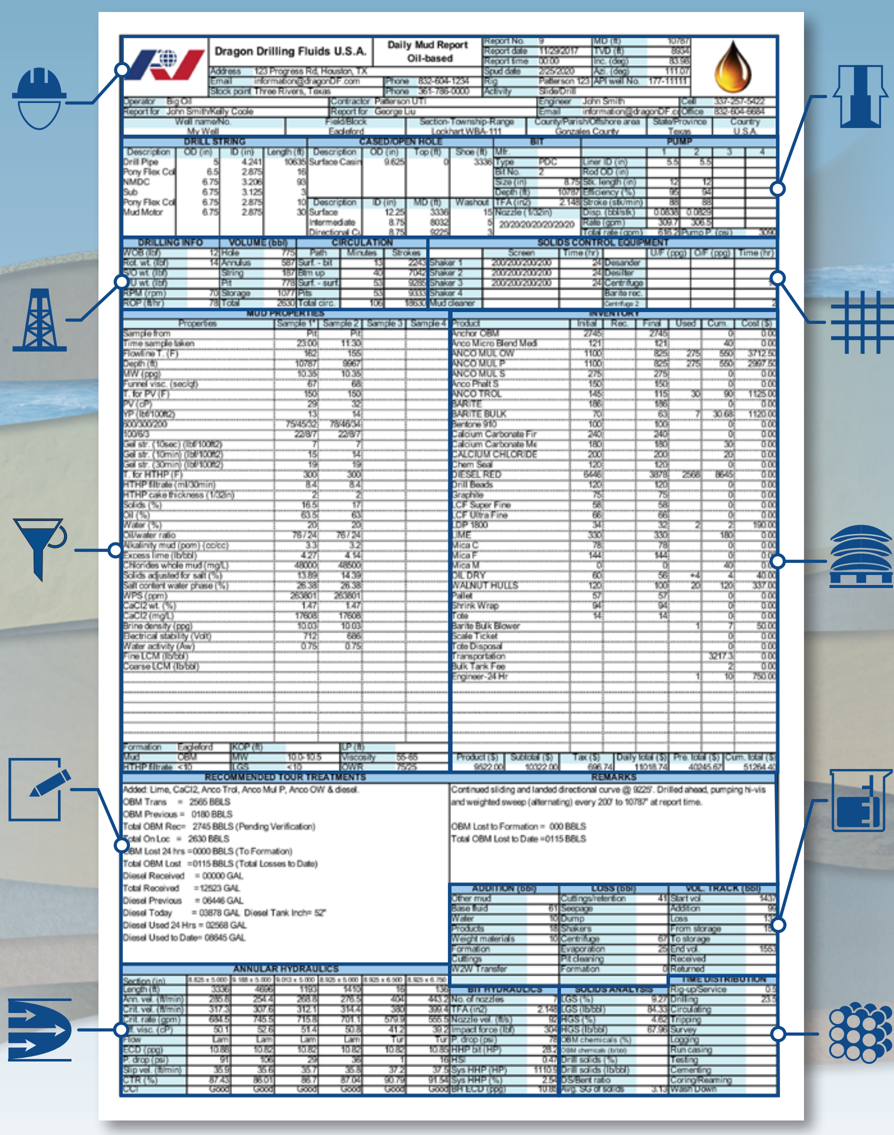
WHITE PAPER

How to Read a Daily Mud Report

A Guide for Mud Engineers



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I. Introduction

Drilling fluids are a vital part of drilling operations. Figure 1 lists the functions of drilling fluids.

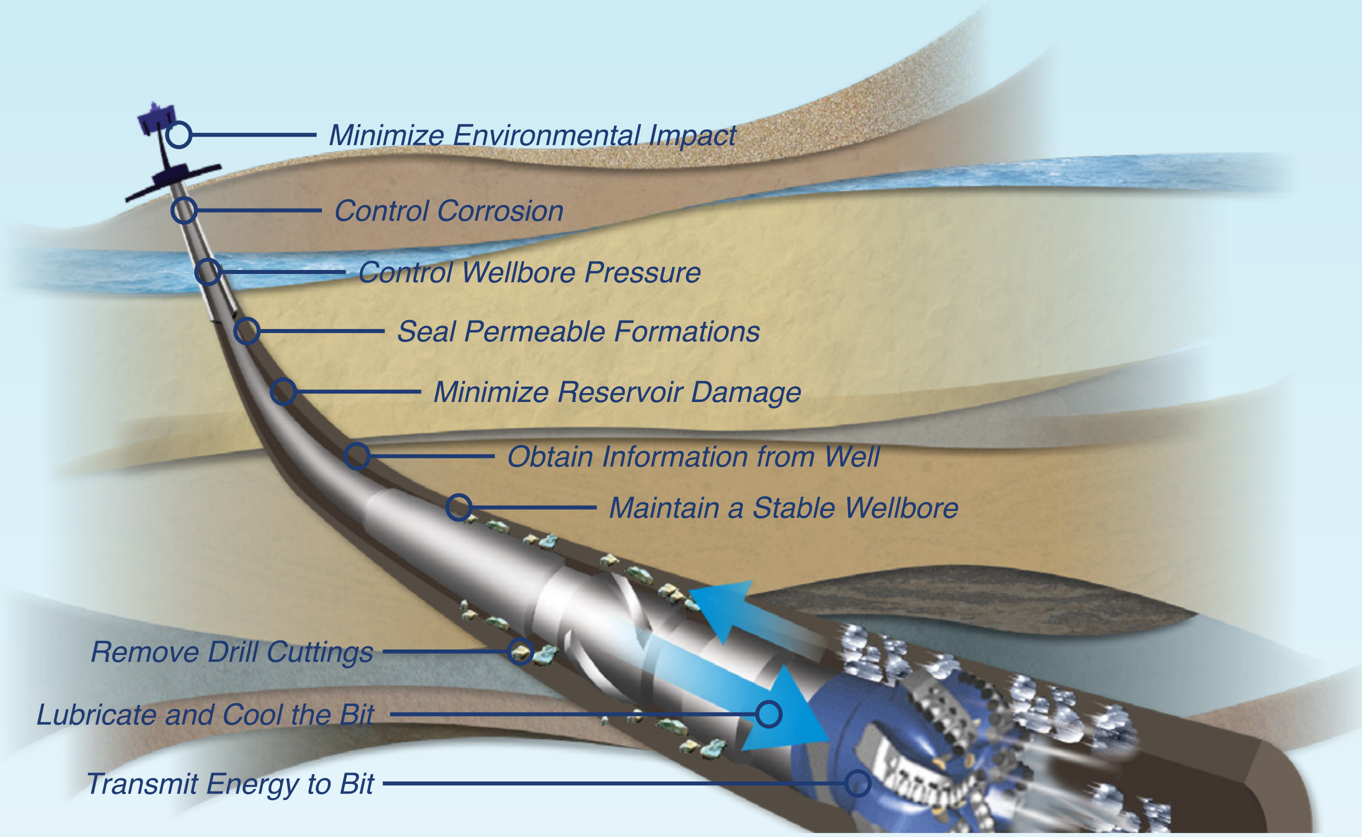

Figure 1: Functions of Drilling Fluids

To achieve these goals, certain additives are incorporated into the mud to control its properties. It is the mud engineer's responsibility to ensure that any new mud that is produced meets the required specifications.

Just as we do annual physical checkups to identify potential problems and to improve our overall health, mud engineers check mud properties and other related data, but more frequently, on a daily basis. Computer models are often used to keep track of chemical product usage, cost and inventory, perform solids analysis and calculate hydraulics and chemical concentrations. The results of the checkup and calculations are documented in daily mud reports.

From mud weight to chemical cost, getting a mud report wrong has very real consequences. But daily mud reports, is a primary method of communication between drilling fluid companies and operators, use unique date-intensive format and contain many technical terms. This article will describe ten main sections of a typical daily mud report, and explain drilling mud terminology contained in them. It's meant to be a helpful guide on how to read and understand daily mud reports.

II. Breakdown

Here is a breakdown of a daily mud report.

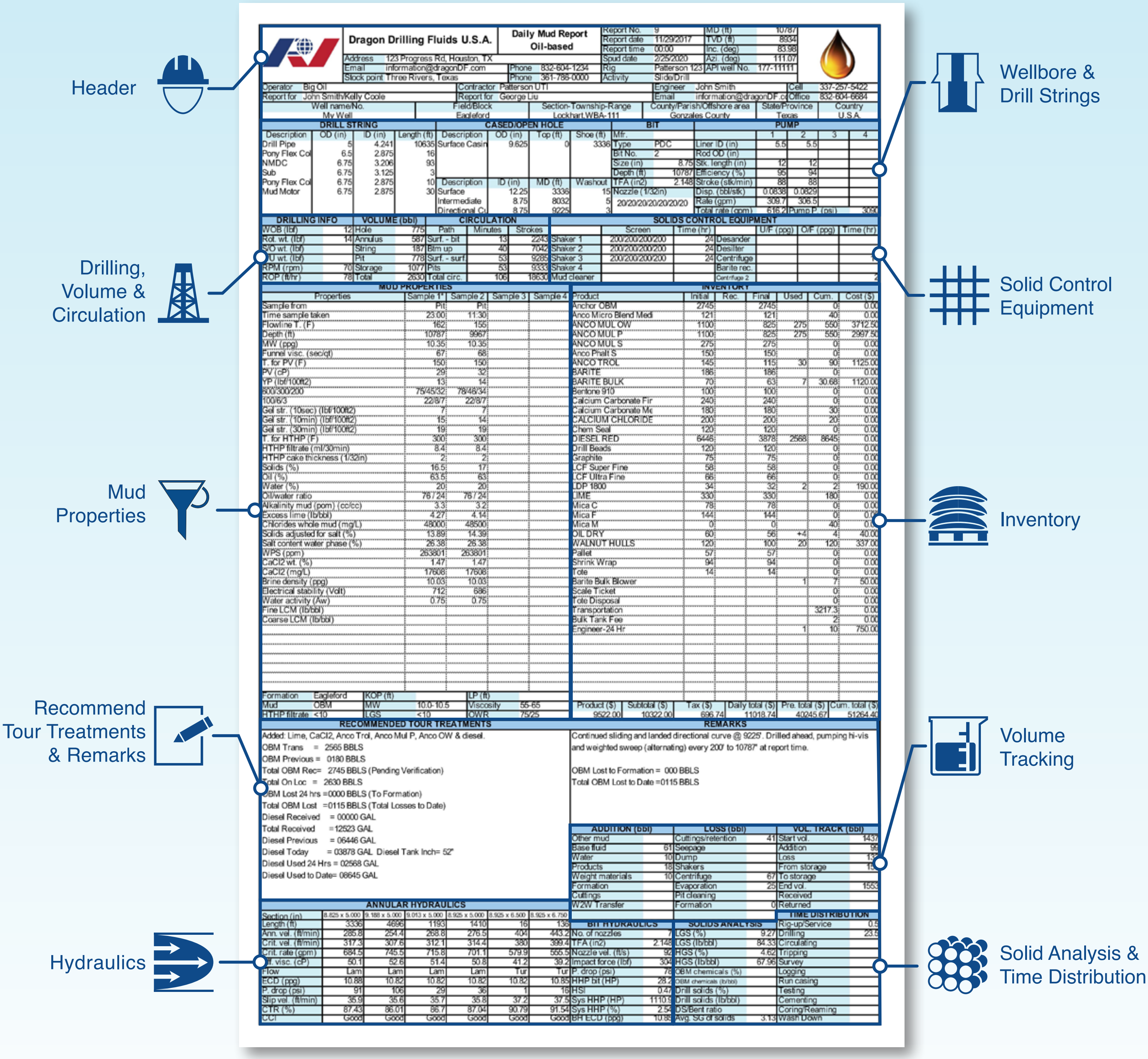

Figure 2: Anatomy of a Daily Mud Report

1. Header

Dragon Drilling Fluids U.S.A.		Daily Mud Report Oil-based		Report No.	9	MD (ft)	10787
				Report date	11/29/2017	TVD (ft)	8934
				Report time	00:00	Inc. (deg)	83.98
Address	123 Progress Rd, Houston, TX			Spud date	2/25/2020	Azi. (deg)	111.07
Email	information@dragonDF.com	Phone	832-604-1234	Rig	Patterson 123	API well No.	177-11111
Stock point	Three Rivers, Texas	Phone	361-786-0000	Activity	Slide/Drill		

Operator	Big Oil	Contractor	Patterson UTI	Engineer	John Smith	Cell	337-257-5422
Report for	John Smith/Kelly Coole	Report for	George Liu	Email	information@dragonDF.co	Office	832-604-6684

Well name/No.	Field/Block	Section-Township-Range	County/Parish/Offshore area	State/Province	Country
My Well	Eagleford	Lockhart,WBA-111	Gonzales County	Texas	U.S.A.

The header section of a daily mud report contains information about the location, status of the well, and other pertinent data such as contact information of on-site personnel. Here are some highlights of fields in the header section.

Mud Type indicates the type of drilling mud used. There are 3 types of mud: (1) Water-based muds are the most commonly used of the mud systems. The base fluid may be fresh water, seawater, brine, saturated brine, or a formate brine. (2) Oil-based muds are formulated with diesel, mineral oil, or low-toxicity linear olefins and paraffins. (3) Synthetic-based muds are non-aqueous, water-internal (invert) emulsion muds in which the external phase is a synthetic fluid rather than an oil. Synthetic-based muds were developed to make drilling muds more environmentally acceptable for offshore use. Different mud types determine the listing of mud property input and subsequent calculation procedures.

Report No. is a default auto-incrementing reports number that increments every time users create a new report.

Report Time is the time when a user generates a report. Since multiple reports can be generated daily, report time is used to distinguish among them.

Spud Date is generally the date the ground has been first penetrated for the purposes of drilling a well.

MD is the measured depth of the wellbore.

TVD is the true vertical depth of the wellbore. It is the vertical distance from the current well bottom to a point at the surface, usually the elevation of the RKB.

Inc. is the inclination angle at the current well bottom.

Azi. is the azimuth angle at the current well bottom.

Operator is an oil and gas exploration and production organization that legally performs all the upstream operations. It is normally the owner of the right to drill or produce a well.

Contractor is the company hired by the operator to provide a drilling rig and crew to conduct drilling operations. Operating companies typically do not own drilling rigs or employ full-time drilling crews.

API Well # is a unique, permanent, numeric identifier assigned to each well drilled in the United States. The standard number is established by the American Petroleum Institute (API).

2. Wellbore and Drill Strings

DRILL STRING			
Description	OD (in)	ID (in)	Length (ft)
Drill Pipe	5	4.241	10635
Pony Flex Co	6.5	2.875	16
NMDC	6.75	3.206	93
Sub	6.75	3.125	3
Pony Flex Co	6.75	2.875	10
Mud Motor	6.75	2.875	30

CASED/OPEN HOLE			
Description	OD (in)	Top (ft)	Shoe (ft)
Surface Cas	9.625	0	3336
Description	ID (in)	MD (ft)	Washout
Surface	12.25	3336	15
Intermediate	8.75	8032	5
Directional C	8.75	9225	3

BIT	
Mfr.	
Type	PDC
Bit No.	2
Size (in)	8.75
Depth (ft)	10787
TFA (in2)	2.148
Nozzle (1/32in)	
20/20/20/20/20/20/20	

PUMP				
	1	2	3	4
Liner ID (in)	5.5	5.5		
Rod OD (in)				
Stk. length (in)	12	12		
Efficiency (%)	95	94		
Stroke (stk/min)	88	88		
Disp. (bbl/stk)	0.084	0.083		
Rate (gpm)	309.7	306.5		
Total rate (gpm)	616.2	Pump P. (psi)		3090

The Wellbore and Drill Strings Section includes the BHA, cased and open holes, bit and pump information.

Cased hole refers to the wellbore section surrounded by the casing, which is a steel pipe lowered and cemented into a wellbore to stabilize the borehole. Open hole is the drilled section without casing. The hole and pipe dimensions determine the interior, annular volumes. Together with the active pit volume, a computer model can keep track of chemical concentrations.

TFA is the total flow area of the nozzles on a bit. It is used to calculate the bit hydraulics.

Pumps are used to circulate fluids and are essential for cooling the drill bit and carrying cuttings from the hole. Up to 4 pumps can be selected to circulate mud.

Rate in Pump Section is the flow rate. It is used to calculate pump pressure and downhole hydraulics.

3. Drilling, Volume and Circulation

DRILLING INFO		VOLUME (bbl)		CIRCULATION		
WOB (lbf)	12	Hole	775	Path	Minutes	Strokes
Rot. wt. (lbf)	14	Annulus	587	Surf. - bit	13	2243
S/O wt. (lbf)		String	187	Btm up	40	7042
P/U wt. (lbf)		Pit	778	Surf. - surf.	53	9285
RPM (rpm)	70	Storage	1077	Pits	53	9333
ROP (ft/hr)	78	Total	2630	Total circ.	106	18630

WOB (Weight on Bit) is the downward force exerted on the formation by the drill bit.

Rot. Wt. is the Rotating Weight or Free Rotating Weight of a drill pipe, when the drill string is rotating off bottom and is not moving up or down.

SO Wt. is the Slack-Off Weight when lowering the pipe into a well.

PU Wt. is the Pick Up Weight when pulling the pipe out of the hole.

RPM (Revolutions Per Minute) is the number of rotations the bit makes in a minute.

ROP (Rate of Penetration) is length drilled in a unit of time in term of ft/hr.

The Circulation Table contains the minutes and number of pump strokes required for mud to pass certain flow paths.

4. Solid Control Equipment

SOLIDS CONTROL EQUIPMENT						
	Screen	Time (hr)		U/F (ppg)	O/F (ppg)	Time (hr)
Shaker 1	200/200/200/200	24	Desander			
Shaker 2	200/200/200/200	24	Desilter			
Shaker 3	200/200/200/200	24	Centrifuge			11
Shaker 4			Barite rec.			
Mud cleaner			Centrifuge 2			2

A mud report tracks the number of running hours of various solid control equipment, screen consumption, screen sizing, input and output slurries.

5. Mud Properties

MUD PROPERTIES				
Properties	Sample 1*	Sample 2	Sample 3	Sample 4
Sample from	Pit	Pit		
Time sample taken	23:00	11:30		
Flowline T. (F)	162	155		
Depth (ft)	10787	9967		
MW (ppg)	10.35	10.35		
Funnel visc. (sec/qt)	67	68		

The physical and chemical properties of a drilling fluid are perhaps the only variables of the entire drilling process that can be altered rapidly for improved drilling efficiency. That is the reason why these properties usually receive the greatest attention, together with the cost of chemicals, in a daily mud report. These mud properties are used to analyze solids and calculate hydraulics. There are 4 columns in this table. Each column denotes one sample of mud taken from a different source or at a different point of time.

Here are some primary characteristics of a drilling fluid.

Flowline T. (°F) is the temperature of the returned mud in the flowline. An increase in flowline temperature when used with other indicators, can show the location of an overpressure zone.

Depth (ft) indicates the current measured depth (MD). MD is the total length of the wellbore measured along the actual well path. TVD is measured vertically from the surface down to a certain target down hole.

Mud Weight (MW) (ppg) is the mass per unit volume of a drilling fluid. Mud weight controls hydraulic pressure of a wellbore and prevents unwanted flow into the well. Mud weight is also used to prevent casing and open hole collapse. Excessive mud weight results in lost circulation.

Funnel Viscosity (sec/qt) is defined as seconds for one quart of mud to flow through a Marsh funnel. This is not a true viscosity, but serves as a qualitative measure of how thick the mud is.

T. for PV (°F): The temperature at which the plastic viscosity is measured.

Plastic Viscosity (PV) (cP) represents the viscosity of a mud when the fluid is characterized by the mathematics of the Bingham plastic model.

Yield Point (YP) (lbf/100 ft^2) is a measure of resistance of initial flow of fluid or the stress required in order to move the fluid. In the Bingham plastic model, YP is the shear stress when shear rate is zero.

Gel Strength (10 sec, 10 min, 30 min) (lbf/100 ft^2) are the shear stress measured at low shear rate after a mud has set quiescently for a period of time (10 sec. and 10 min. and 30 min.). The strength is a function of suspended solids, solid contents, temperature, chemical content and time. They are also measured with the rotating viscometer.

API Filtrate (ml/30 min) is the filtrate volume after 30 min. in API fluid loss test. API fluid loss test measures static filtration behavior of water-based mud at room temperature and 100 psi differential pressure.

API Cake Thickness (1/32 in) is a buildup of mud solids during an API fluid loss test.

T. for HTHP (°F): Temperature for high temperature and high pressure fluid loss test. HTHP filtration test is used to measure static filtration behavior of water-based mud or oil-based mud at elevated temperature. Although the test has the ability to simulate downhole temperature conditions, it does not simulate downhole pressure. Total pressure in a cell should not exceed 700 psi or 4900 kPa and the differential pressure across the filter medium is specified as 500 psi or 3500 kPa.

HTHP Filtrate (ml/30 min) is the filtrate volume after 30 min., in HTHP fluid loss test.

HTHP Cake Thickness (1/32 in) is a buildup of mud solids during an HTHP fluid loss test.

Solids (%) is the fraction of solid in the mud. The solid, such as barite or hematite, is used to increase the density of mud. Usually, solids (both high and low gravity solids) are reported as lbm/bbl or vol %.

Oil (%) is the fraction of oil in the mud. In a water-based mud, water is the continuous phase of the mud. Oil can also be presented in a small amount, but will typically not exceed the amount of the water, so that the mud will retain its character as a water-continuous-phase material.

Water (%) is the fraction of water in the mud. In a water-based mud, water is usually more than 50% of the entire composition. Fresh water, seawater, and salt water are the common sources to make water based mud.

Sand Content (%) is the fraction of solids in a mud estimated by sand test. The sand content in a mud system is estimated by wet screen analysis using a 200-mesh screen. The test measures the percentage of solids above 74 mm.

Methylene blue (MBT Capacity) (lb/bbl) is measured by MBT test to determine the concentration of reactive clays present in a water-base drilling fluid based on the amount of methylene blue dye absorbed by the sample. Commercial clays such as bentonite and formation solids such as shales adsorb methylene blue and contribute to the methylene blue capacity of the mud.

pH indicates how acidic or basic a mud is.

Mud Alkalinity (Pm) (ml), Filtrate Alkalinity (Pf) (ml), Filtrate Alkalinity (Mf) (ml): P-M test is a common method to test the alkalinity in the water based mud. Mud alkalinity and filtrate alkalinity are results of the presence of bicarbonate, carbonate, and hydroxides, of calcium magnesium, sodium and other cations. Alkalinity is determined by titrating a sample with standard sulfuric acid with a pH indicator to determine the endpoint.

Calcium (mg/L), Total hardness (mg/L): Total hardness of water or mud filtrate is due to the presence of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions.

Chlorides (mg/L) is determined by the salty of water-based mud. Chlorides acts as a contaminant in freshwater mud systems. Salt contamination can cause an increase in viscosity, gel strengths, and fluid loss.

Excess Lime (lb/bbl): Lime is the common name for $Ca(OH)_2$. It is a source of calcium and alkalinity. Excess lime in mud is used as an alkalinity buffer. Excess lime (lb/bbl) = 0.26 [Pm - (Fw x Pf)], where $F_w = \frac{\text{\% of water volume}}{100}$.

K^+ (mg/L): Potassium muds increase the drilling efficiency in water sensitive shales and improve the stability of the formation, especially hard and brittle shales. K^+ can help make the cuttings together, minimizing dispersion into finer particles. KCl is the most common sources for K^+.

Make Up Water: Chlorides (mg/L): Chlorides in make-up water. Make-up water is the water added to maintain or dilute a water-based mud. Make-up water volume is an important parameter in a material balance check on solids content and solids removal efficiency for a mud system.

Solids Adjusted for Salt (%): Solid used for the adjustment of salinity in the mud. Sodium chloride (NaCl) is used for the source of salt.

Fine LCM (lb/bbl), Coarse LCM (lb/bbl): Lost circulation materials (LCM) are used in the mitigation and remediation of seepage, partial, or complete loss of drilling fluid from the hole into rock formation. Fine lost circulation materials (LCM) can pass through 20-mesh screen. On the contrary, coarse LCM cannot pass through 20-mesh screen.

For Oil- and Synthetic-Based Muds:

Oil/Water Ratio: O/w.= $\frac{\text{volume percentage of oil}}{\text{volume percentage of water}}$

Alkalinity Mud (pom) (cc/cc) indicates the alkalinity level of an oil-based mud. Alkalinity of the mud and filtrate is a result of the presence of bicarbonate, carbonate, and hydroxides, of calcium magnesium, sodium and other cations.

Chlorides Whole Mud (mg/L) is the amount of chlorides in fresh mud for whole mud dilution. Whole mud dilution is a process for the replacement of the lost volume with fresh mud. This method is an efficient way to remove colloidal size particles.

Salt Content Water Phase (%) is the content of salt in water phase of mud. If salt content of the water phase is too high, water is pulled out of the formation into the mud.

Water phase salinity (WPS) (ppm) is an important factor to show the activity level of salt in oil-based mud. Calcium chloride ($CaCl_2$) and sodium chloride (NaCl) are two common chemical additives to be used.

$CaCl_2$ Wt. (%): $CaCl_2 \text{ wt.}(\%) = \frac{\text{weight of } CaCl_2}{\text{weight of mud}}$. $CaCl_2$ (mg/L) is the amount of $CaCl_2$ in mg per liter of mud. $CaCl_2$ brine is a crucial additive in oil and synthetic based mud because of its improvement of wellbore stability in water-sensitive shale zones.

Brine Density (ppg): $\text{Brine density (ppg)} = \frac{\text{mass of brine}}{\text{volume of brine}}$, usually, the brine is the emulsified $CaCl_2$ solution in oil and synthetic based mud.

Electrical Stability (Volt) is the voltage of the current flowing in the mud represented by ES (Electrical Stability) value. The ES value is tested by an electrical stability tester kit. If ES value is low, the emulsion of the oil based mud is low.

Water Activity (Aw) is the water vapor pressure generated by the free water in the mud. The mathematic formula is $Aw = \frac{\text{vapor pressure of the water in the mud at °C}}{\text{vapor pressure of pure water at °C}}$. It is used to determine the mud quality when the salts in an oil based mud are too complicated to analysis (usually in field work). Electrohygrometer is employed to measure the Aw value.

6. Inventory

INVENTORY						
Product	Initial	Rec.	Final	Used	Cum.	Cost ($)
Anchor OBM	2745		2745		0	0.00
Anco Micro Blend Medi	121		121		40	0.00
ANCO MUL OW	1100		825	275	550	3712.50
ANCO MUL P	1100		825	275	550	2997.50
ANCO MUL S	275		275		0	0.00
Anco Phalt S	150		150		0	0.00

Keeping track of inventory is key to cost containment, supply reordering and for getting the job done. This table tracks the inventory and cost of all products used, services and engineering. Individual product cost, daily total cost, previous total and cumulative total are calculated and displayed at the end of this inventory table.

7. Recommend Tour Treatments and Remarks

RECOMMENDED TOUR TREATMENTS	REMARKS
Added: Lime, CaCI2, Anco Trol, Anco Mul P, Anco OW & diesel.	Continued sliding and landed directional curve @ 9225'. Drilled ahead, pumping hi-vis
OBM Trans = 2565 BBLS	and weighted sweep (alternating) every 200' to 10787' at report time.
OBM Previous = 0180 BBLS	
Total OBM Rec= 2745 BBLS (Pending Verification)	OBM Lost to Formation = 000 BBLS
Total On Loc = 2630 BBLS	Total OBM Lost to Date =0115 BBLS

The table of recommend tour treatments and remarks contains the comments a mud engineer types in the input window.

8. Volume Tracking

ADDITION (bbl)		LOSS (bbl)		VOL. TRACK (bbl)	
Other mud		Cuttings/retention	41	Start vol.	1437
Base fluid	61	Seepage		Addition	99
Water	10	Dump		Loss	133
Products	18	Shakers		From storage	150
Weight materials	10	Centrifuge	67	To storage	
Formation		Evaporation	25	End vol.	1553
Cuttings		Pit cleaning		Received	
W2W Transfer		Formation	0	Returned	

This table tracks how much volume is added (Additions Volume) and how much mud is lost (Losses Volume), plus how much is added from external sources (e.g., from storage) and how much is returned to an external source. The volume should balance before the engineer can move forward and create the next report. By this process, we ensure accurate volume tracking and chemical concentrations each and every day while drilling.

9. Hydraulics

ANNULAR HYDRAULICS							BIT HYDRAULICS	
Section (in)	8.825 x 5.000	9.188 x 5.000	9.013 x 5.000	8.925 x 5.000	8.925 x 6.500	8.925 x 6.750	No. of nozzles	7
Length (ft)	3336	4696	1193	1410	16	136	TFA (in2)	2.148
Ann. vel. (ft/min)	285.8	254.4	268.8	276.5	404	443.2	Nozzle vel. (ft/s)	92
Crit. vel. (ft/min)	317.3	307.6	312.1	314.4	380	399.4	Impact force (lbf)	304
Crit. rate (gpm)	684.5	745.5	715.8	701.1	579.9	555.5	P. drop (psi)	78
Eff. visc. (cP)	50.1	52.6	51.4	50.8	41.2	39.2	HHP bit (HP)	28.2
Flow	Lam	Lam	Lam	Lam	Tur	Tur	HSI	0.47
ECD (ppg)	10.88	10.82	10.82	10.82	10.82	10.85	Sys HHP (HP)	1110.9
P. drop (psi)	91	106	29	36	1	16	Sys HHP (%)	2.54
Slip vel. (ft/min)	35.9	35.6	35.7	35.8	37.2	37.5	BH ECD (ppg)	10.85

The Annular Hydraulics Table displays the calculated annular velocities in each annular sections. The bit hydraulics table shows the hydraulic energy transmitted through bit to the bottom of the hole.

Critical Vel. (ft/min) is the speed at which the flow of the circulating mud changes from smooth, or "laminar," to turbulent. The critical velocity depends on multiple variables, but it is the Reynolds number that characterizes the flow of the liquid through a pipe or annulus as either laminar or turbulent. Critical Rate (gpm) is the corresponding flow rate.

Equivalent Circulating Density (ECD) (ppg) is the effective density that combines current mud density and frictional pressure losses in the annulus above the point being considered. It is an important parameter in avoiding kicks and losses.

Slip velocity (ft/min) is the velocity of cutting that falls down due to gravitation. In order to effectively clean the hole, the effect of mud flow upward direction and mud properties must be greater than cutting slip velocity. Otherwise, cutting will fall down and create cutting bed.

Jet Impact Force (lbf) is the force generated by the jetted fluid through bit nozzles against the hole bottom.

Bit Hydraulic Horsepower (HHP) is a measure of the energy per unit of time that is being expended across the bit nozzles. It is calculated with the equation HHP=Delta P*Q/1714, where Delta P (psi) stands for pressure drop across nozzles, Q (gpm) stands for flow rate.

HSI is the hydraulic horsepower per square inch at the hole bottom.

Bit hydraulic horsepower, impact force, and nozzle velocity are common criteria for optimizing jet-bit hydraulics.

10. Solids Analysis and Time Distribution

SOLIDS ANALYSIS		TIME DISTRIBUTION	
LGS (%)	9.27	Rig-up/Service	0.5
LGS (lb/bbl)	84.33	Drilling	23.5
HGS (%)	4.62	Circulating	
HGS (lb/bbl)	67.96	Tripping	
OBM chemicals (%)		Survey	
OBM chemicals (lb/bbl)		Logging	
Drill solids (%)		Run casing	
Drill solids (lb/bbl)		Testing	
DS/Bent ratio		Cementing	
Avg. SG of solids	3.13	Coring/Reaming	
		Wash Down	

Soluble and insoluble solids in drilling muds are referred to as solids content. They include chemical additives, weighting agents and drill cuttings. The concentration of these solids increases while drilling. There are following three types of solid content.

Soluble Solids are mainly salts that are added to the drilling mud to stabilize the well and stimulate the formation of the filter cake.

Low Gravity Solids (LGS) is a type of drilling mud solid, having a lower density than the barite or hematite that is used to weight up a drilling fluid. LGS includes drill cuttings and the added bentonite clay. Solids are reported in terms of lbm/bbl or vol.%. Low-gravity solids are normally assumed to have a density of 2.60 g/cm^3.

High Gravity Solids (HGS) are dense solids, such as barite, calcium carbonate or hematite, which are added to increase mud density, also known as weighting material. The specific gravity of water is 1.00, barite is 4.20, and hematite 5.505 g/cm^3.

As drilling continues, more drill cuttings and other additives are accumulated in the mud, solid fraction always increases and it gradually deteriorates mud properties. To keep optimal mud performance, a general rule of thumb is to have the drill solids lower than 6-7% by volume or approximately 55 – 60 lb/bbl.

The Time Distribution Table keeps track of time spent in various activities.

III. Conclusion

Accurate and timely dissemination of the data captured in a daily mud report keeps operations on track and on budget, it also keeps the drilling fluid company and the operator on the same page. Archimedes once said: “The shortest distance between two points is a straight line.” In our case, the shortest distance between a drilling fluid company and an operator, is a daily mud report. We hope this guide will enhance your knowledge on drilling mud and make the ride of this short distance smooth and pleasant.

At PVI, we provide the most advanced mud reporting software MUDPRO to ensure quality data is collected, analyzed, and distributed to all parties.

For more information, please contact PVI at:

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