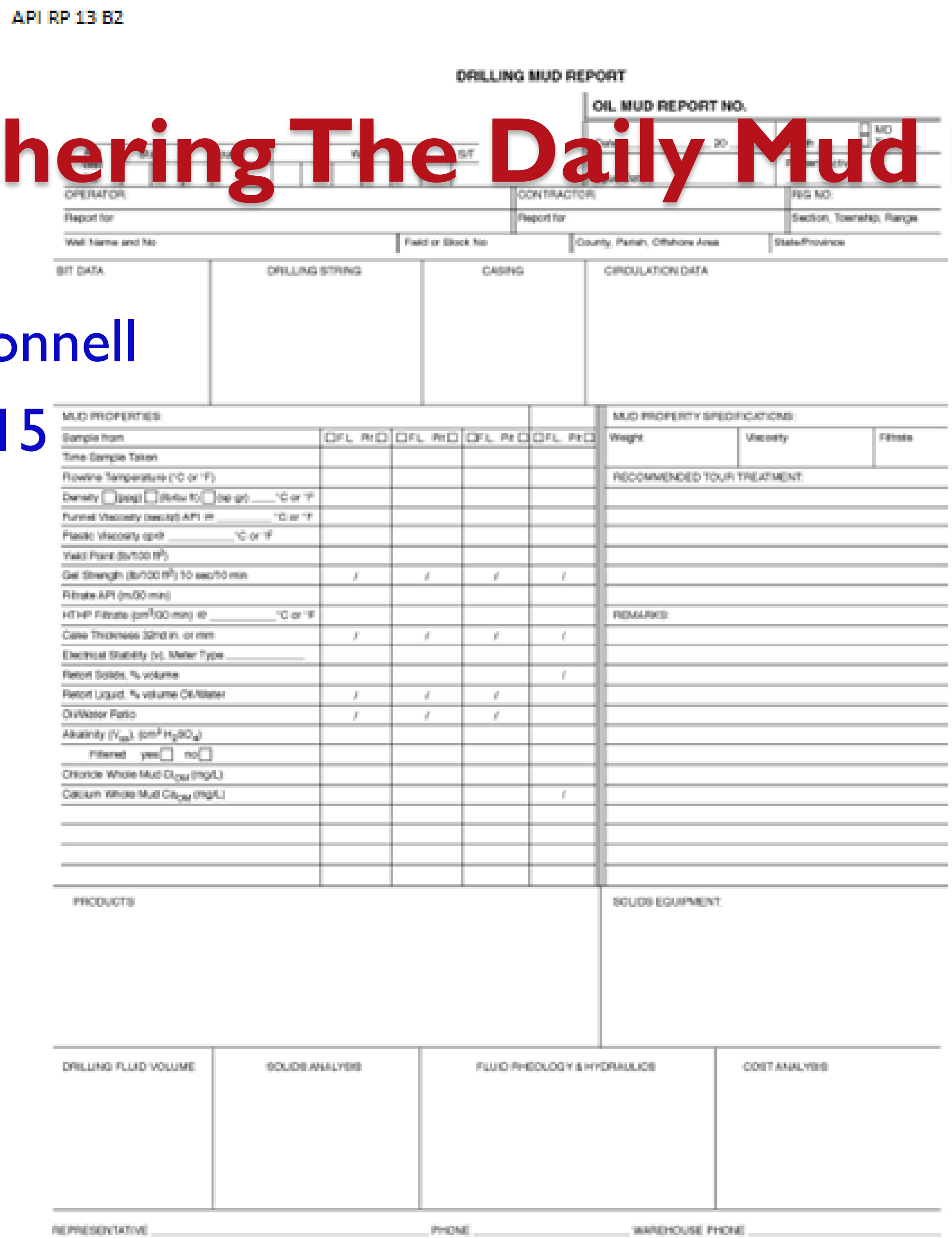
Deciphering The Daily Mud Report

Rusty Connell

April 2015


API RP 13 B2

DRILLING MUD REPORT

OIL MUD REPORT NO.

OPERATOR | CONTRACTOR | RIG NO.

Report for | Report for | Section, Township, Range

Well Name and No. | Field or Block No. | County, Parish, Offshore Area | State/Province

BIT DATA | DRILLING STRING | CASING | CIRCULATION DATA

MUD PROPERTIES | MUD PROPERTY SPECIFICATIONS

Sample from | Weight | Viscosity | Filtrate

Time Sample Taken

Flowline Temperature (°C or °F) | RECOMMENDED TOUR TREATMENT

Density

Funnel Viscosity (sec/qt) API @ °C or °F

Plastic Viscosity cp @ °C or °F

Yield Point (lb/100 ft²)

Gel Strength (lb/100 ft²) 10 sec/10 min

Filtrate API (ml/30 min)

HTHP Filtrate (cm³/30 min) @ °C or °F | REMARKS

Cake Thickness 32nd in. or mm

Electrical Stability (v), Meter Type

Retort Solids, % volume

Retort Liquid, % volume Oil/Water

Oil/Water Ratio

Alkalinity

Filtered yes no

Chloride Whole Mud (mg/L)

Calcium Whole Mud (mg/L)

PRODUCTS | SOLIDS EQUIPMENT

DRILLING FLUID VOLUME | SOLIDS ANALYSIS | FLUID RHEOLOGY & HYDRAULICS | COST ANALYSIS

REPRESENTATIVE | PHONE | WAREHOUSE PHONE

Contact Information

Oxy Central Drilling Group (CDG)

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Rusty Connell – Houston BU Drilling Fluid Specialist

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Agenda - Objectives

1. Daily Mud Report Contents
2. Drilling Fluid Systems
   - Water-based Mud (WBM) Systems
   - Non-aqueous Drilling Fluid (NADF) Systems
3. Mud Properties and Tests
   - WBM
   - NADF
4. Effects of Contamination

Drilling Fluid References

- API RP 13 B1 – Field Testing Water-based Drilling Fluids
- API RP 13 B2 – Field Testing of Oil-based Drilling Fluids
- API RP 13C – Mud Processing (Solids Control)
- API RP 13D – Rheology and Hydraulics
- API RP 13L – Training and Qualification Drilling Fluid Technologists

Daily Mud Report

What is a Daily Drilling Mud Report?

- Link between the drilling fluid (mud) company and the Oil and Gas Company (Operator)
- Used to evaluate the daily progress of the well and a means of summarizing the drilling operation once a well is completed (recap)
- Used as a reference to program future wells
- Data used to run hydraulics programs
- Used to monitor, identify and treat mud property trends

Daily Mud Report Software

- Baroid – DFG Software © with DrillAhead Hydraulics Module ©
- MI – OneTrax © with Virtual Hydraulics ©
- Baker Hughes – Advantage ©
- Newpark – MudPIT © (coming out with update version soon)
- NOV FluidControl – Drilling Fluids Engineer ©/Reporting Software

Daily Mud Report Content

Daily Mud Report - Contents

- Report Number and Date
- Well Information
- Drilling Assembly
- Casing Data
- Mud Volume
- Circulation Data
- Mud Properties/Specifications
- Mud Products/Inventory
- Solids Control Equipment
- Treatment Remarks
- Activity Remarks
- Mud Volume Accounting
- Solids Analysis
- Rheology/Hydraulics
- Cost
- Contact Information

Daily Mud Report – Contents - Examples

- Report Number, Date, Well Information

Daily Drilling Fluid Report API No: [illegible] Report No: 002

Date	06-22-2014 11:59:00 PM	**Well Name**	[illegible]	**Spud Date**	06-21-2014
Operator		**Country**	United States of America	**Depth (MD/TVD)**	1,907 / 1,907 ft
Operator Rep		**State**	Texas	**Rig Name**	[illegible]
Contractor		**County**	Hidalgo	**Rig Activity**	Drilling
Contractor Rep		**Field or Block**		**Unit System**	WSE API(Copy)

Daily Mud Report – Contents - Examples

- Drilling Assembly, Casing Data, Mud Volume, Circulation Data

DRILLING ASSEMBLY
15999 ft, 4.5-in DP
1302 ft, 4.5-in HWDP
32 ft, 5.25-in SUB
62 ft, 4.75-in DC
8 ft, 4.75-in STAB/SUB
31 ft, 4.875-in MM
Nozzles 16x6 1/32"
Bit 6.75-in PDC

CASING (*TVD)
9.625-in @5772 ft (5772 TVD)
7.625-in L @9795 ft (8445 TVD)

MUD VOLUME (bbl)	
Hole	Active Pits
837	444
Total Circulating Volume	
1281	
Depth Drilled Last 24hr	
354 ft	
Volume Drilled Last 24hr	
16 bbl	

CIRCULATION DATA		
Pump Make	ARDNER DENVER PZ	GARDNER DENVER PZ-11
Pump Liner x Stk	6x11 in	6x11 in
Pump Capacity gal/stk	3.837	3.837
Pump stk/min	40@95%	40@95%
Flow Rate	307 gal/min	
Pump Pressure	3420 psi	
Bottoms Up	85.1 min	6808 stk
Total Circulation	175.3 min	14020 stk

Daily Mud Report – Contents - Examples

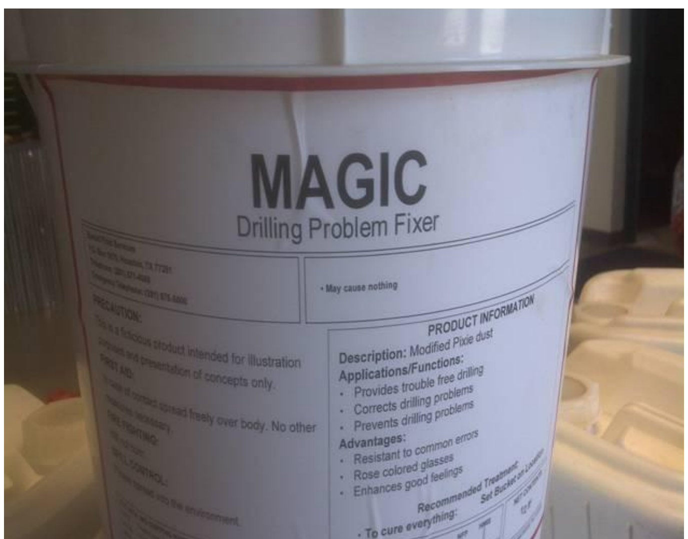
- Mud Properties and Specifications

Properties		Hyd 1	2	3	4	Targets	Program
Fluid Set		Polymer Mud					
Source		ACTIVE					
Time		17:00					
Depth (MD/TVD)	ft	7,242/7,242					
FL Temp	°F	90					
Density @ °F	ppg	9.10@60					
FV @ °F	sec/qt	35@60					
PV @ °F	cp	3@60					
YP	lbs/100ft2	7					
GELS	lbs/100ft2	4/8/12					
600/300		13.0/10.0					
200/100		8.0/6.0					
6/3		5.0/4.0					
Filtrate (API)	mL/30min	18.0					
HTHP @ °F	mL/30min						
Cake (API/HTHP)	32nd in	2/0					
Corr Solid	% by vol	3.8					
NAP / Water	% by vol	0.0/94.7					
NAP / Water Ratio							
Sand	% by vol	0.10					
MBT	ppb eq.						
pH @ °F		10.5@80					
ALK Mud (Pm)	mL	1.30					
ALK Filt (Pf/Mf)	mL	0.60/1.00					
Chlorides	mg/L	29,000					
Total Hardness	mg/L	1,320					
LGS / HGS	% by vol	3.8/0.0					
LGS / HGS	ppb	34.20/0.09					
ASG	SG	2.603					
Additional Properties							

Daily Mud Report – Contents - Examples

Products and Solids Control

Products Used Last 24 Hrs						
Product Name	Units	Start	Rec	Used	End	Cost
Lime	50 lb	50	0	5	45	
Barite	100 lb	200	200	50	350	
Caustic Soda	50 lb	50	0	5	45	
Bentonite (Bulk)	2000 lb	20	20	10	30	
Starch	50 lb	50	0	5	45	
Defoamer	5 gal	32	0	6	26	



SOLIDS CONTROL EQUIPMENT Last 24 hr		
Type	Model/Size	Hrs Used
SHAKER 1	200/200/200/200	24.0
SHAKER 2	200/200/200/200	24.0
SHAKER 3	200/200/200/200	24.0
414 Centrifuge	0	24.0

RC 3_15

Daily Mud Report – Contents - Examples

- Treatment and Activity Remarks

REMARKS AND TREATMENT	REMARKS
Limited treatments added as majority of day spent out of hole tripping. Ran centrifuge to lower drill solids content, which showed improvement of properties. Running diesel while drilling to maintain low viscosity (50-55 sec/qt). Continuing treatments when back drilling.	Drilled to 17434', then decision made to POOH to check MWD. Circulated 5 bottom's up, then POOH. Currently RIH. Next 24 hours: Contininue RIH to bottom. Drill to TD.

- Mud property, hole condition and equipment changes

- Time, Mud Volume, Solids Analysis, Rheology/Hydraulics

TIME DISTRIBUTION Last 24 hrs		MUD VOL ACCTG (bbl)		SOLIDS ANALYSIS		RHEOLOGY & HYDRAULICS	
Rig Up/Service		Oil Added	8	Salt Wt%	25.11	n	0.755
Drilling	5	Water Added		Salt Conc	16.44	k, lb-s^n/100ft²	0.184
Tripping	15	Mud Received		Adjusted Solids	8.82	TauY/LSYP, lb/100ft²	7.08/6
		Mud Returned		Oil/Water Ratio	84/16	Bit Loss/%, psi/%	56 / 1.6
Make up BHA		Shakers		Average SG Solids	3.6	Bit HHP/HIS	10 / 0.3
CIRCULATE	4	Evaporation		Low Gravity %	2.8	Jet Velocity, ft/s	83.6
MWD Issues		Centrifuge		Low Gravity Wt.	25.03	Va Pipe, ft/min	297.3
		Formation		High Gravity %	6.1	Va Collars, ft/min	327.1
		Left in Hole		High Gravity Wt.	87	CVa Pipe, ft/min	456
		Other				CVa Collars, ft/min	480.2
		Dump for Dilution				ECD at Shoe, lb/gal	10.03
						ECD at TD, lb/gal	10.54

Daily Mud Report – Contents - Examples

- Cost and Contact Information

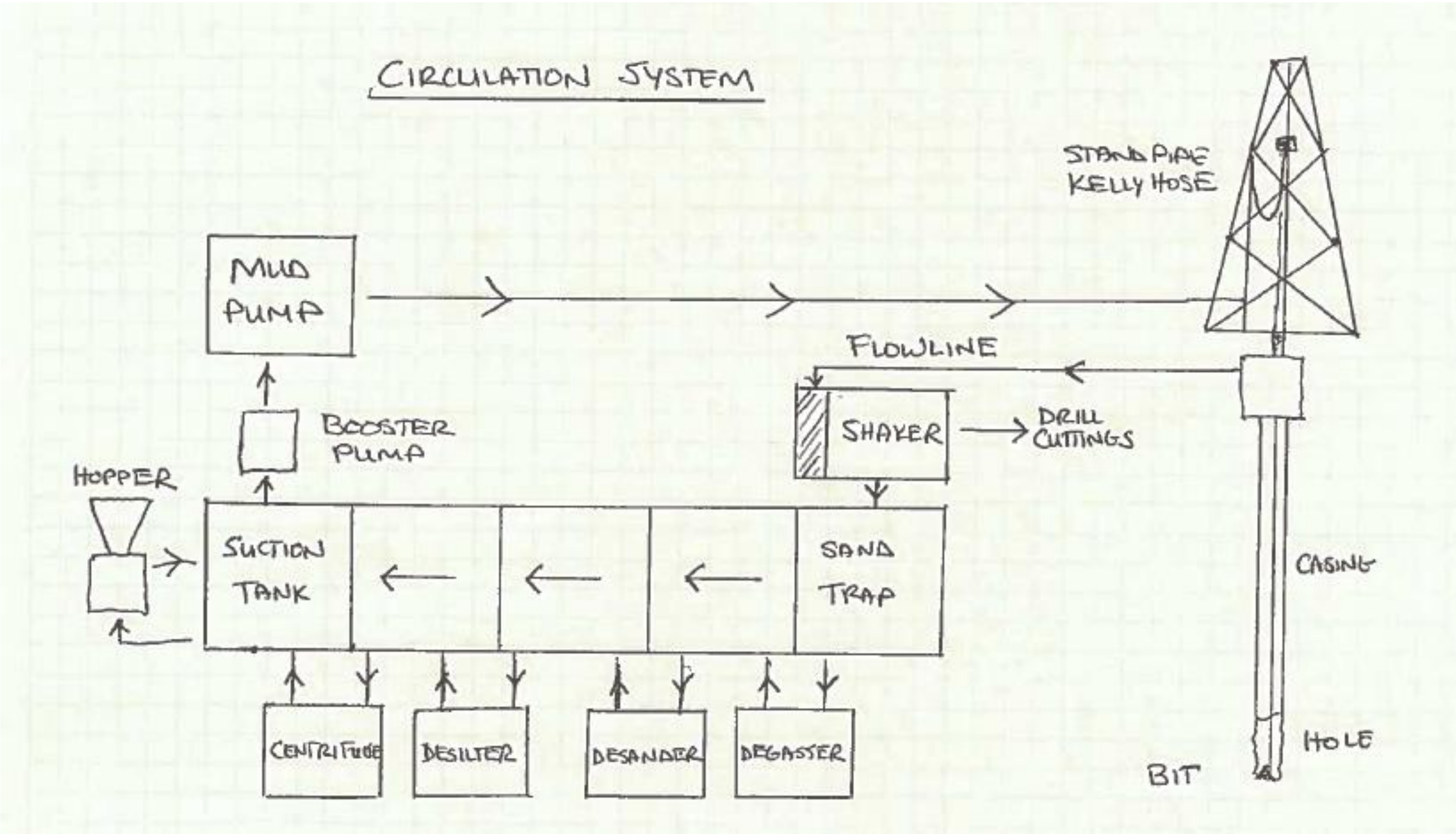
Daily Products Cost	$10,787.48	Total Daily Cost	$11,822.28
Cumulative Products Cost	$44,740.30	Total Cumulative Cost	$61,426.20
Representatives			
Office		Telephone	Monahans,Tx.
Warehouse		Telephone	

- Volume Accounting (More Detail)

TANK	CAPACITY bbl	WEIGHT lb/gal	VOLUME bbl	REMARKS	CLASS	SUM PIT VOLUMES	
Active	500		411		Active	MUD VOLUME	bbl
Slug Pit	100		29		Active	Active	444
Trip Tank	70		4		Active	Reserve	395
OBM Frac 1	500		31		Reserve	Premix	
OBM Frac 2	500		20		Reserve	OTHER VOLUME	
OBM Frac 3	500		26		Reserve	Pill	
OBM Frac 4	500		206		Reserve	Breaker	
OBM Frac 5	500		112		Reserve		

Drilling Fluids

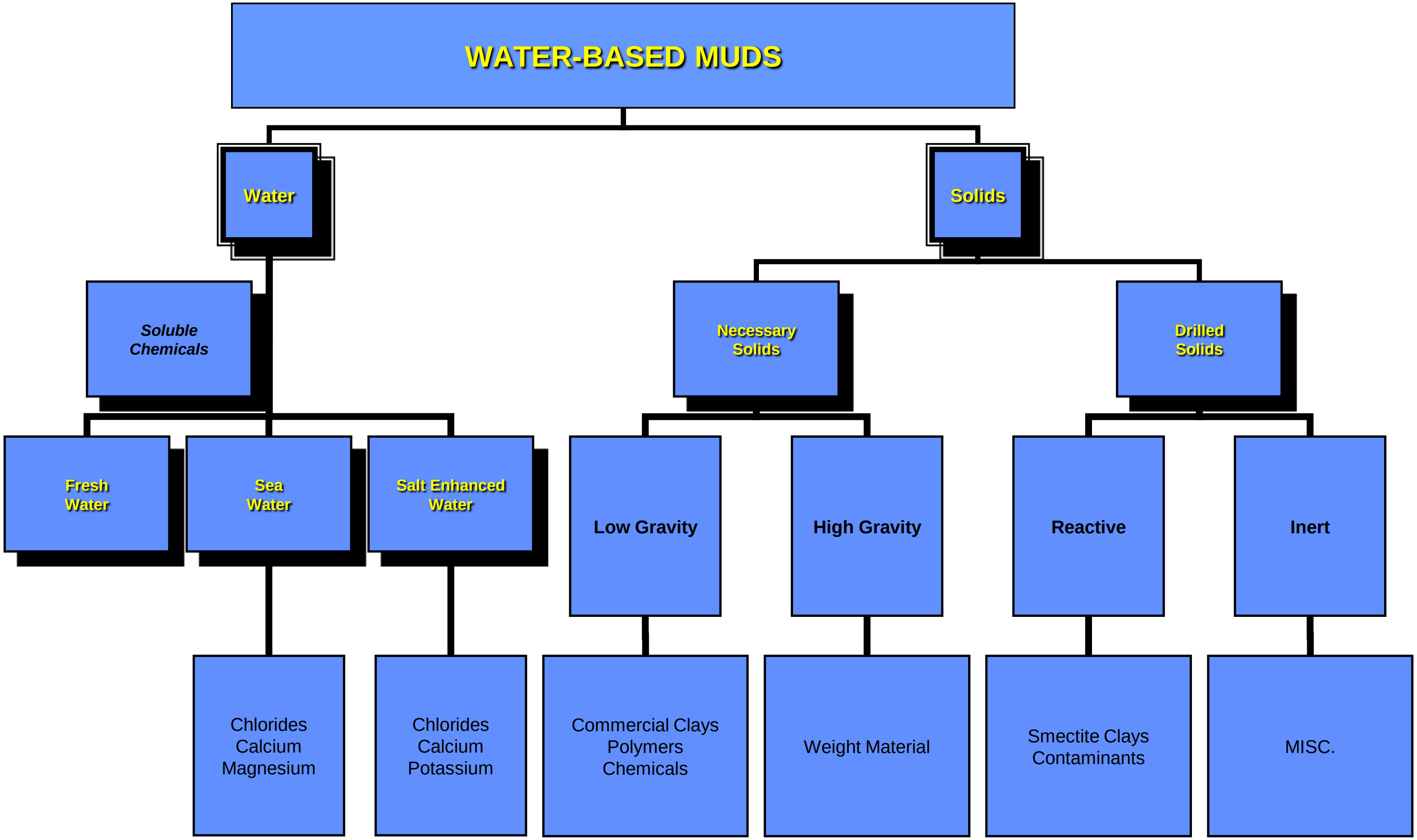
Mud Circulating System



FUNCTIONS OF DRILLING FLUIDS

1. *Remove drilled cuttings from the hole*
2. *Control subsurface pressure*
3. *Suspend and release cuttings and suspend weight material*
4. *Seal permeable formations*
5. *Promote borehole stability*
6. *Minimize reservoir damage*
7. *Cool, lubricate and support the bit and drilling assembly*
8. *Transmit hydraulic energy to tools and bit*
9. *Ensure adequate formation evaluation*
10. *Control corrosion*
11. *Minimize impact on environment*

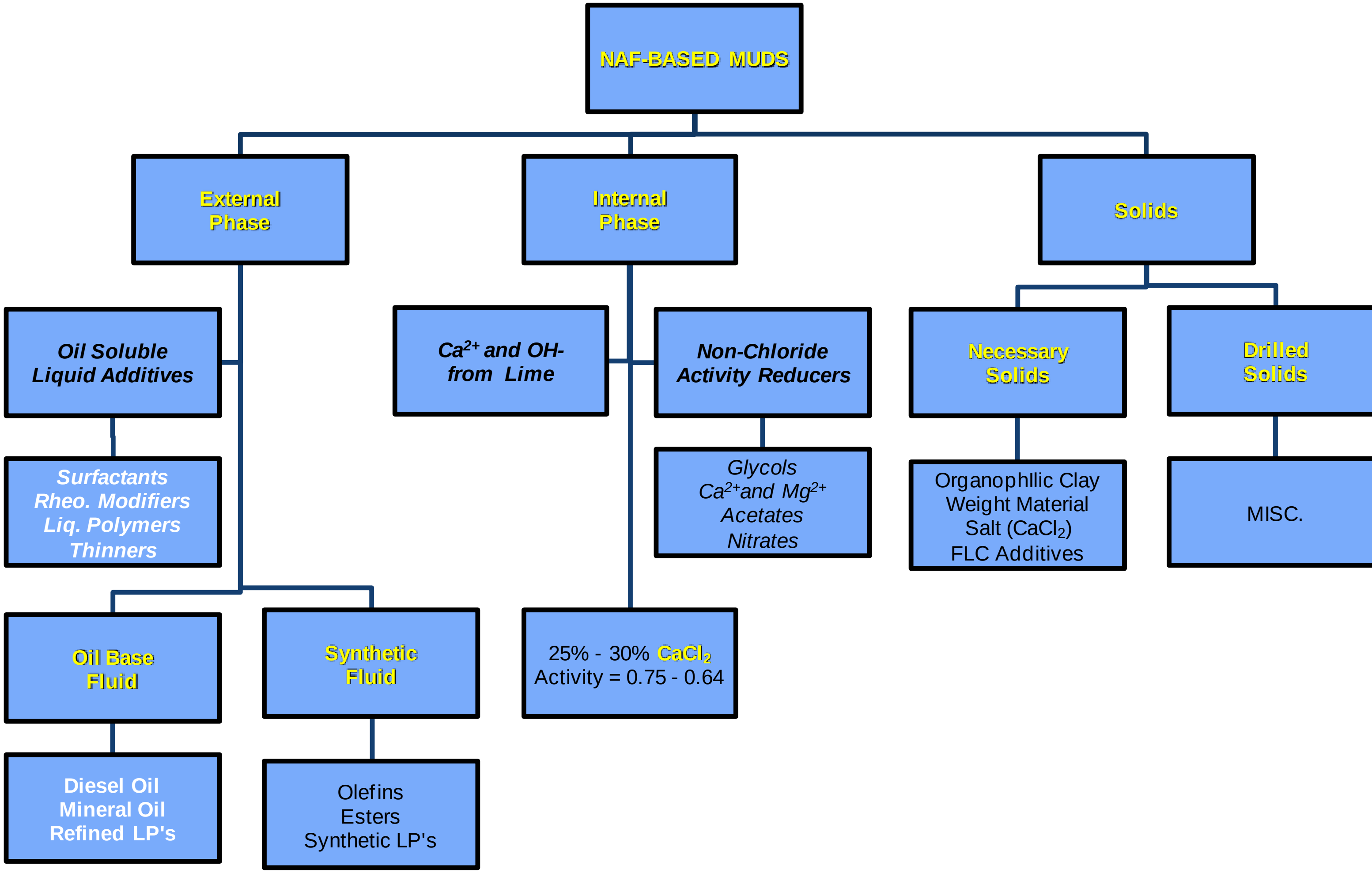
Water-Based Mud



Classification of Water-Based Drilling Fluids

- Spud Mud - Un-weighted clay water suspensions
- Low Solids Mud (typically < 6 vol% LGS) e.g. fw gel, polymer, phpa, salt saturated, potassium, designed for higher ROP
- Deflocculated, weighted clay-water suspensions, e.g. lignosulfonate-based muds
- Calcium-treated, weighted deflocculated clay-water suspensions, e.g. Gyp or Lime muds
- HTHP Systems, e.g. lime-clay-extender muds and muds based on thermally stable synthetic polymers
- Salt-water systems, brine based, e.g. using attapulgite clay
- Inhibitive mud – Glycol, polyamine, potassium, silicate, etc.

Oil- and Synthetic-Based Mud (NADF)



Most NADFs are Invert Emulsions

THREE PHASE SYSTEMS - Two immiscible fluids, and the solids phase

- *OIL / SYNTHETIC FLUID* - continuous - external phase, lipophilic liquid product additives.
- *WATER* - emulsified droplets (typically $CaCl_2$ brine), as internal phase, soluble lime.
- *SOLIDS* - barite, organophilic clays, drill solids, insoluble additives - fluid loss control products, LCM, etc. (soluble additives)

WBM Properties and Tests

Standard Properties of WBM (API RP13 B1)

	PROPERTY	UNITS	
1.	*Mud Weight*	*ppg, lb/ft^3, SG*	Physical
2.	*Funnel Viscosity*	*sec/qt*	Physical
3.	*Plastic Viscosity*	*cP*	Physical
4.	*Yield Point*	*lb/100 ft^2*	Physical
5.	*Gel Strengths*	*lb/100 ft^2*	Physical
6.	*Filtrate (API Fluid Loss)*	*cm^3 /30 min*	Physical
7.	*HTHP Filtrate*	*cm^3 /30 min*	Physical
8.	*Filter Cake Thickness*	*32nd in*	Physical
9.	*Solids Content*	*% by vol*	Chemical
10.	*Liquid Content (Oil / Water)*	*% by vol*	Chemical
11.	*Sand Content*	*% by vol*	Chemical
12.	*Methylene Blue Capacity (CEC)*	*eq. ppb*	Chemical
13.	*pH*	none	Chemical
14.	P_m	*cc acid*	Chemical
15.	P_f	*cc acid*	Chemical
16.	M_f	*cc acid*	Chemical
17.	*Chlorides*	*mg/L*	Chemical
18.	*Total Hardness as Calcium*	*mg/L*	Chemical

Mud Properties – WBM

General Properties:
Mud Weight & Viscosity
First Warning Signs

Rheology
Hole cleaning, barite sag, suspension, ECD

Filtration
Invasion, cake quality

Retort & MBT
Solids, liquids %, sand, reactive solids (clay)

Chemical Properties
Chemical Contaminants, Alkalinity

Misc. Properties

MUD PROPERTIES					
Sample From		Suction@22:00	Suction@13:30		
Flow Line Temp	°F	110	104		
Depth/TVD	ft	11038/9062	10379/9058		
Mud Weight	lb/gal	8.5@110°F	8.4@102°F		
Funnel Viscosity	s/qt	43	47		
Rheology Temp	°F	120	120		
R600/R300		38/33	37/32		
R200/R100		31/27	29/25		
R6/R3		15/12	14/12		
PV	cP	5	5		
YP	lb/100ft²	28	27		
10s/10m/30m Gel	lb/100ft²	15/17/18	14/16/17		
API Fluid Loss	cc/30 min	7	6.9		
HTHP FL Temp	cc/30 min				
Cake API/HTHP	1/32"	1/	1/		
Solids	%Vol	1	.5		
Oil/Water	%Vol	5/94	5/94.5		
Sand	%Vol	1	.05		
MBT	lb/bbl	.5	.5		
pH		9.2	9.2		
Alkal Mud (Pm)		.1	.1		
Pf/Mf		.05/1.4	.1/1.9		
Chlorides	mg/l	3750	4300		
Hardness Ca	mg/l	60	60		
LSRV	cP	21000	33200		
TOTAL ACTIVE	bbl	1190			
WASTE MANAGEME	$	1250.95			
SOLIDS VAN	$	4175.00			
Conqor test	ppm	3250	2450		
Dissolved O2	ppm	2	1		

Mud Weight / Density

Courtesy of Fann Instrument Company

Mud Weight (Density)

- lb/gal (ppg) - pounds / gallon
- kg/m^3 – kilograms / cubic meter
- lb/ft^3 - pounds / cubic foot
- psi/1000 ft - pounds / square inch per 1000 ft (vertical depth), hydrostatic pressure gradient
- s.g. - specific gravity (no units)

Funnel Viscosity

Courtesy of Fann Instrument Company

Funnel Viscosity

The timed *rate of flow in sec / quart* or sec / liter through funnel with 3/16” opening:

- Begin with ~1.5 qts of mud poured thru a 12-mesh screen
- Time the first 1 quart (or liter if metric)
- Calibrate the Funnel with water: 26 +/- 0.5 sec/qt
- Note: Funnel viscosity is not a quantitative measurement of viscosity. Viscosity of most drilling fluids varies with the shear rate (velocity) of the fluid. The shear rate in a Funnel is not defined and varies with the thickness, temperature and level of fluid in the Funnel.

Viscosity is a function of Shear Rate: $\frac{\text{Shear Stress}}{\text{Shear Rate}}$

Bingham Plastic (or Pseudoplastic) has been the preferred Flow Model:

Shear Stress = *Yield Point* + Shear Rate x *Plastic Viscosity*

or

$$\tau = YP + \gamma \times PV$$

Chemical Interactions (→ *YP*)

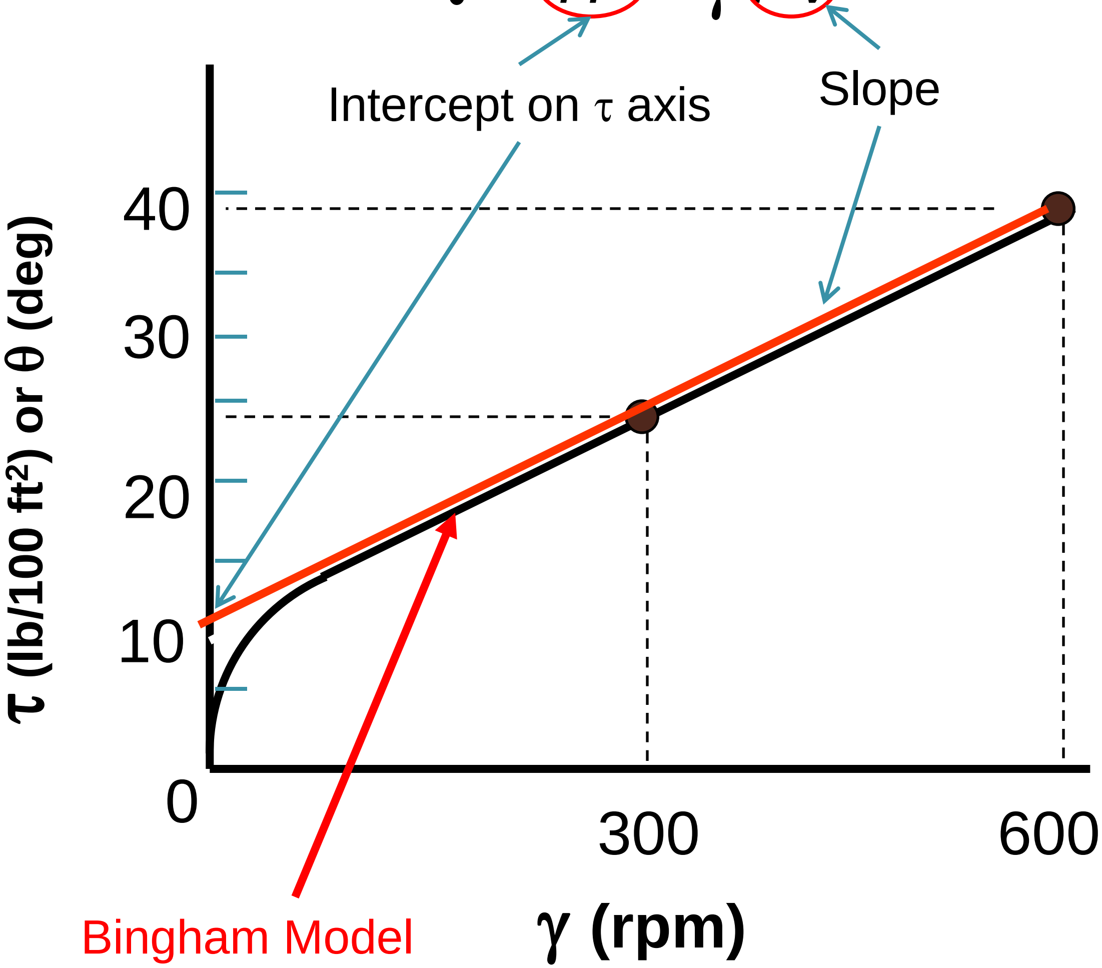
- Type of solids and associated charges
- Concentration of active solids
- Dissolved salts

Mechanical Interactions (→ *PV*)

- Solids concentration
- Size and shape of the solids
- Viscosity of the fluid phase

Bingham Plastic Model – 6-Speed Viscometer

$$\tau = YP + \gamma PV$$



$\theta_{600} = 40$

$\theta_{300} = 25$

$PV = \theta_{600} - \theta_{300} = 15$

$YP = \theta_{300} - PV = 10$

Water-Based Mud Kit

Courtesy of Fann Instrument Company

Viscosity Profile (Rheology)

Fann Model 35 Viscometer

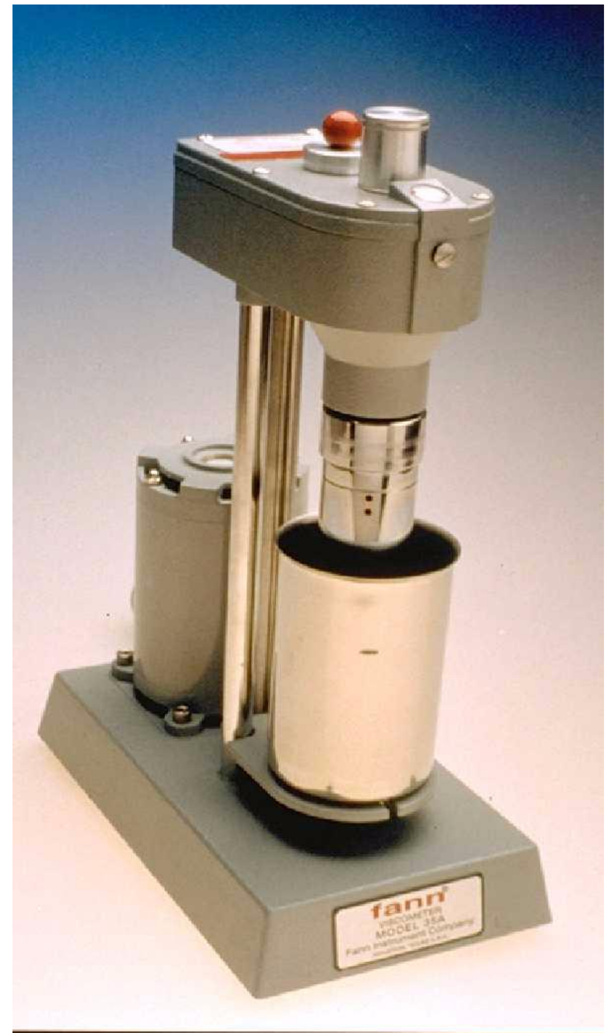
(6 - Speed VG-Meter)

- θ_{600}
- θ_{300}
- θ_{200}
- θ_{100}
- θ_{6}
- θ_{3}

$$\begin{array}{r} \theta_{600} \\ \underline{-\ \theta_{300}} \\ PV \end{array}$$

$$\begin{array}{r} \theta_{300} \\ \underline{-\ PV} \\ YP \end{array}$$

- Gel Strengths – 10 s, 10 m, 30 m



Courtesy of Fann Instrument Company

Static Filtration at Ambient Temperature

API Filter Press: *Fluid Loss* (Volume of Filtrate Collected, cc or mL)

- 100 psi
- 30 min
- 7.5 in^2 # 50 Whatman Paper (2.7 micron)
- Ambient Temperature

Courtesy of Fann Instrument Company

Static Filtration at Ambient Temperature

API Filter Press: *Filter Cake Thickness* (in increments of 1/32")

HTHP Fluid Loss (Static)

Volume (cc) of Filtrate collected X 2

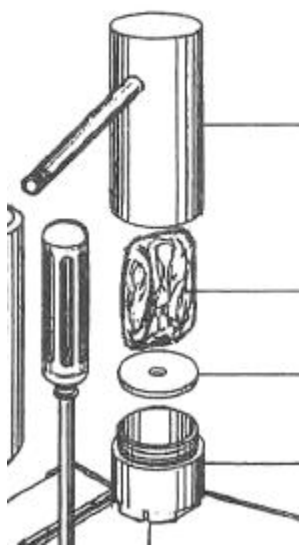
- 30 min
- 300°F (or less - BHST > 175°F)
- 3.75 sq. in. #50 Whatman paper
- 500 psi - Differential Pressure
- 600 psi – TOP
- 100 psi - BOTTOM (back pressure)

Courtesy of Fann Instrument Company

Retort

<u>Distilled Fractions</u>

- *% Solids*
- *% NAF (Oil or Synthetic Fluid*
- *% Water*



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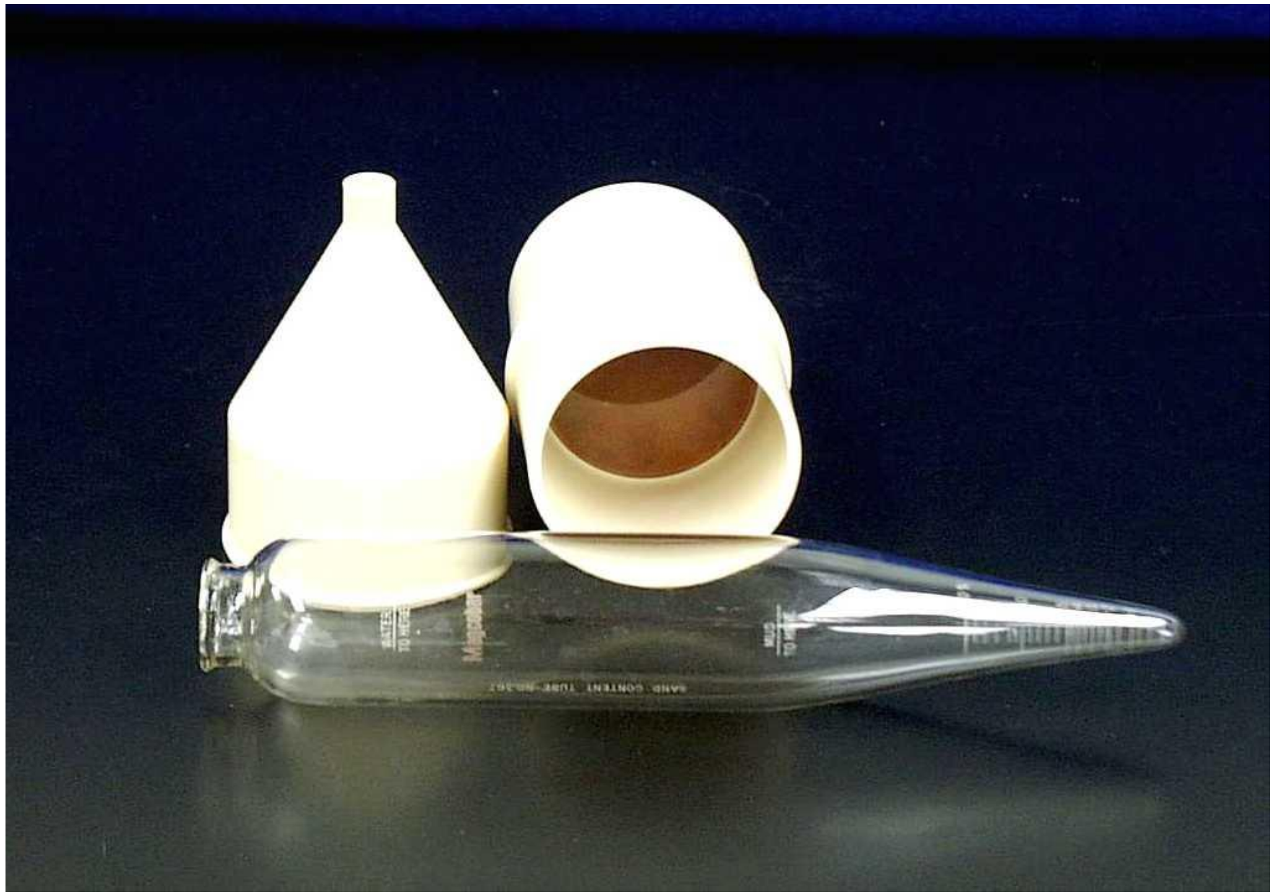
Sand Content

<u>% By Volume (% v/v)   Sand</u>



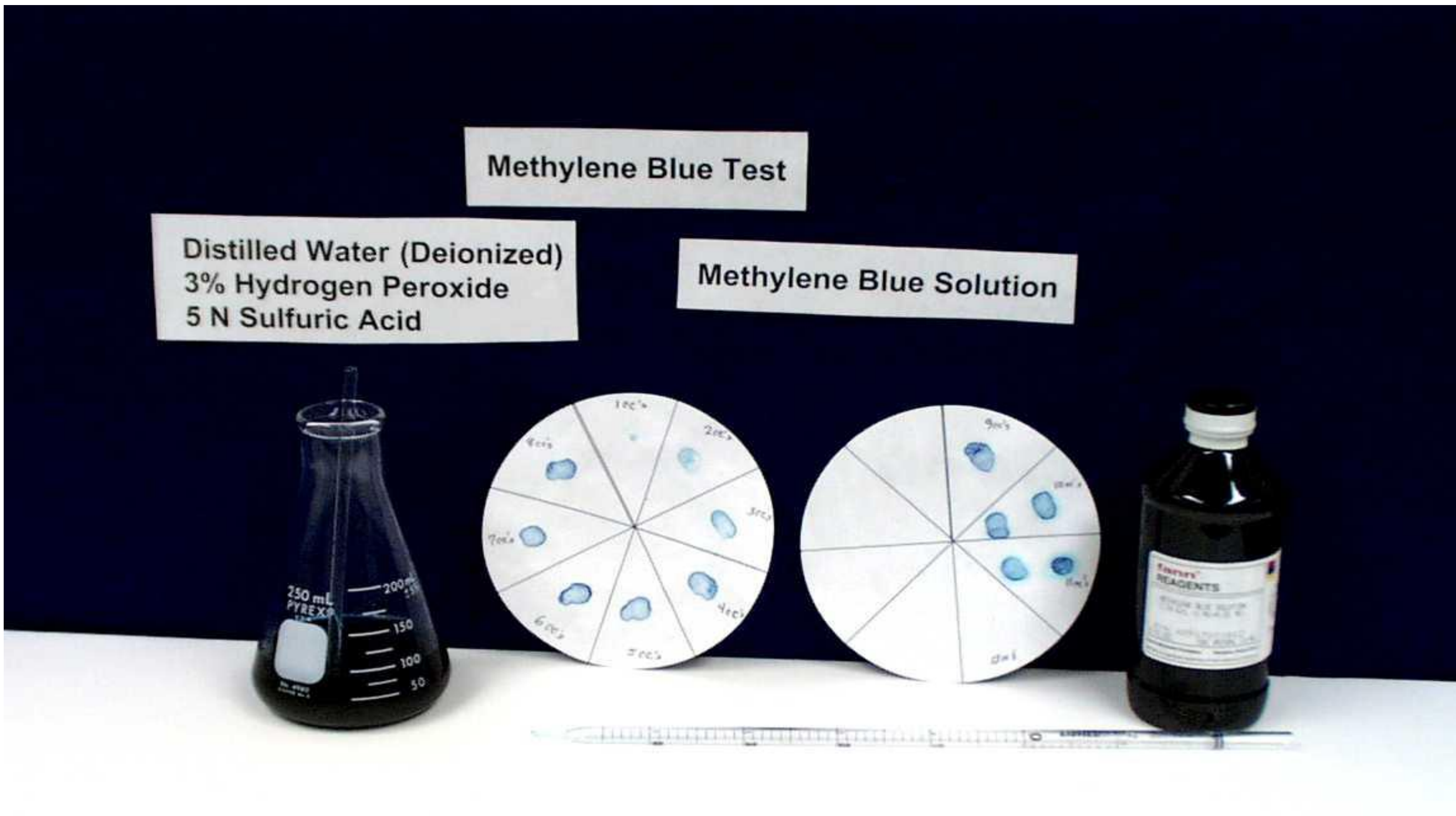
Note: These are particles that are “sand-size”: coarser than 200 mesh (74 μm)

Courtesy of Fann Instrument Company

CEC - Cation Exchange Capacity

Methylene Blue Test: activity and concentration of clays

CEC (Equiv lb/bbl Bentonite) = 2.5 x Total Vol Methylene Blue



Courtesy of Fann Instrument Company

pH

pH – negative log of H+ ion

- **pH Meter -** Electrometric (Preferred Method)
- **pH Strips -** Colorimetric (General Range)

Courtesy of Fann Instrument Company

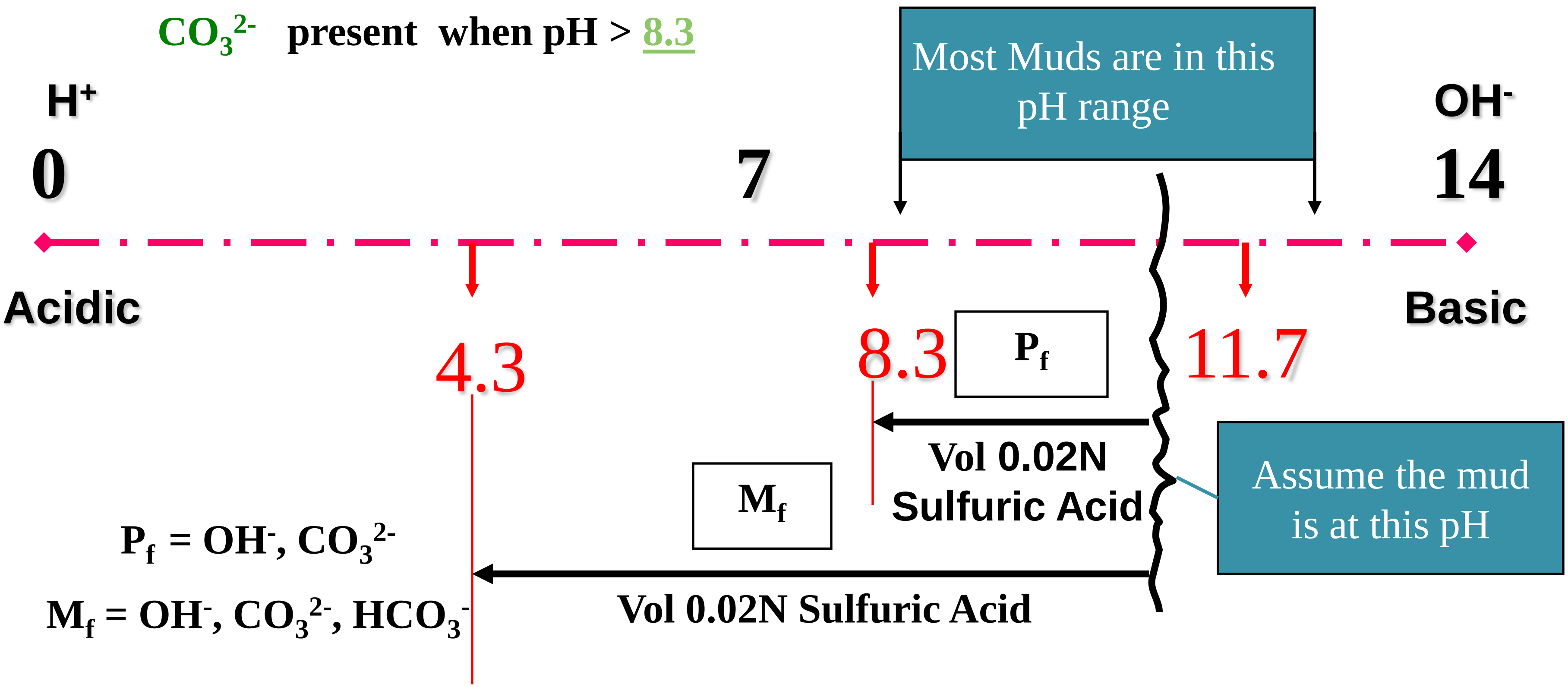
pH & Alkalinity

Alkalinity – measure of the quantity of an acid to reduce the pH to a particular value

OH^- present when pH > 7.0

HCO_3^- present when pH is between 4.3 and 11.7

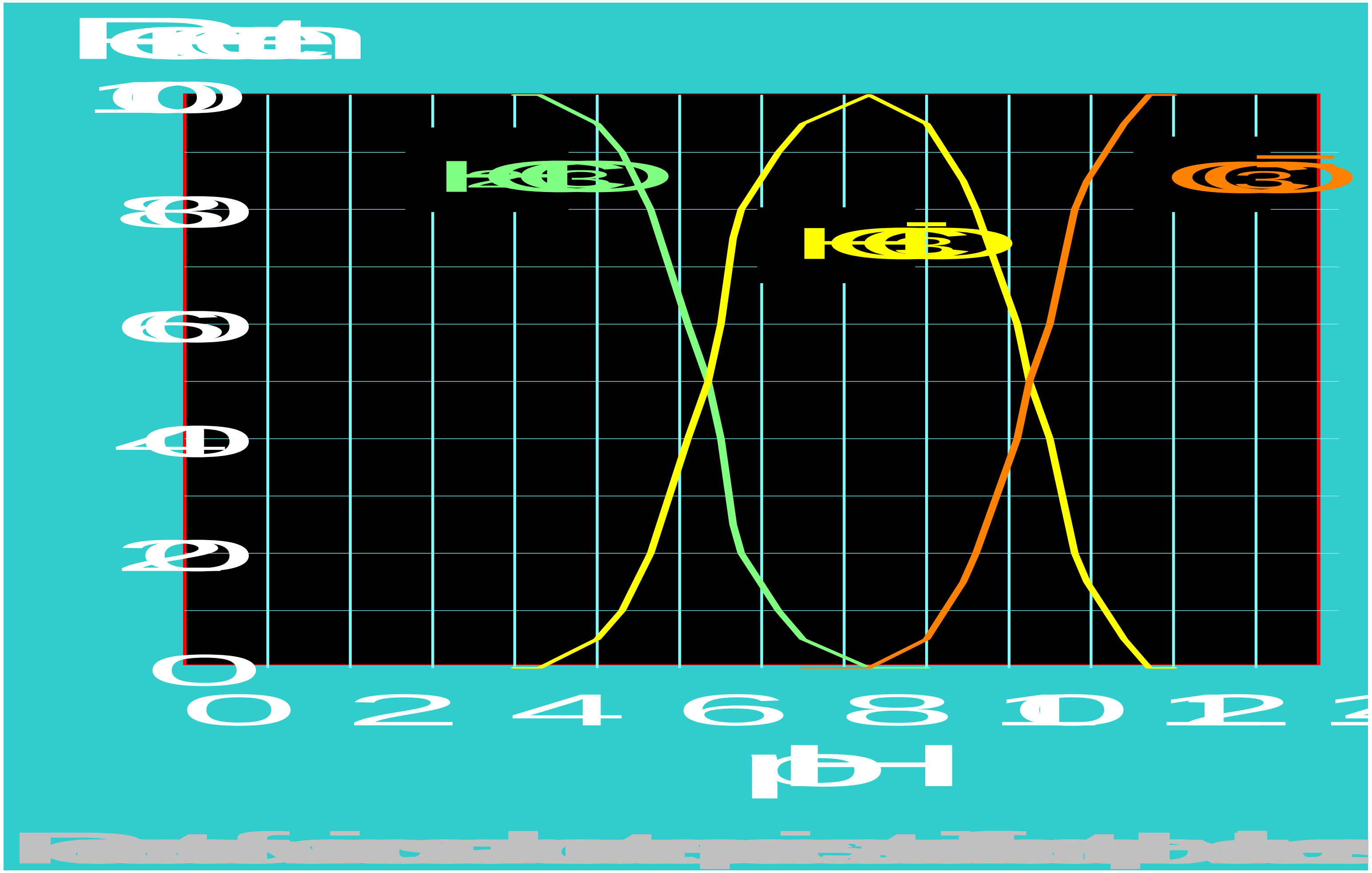
CO_3^{2-} present when pH > 8.3



$P_f = OH^-, CO_3^{2-}$

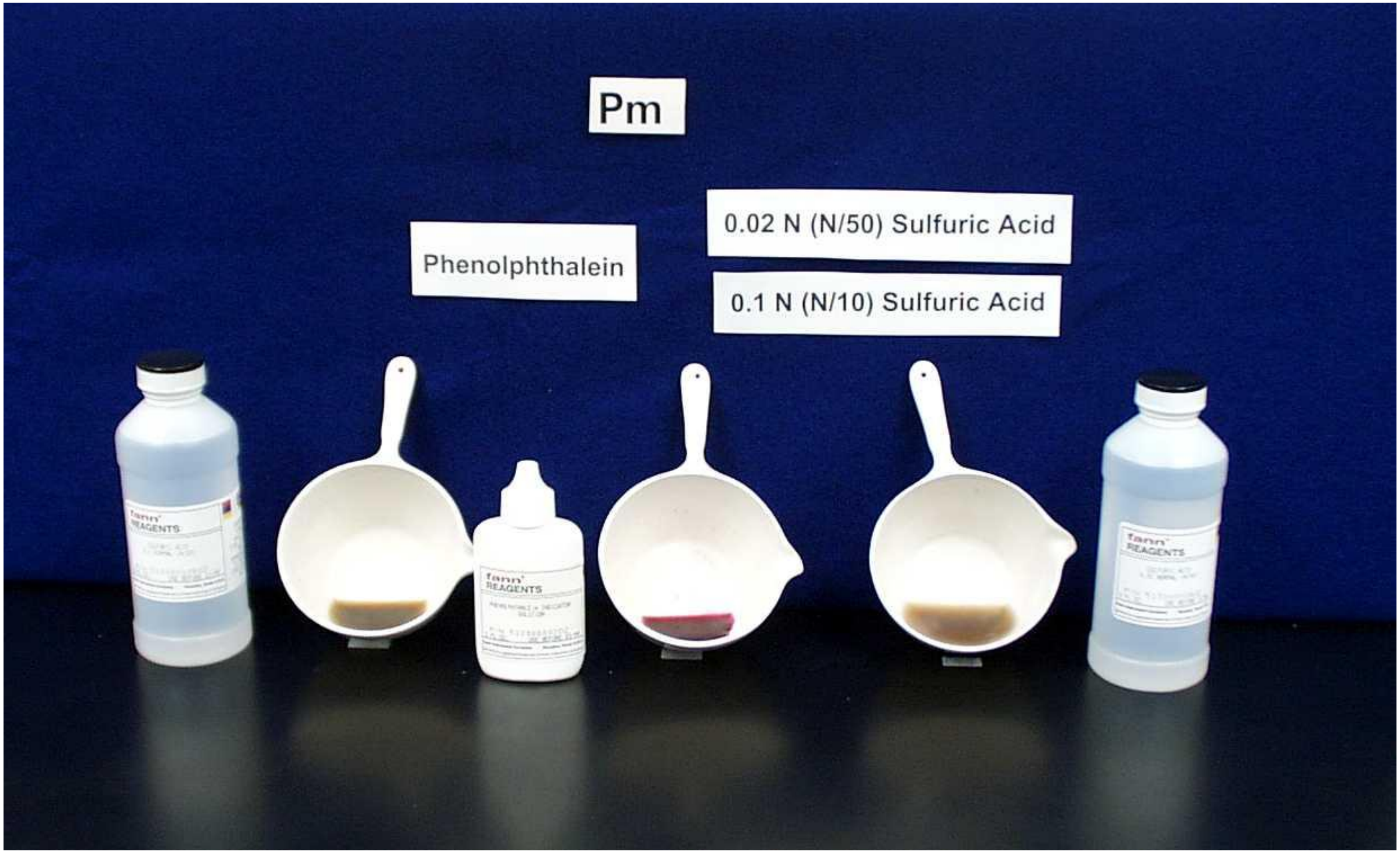
$M_f = OH^-, CO_3^{2-}, HCO_3^-$

Carbonate / Bicarbonate Equilibrium



Pm (<u>P</u>henolphthalein Endpoint of the <u>M</u>ud)

Pm – alkalinity measurement of whole mud – measure lime/cement solids in mud



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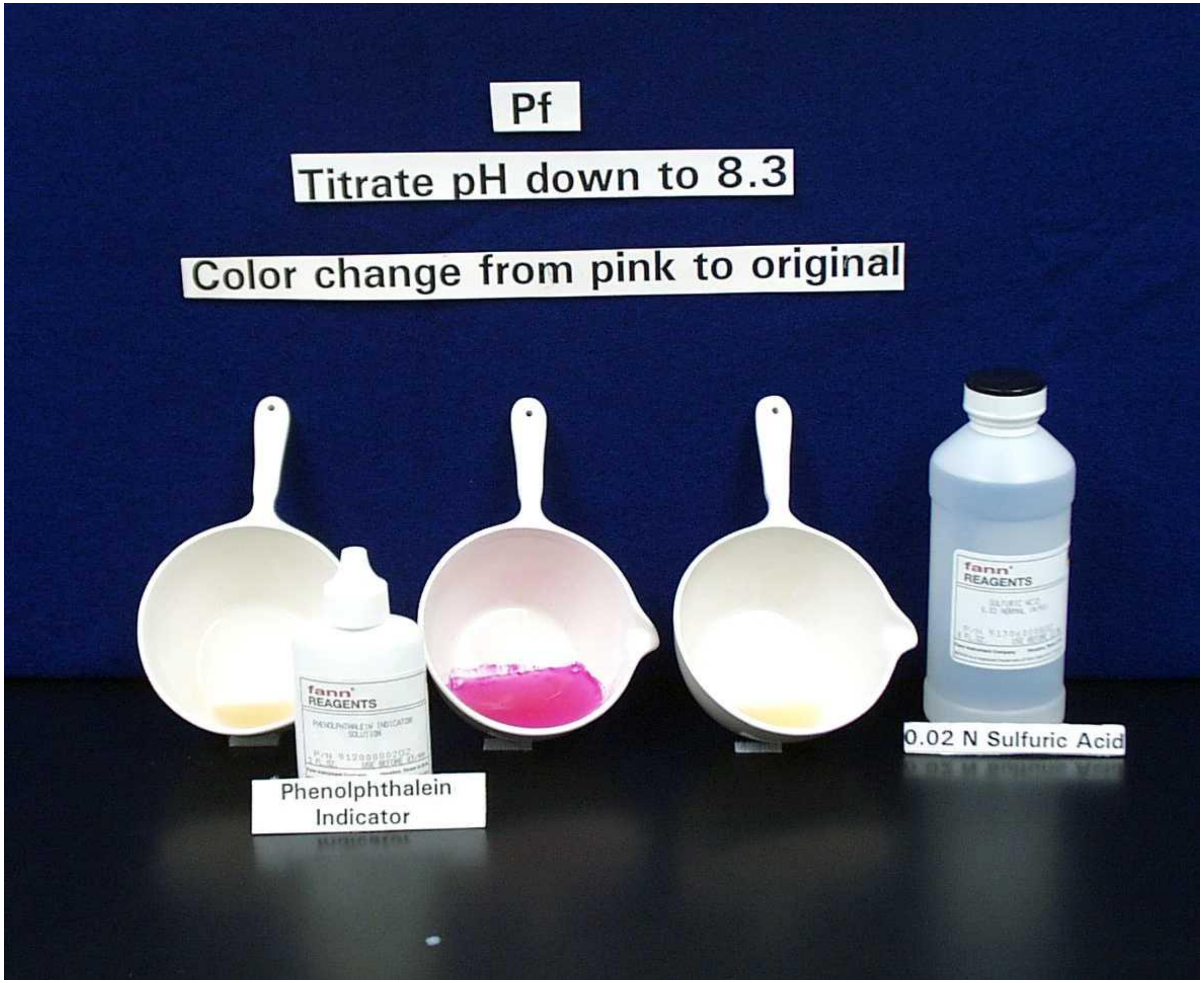
Pf (Phenolphthalein Endpoint of the Filtrate)



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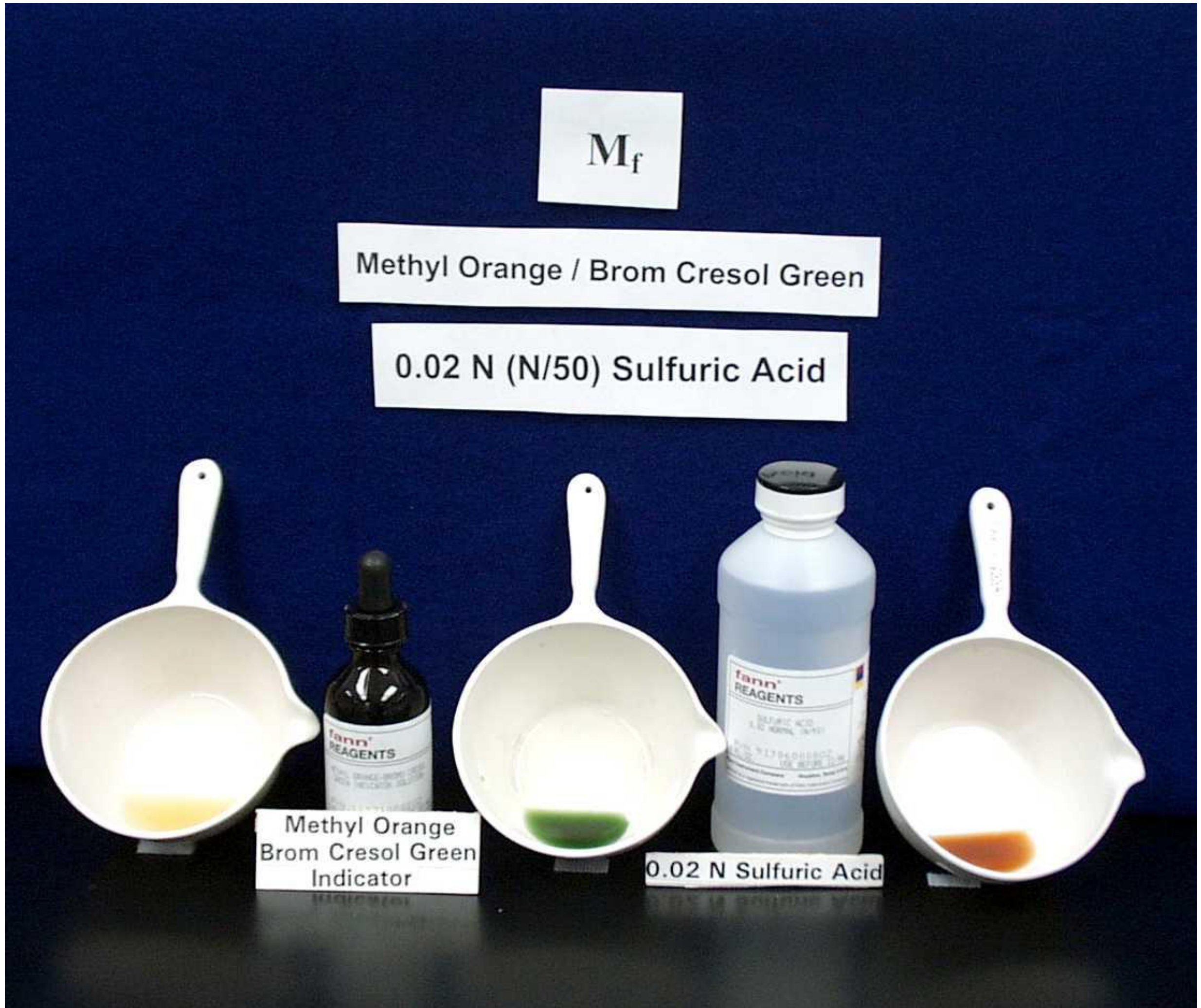
Mf (Methyl Orange Endpoint of the Filtrate)



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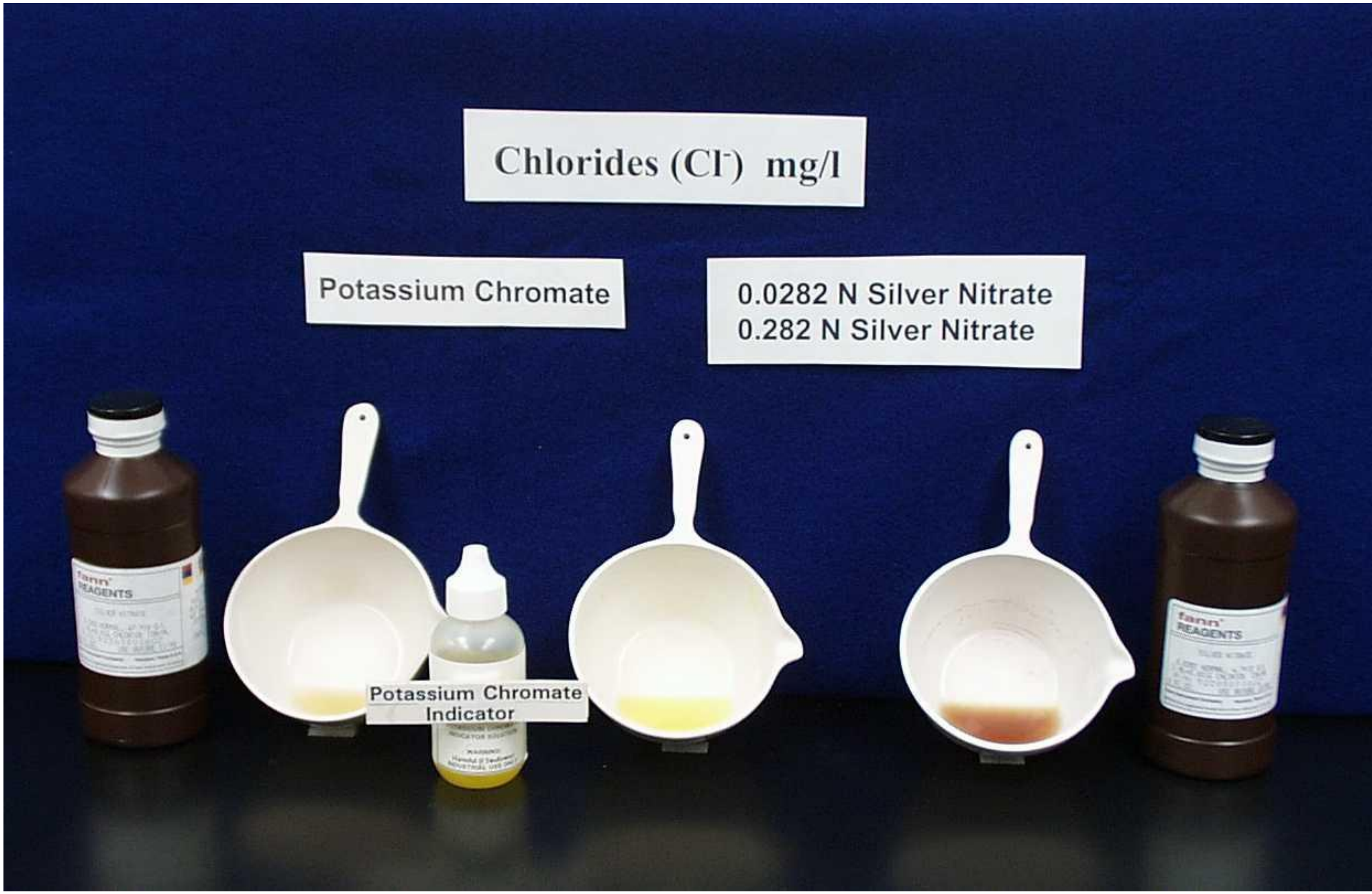
Cl^- (Chlorides)



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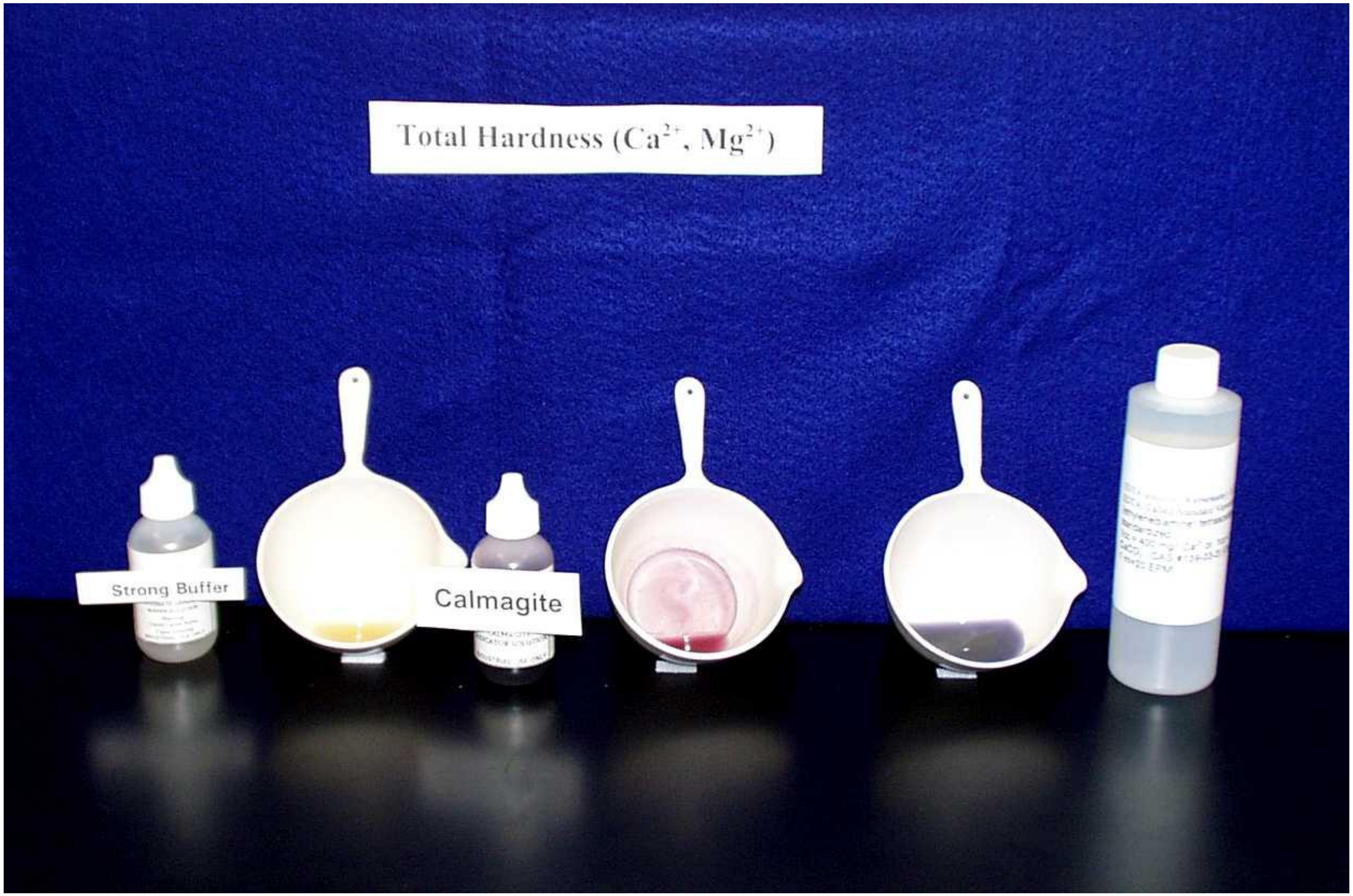
Total Hardness (Ca^{2+} & Mg^{2+})



Courtesy of Fann Instrument Company

Calcium (Ca^{2+})

Courtesy of Fann Instrument Company

NADF Properties and Tests

Mud Properties – OBM

General Properties: Mud Weight & Viscosity (First Warning Signs)

Rheology

Hole cleaning, barite sag, suspension, ECD

Filtration

Invasion, cake quality

Retort

Solids, liquids %, SWR

Chemical Properties

Salt & Lime Content

Emulsion Stability

Misc. Properties

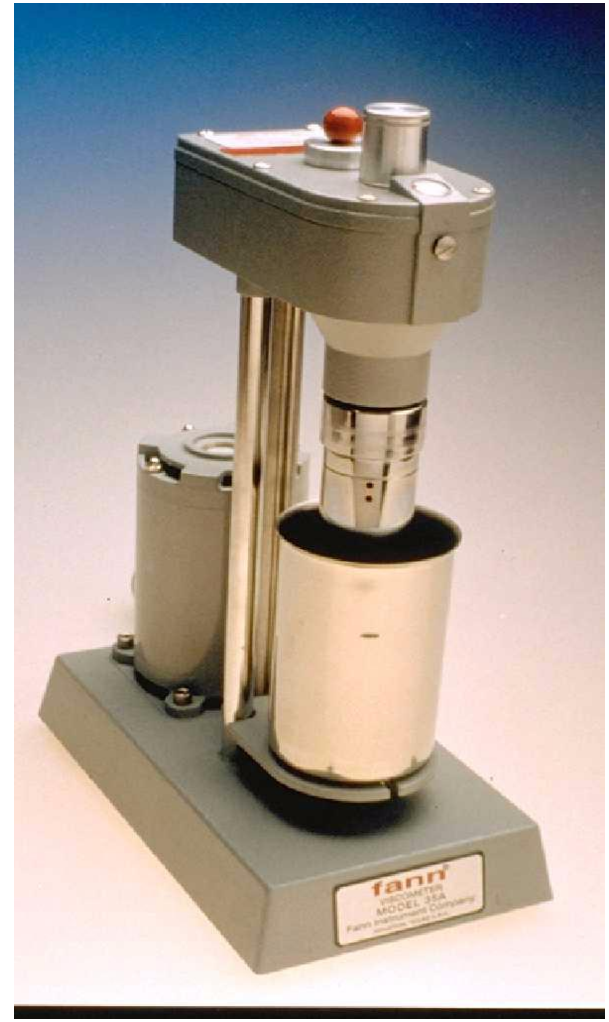
MUD PROPERTIES

Sample From		Suction@22:00	Suction@12:00		
Flow Line Temp	°F	80	77		
Depth/TVD	ft	11829/4591	10750/4551		
Mud Weight	lb/gal	9.2@80°F	9.2@74°F		
Funnel Viscosity	s/qt	70	73		
Rheology Temp	°F	120	120		
R600/R300		53/36	57/39		
R200/R100		30/23	31/24		
R6/R3		14/13	14/13		
PV	cP	17	18		
YP	lb/100ft²	19	21		
10s/10m/30m Gel	lb/100ft²	20/26/32	23/33/38		
API Fluid Loss	cc/30 min	na	na		
HTHP FL Temp	cc/30 min	4.4@100°F	4.4@100°F		
Cake API/HTHP	1/32"	na/1	na/1		
Unc Ret Solids	%Vol	17.5	17		
Correct Solids	%Vol	15.15	14.62		
Oil	%Vol	61.5	61		
Uncorr Water	%Vol	21	22		
Oil/Water Ratio		75/25	73/27		
Alkal (Pom)		2.0	1.6		
Cl Whole Mud	mg/l	57000	58000		
Salt	%Wt	29.81	29.21		
Lime	lb/bbl	2.6	2.08		
E-Stability		805	880		
PPA	cc/30min	2.2	2.2		

Rheology (Viscosity and Gel Strength)

- Test at 120° or <u>150°</u>
- Run VG meter at 300 rpm while heating sample
- After completing viscosity profile (600, 300, 200, 100, 6, 3 rpm) and gel strengths (10 sec, 10 min, 30 min), check the heat cup for barite settling

Heat Cup

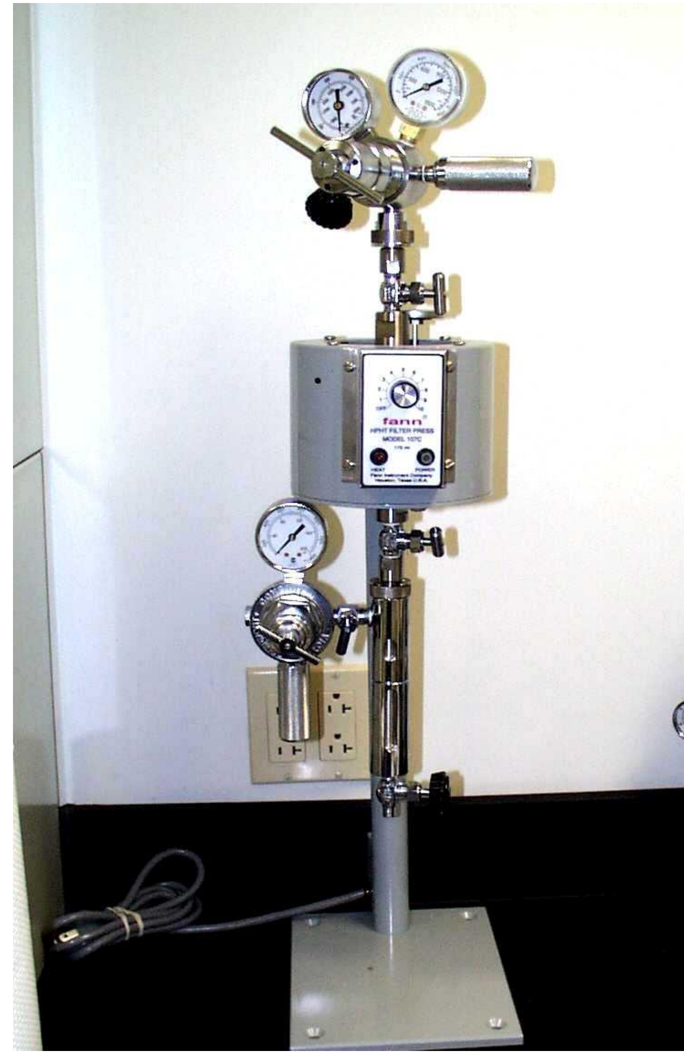


Courtesy of Fann Instrument Company

HTHP Fluid Loss Tester

- This is one of several types of units. Good For 300°F on a regular basis.

- For higher temperatures a different type unit must be used, and higher pressures (top and bottom) should be used. (Differential pressure should still be 500 psid)



Courtesy of Fann Instrument Company

HTHP Fluid Loss

- This type of unit is used for temperatures above 300 °F.
- Usually employs Nitrogen pressurization from a big cylinder.

Courtesy of Fann Instrument Company

Electrical Stability

- Electrical stability is a relative value
- Electrical stability related to emulsion stability, wettability, %water, water droplet size, viscosity, temperature...
- Electrical stability of new mud will be low until sheared through the bit
- Check at 120° or 150 °F (65 °C)
- Meters
  - Operator ramped - (old style) (reading is doubled)
  - Self ramping digital - (read directly)

Courtesy of Fann Instrument Company

Retort Analysis

- Retort allows us to determine:
  - % Solids
  - % Oil or Synthetic fluid
  - % Water
  - Oil (or Synthetic) / Water Ratio
  - Salt content
- Use 50 ml retort for precision and accuracy since O/W is critical (10 & 20 ml)
- Watch for trends and major changes

Courtesy of Fann Instrument Company

Invert Emulsion Calculated Data

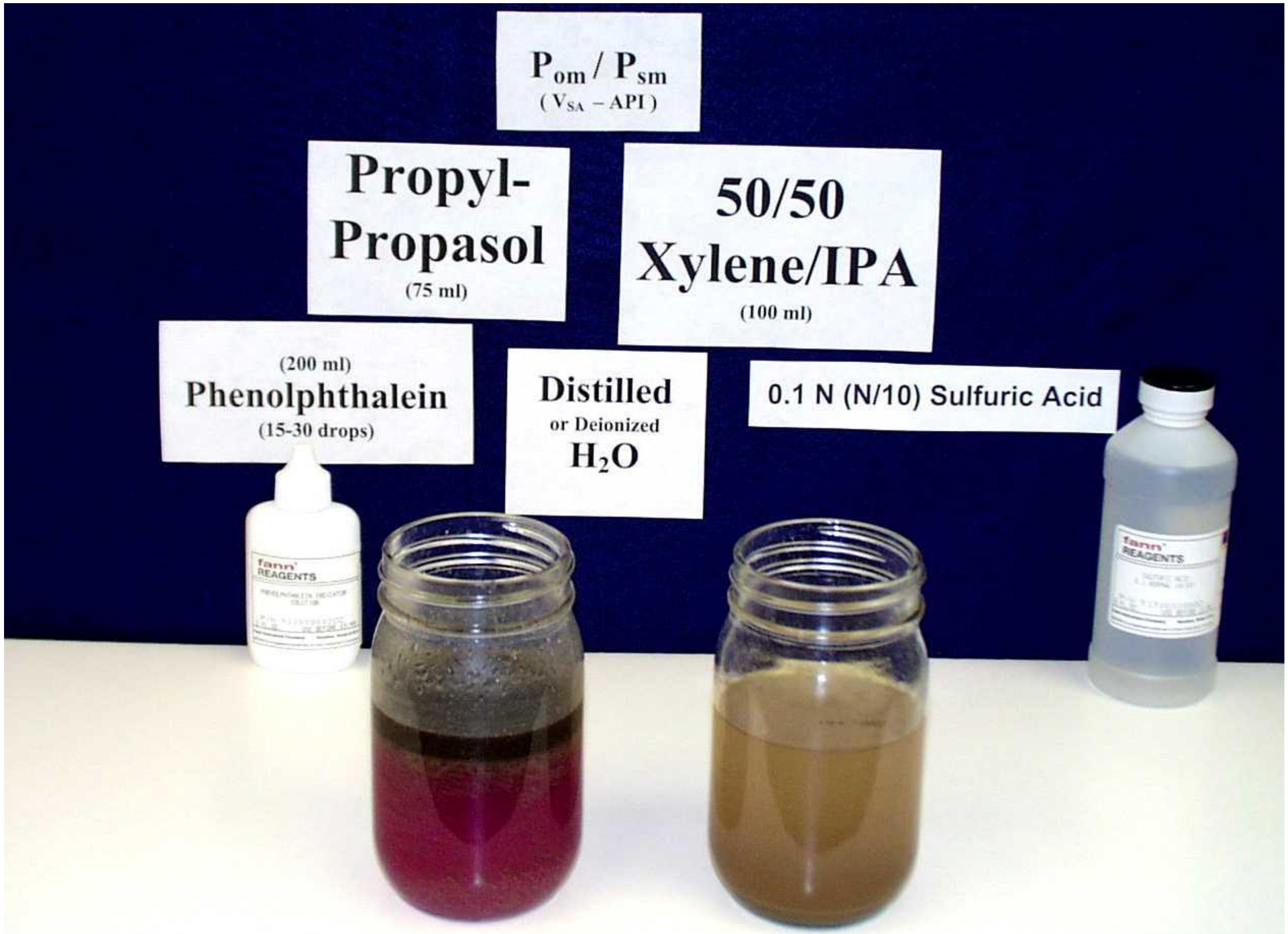
- ***Oil / Water Ratio (OWR)***
  - *Oil Fraction* = $\frac{\%\ Oil}{\%\ Oil + \%\ Water}$ X (100)
  - *Water Fraction* = 100 - Oil Fraction
  - Oil Fraction / Water Fraction = OWR
- ***Excess Lime (ppb lime)*** = Pom X 1.3

Titrations

- Standard titrations:
  - Alkalinity – Pom (Psm)
  - Chlorides - Cl^- (whole mud)
- Must use whole mud - (2 cc)

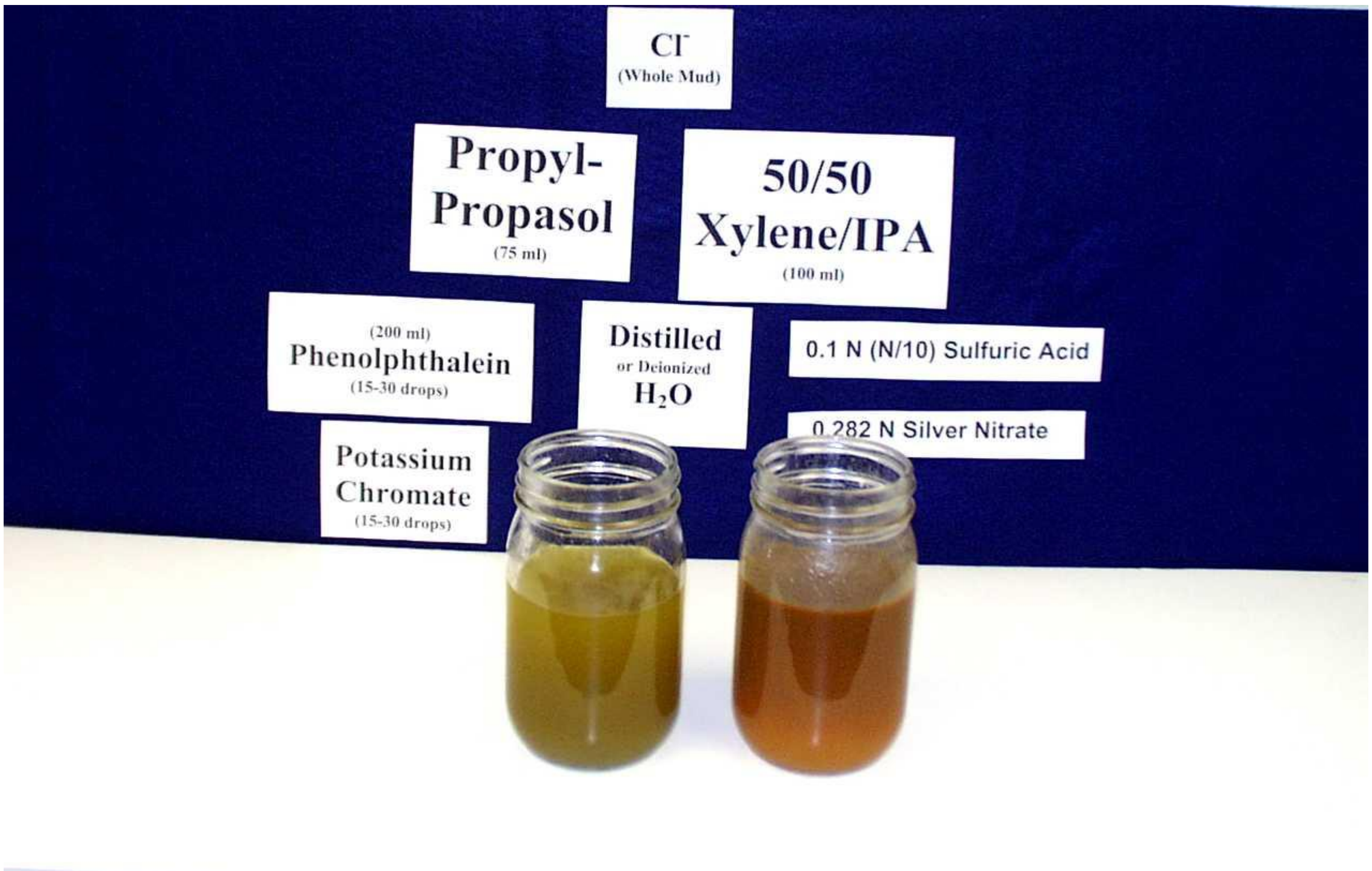
  (filtrate is Oil/Synthetic fluid)
- Mix mud with solvent to break the emulsion
- Dilute sample with distilled water and add indicator.
- Titrate!

P_{om} (P_{sm}) (V_{SA}) - Color change



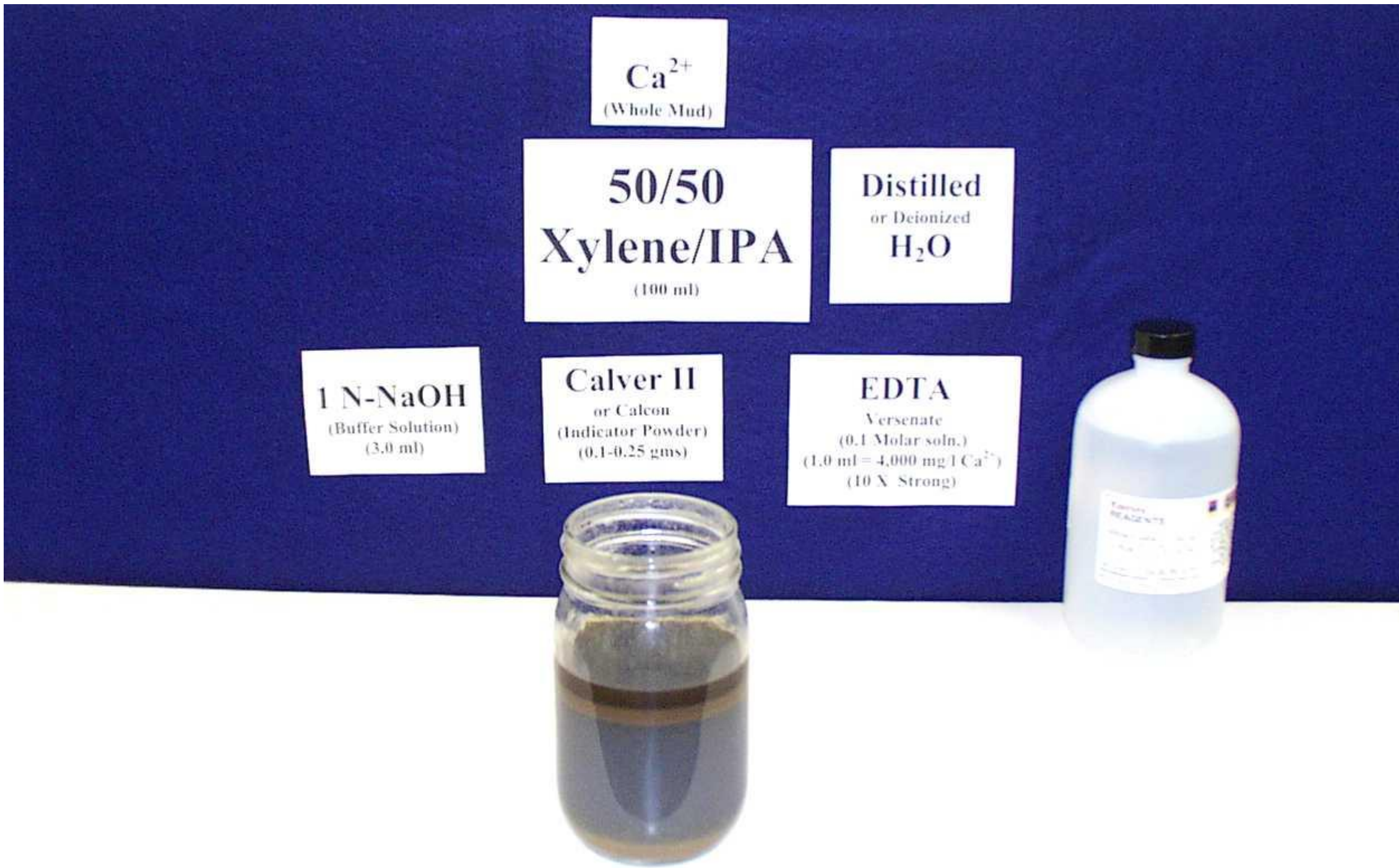
Courtesy of Fann Instrument Company

Chlorides (whole mud) - Color change



Courtesy of Fann Instrument Company

Calcium (whole mud) - Color change



Courtesy of Fann Instrument Company

Effects of Contaminants

Contaminant – Anything that causes undesirable changes in mud properties

Water-Based Drilling Fluids

Contamination

Major Contaminants of WBM

- Solids (Cuttings), especially clays
- Bicarbonate (HCO_3^-)
- Carbonate ($CO_3^=$)
- Sodium Chloride (NaCl)
- Cement
- Anhydrite ($CaSO_4$)
- Hydrogen Sulfide (H_2S)

Contamination Examples

Solids Contamination

Sample Daily Mud Check		
	Mud Properties	
Sample From	Flowline	Flowline
Time Sample Taken	06:00	09:45
Flowline Temperature (F)	120	125
Depth (ft)	8788	8999
Mud Weight (ppg)	14.1	14.4
Funnel Viscosity (sec/qt)	47	58
Plastic Viscosity (cP)	33	56
Yield Point (lbf/100ft2)	6	17
Gel Strength 10 sec/10 min (lbf/100 ft2)	6/10	4/32
Filtrate API (ml/30 min)	8	13
Filtrate HTHP (ml/30 min) @250F	17.6	22
API Cake Thickness (32nd inch)	2	4
Retort Solids Content (vol%)	16	20
Retort Liquid Content (Oil vol%/Water vol%)	0/84	0/80
Sand Content (vol%)	Tr	Tr
MBT (lb/bbl equiv)	3.5	5
pH (strip)	10	9.5
Alkalinity Mud (Pm) (ml of N50 Sulf Acid/ml mud)	1.6	1.1
Alkalinity Filtrate (Pf/Mf) (ml of N50 Sulf Acid/ml mud)	1.0/2.4	0.8/1.9
Chlorides (mg/L)	4,000	4,000
Total Hardness as Calcium (mg/L)	200	200

Solids Contamination (Clay/Shale)

- Identification
  - Total Solids and Low-Gravity Solids (LGS) increase
  - MBT increases
  - Alkalinity (Pf and Mf) decreases
- Treatment
  - Optimize or reconfigure Solids Control Equipment
  - Dilute with base fluid (water, produced brine)
  - Disperse with thinners/deflocculants (may need pH raised)
  - Add Fluid Loss Control product

Contamination Examples

Bicarbonate Contamination

Sample Daily Mud Check		
	Mud Properties	
Sample From	Flowline	Flowline
Time Sample Taken	06:00	09:45
Flowline Temperature (F)	120	125
Depth (ft)	8788	8999
Mud Weight (ppg)	15	15
Funnel Viscosity (sec/qt)	47	74
Plastic Viscosity (cP)	33	55
Yield Point (lbf/100ft2)	11	34
Gel Strength 10 sec/10 min (lbf/100 ft2)	3/10	21/49
Filtrate API (ml/30 min)	8	16.8
Filtrate HTHP (ml/30 min) @250F	17.6	28
API Cake Thickness (32nd inch)	2	4
Retort Solids Content (vol%)	25	25
Retort Liquid Content (Oil vol%/Water vol%)	0/75	0/75
Sand Content (vol%)	Tr	Tr
MBT (lb/bbl equiv)	4	4
pH (strip)	10.5	8.8
Alkalinity Mud (Pm) (ml of N50 Sulf Acid/ml mud)	1.6	0.7
Alkalinity Filtrate (Pf/Mf) (ml of N50 Sulf Acid/ml mud)	1.2/3.1	1.1/17.4
Chlorides (mg/L)	4,000	4,000
Total Hardness as Calcium (mg/L)	200	0

Bicarbonate Contamination

- Identification
  - No Calcium (Ca^{2+})
  - Pf is low
  - Mf is high
  - Fluid Loss increases
  - Gel Strength increases
- Treatment
  - Usually caused by over-treatment with sodium bicarbonate ($NaHCO_3$) prior to drilling cement or influx of CO_2
  - Maintain 150 to 200 mg/L total hardness in the filtrate to buffer the problem so that it does not reoccur. This is usually easy to obtain with lime treatments, so add lime ($Ca(OH)_2$) to pH 9.5 to 10.0. It may be necessary to supplement the lime with caustic soda (NaOH).
  - Add thinners to chemically disperse clays and provide better rheology control
  - Add water to offset dehydration

Contamination Examples

Carbonate Contamination

Sample Daily Mud Check		
	Mud Properties	
Sample From	Flowline	Flowline
Time Sample Taken	06:00	09:45
Flowline Temperature (F)	120	125
Depth (ft)	8788	8999
Mud Weight (ppg)	15	15
Funnel Viscosity (sec/qt)	47	74
Plastic Viscosity (cP)	33	55
Yield Point (lbf/100ft2)	11	32
Gel Strength 10 sec/10 min (lbf/100 ft2)	4/11	21/43
Filtrate API (ml/30 min)	8	16.8
Filtrate HTHP (ml/30 min) @250F	17.6	28
API Cake Thickness (32nd inch)	2	4
Retort Solids Content (vol%)	25	25
Retort Liquid Content (Oil vol%/Water vol%)	0/75	0/75
Sand Content (vol%)	Tr	Tr
MBT (lb/bbl equiv)	4	4
pH (strip)	9.5	10.8
Alkalinity Mud (Pm) (ml of N50 Sulf Acid/ml mud)	1.6	0.7
Alkalinity Filtrate (Pf/Mf) (ml of N50 Sulf Acid/ml mud)	1.2/3.1	8/17.4
Chlorides (mg/L)	4,000	4,000
Total Hardness as Calcium (mg/L)	200	0

Carbonate Contamination

- Identification
  - Gel strengths are high
  - Fluid loss is high
  - Alkalinity (Pf and Mf) is high
  - No calcium most of the time
- Cause
  - Problem may be induced through addition of excess soda ash to treat make-up water for removal of hardness
  - Avoid over-treatment by controlling total hardness of filtrate between 150 and 200 mg/L
  - Do not pre-treat system with large amounts of soda ash

Carbonate Contamination (Cont'd)

➢ Treatment

- Add gypsum, or gyp ($CaSO_4 \cdot 2H_2O$), to remove carbonate by precipitating it as $CaCO_3$, and adjust pH to 9.5-10.5 with lime or caustic soda
- Monitor total lb/bbl of gyp added to the system. Too much $SO_4^=$ in system will cause viscosity problems (see Anhydrite Contamination)
- Add thinners as needed for chemical dispersion
- Add water to offset dehydration
- When acid gas continues to contaminate the fluid, the normal reaction is to add caustic soda (NaOH), thus forming $CO_3^=$ and HCO_3^-, depending on pH
- Lime and gyp can be added together to achieve the proper pH and to precipitate $CaCO_3$ from the system

Contamination Examples

Salt Contamination

Sample Daily Mud Check		
	Mud Properties	
Sample From	Flowline	Flowline
Time Sample Taken	06:00	09:45
Flowline Temperature (F)	120	125
Depth (ft)	8788	8999
Mud Weight (ppg)	14.6	14.7
Funnel Viscosity (sec/qt)	44	67
Plastic Viscosity (cP)	33	56
Yield Point (lbf/100ft2)	7	22
Gel Strength 10 sec/10 min (lbf/100 ft2)	4/8	13/18
Filtrate API (ml/30 min)	8	16.8
Filtrate HTHP (ml/30 min) @250F	17.6	38
API Cake Thickness (32nd inch)	2	6
Retort Solids Content (vol%)	20	23
Retort Liquid Content (Oil vol%/Water vol%)	0/80	0/77
Sand Content (vol%)	Tr	Tr
MBT (lb/bbl equiv)	4	4
pH (strip)	10	9
Alkalinity Mud (Pm) (ml of N50 Sulf Acid/ml mud)	1.8	1.1
Alkalinity Filtrate (Pf/Mf) (ml of N50 Sulf Acid/ml mud)	1.0/2.4	0.7/1.8
Chlorides (mg/L)	4,000	28,600
Total Hardness as Calcium (mg/L)	200	420

Salt (NaCl) Contamination

- Identification
  - API and HTHP Filtration (fluid loss) increase
  - pH drops
  - Alkalinity (Pf and Mf) drop
  - [Cl^-] increases
  - Hardness ([Mg^{2+}] and [Ca^{2+}]) also increases if other salts are mixed with the NaCl
- Treatment
  - Treat with thinners to reduce viscosity, gel strength and yield point
  - Adjust pH with caustic soda
  - Add polymers for filtration (fluid loss) control
  - If the salt concentration is maintained, or the system is broken over to a saturated salt system, pre-hydrated bentonite or polymers must be used to maintain viscosity
  - If the clay solids content (LGS) of the fluid is too high, dilution with water may also be necessary.

Contamination Examples

Cement Contamination

Sample Daily Mud Check		
	Mud Properties	
Sample From	Flowline	Flowline
Time Sample Taken	06:00	09:45
Flowline Temperature (F)	120	125
Depth (ft)	8788	8999
Mud Weight (ppg)	15	15
Funnel Viscosity (sec/qt)	41	69
Plastic Viscosity (cP)	32	39
Yield Point (lbf/100ft2)	11	28
Gel Strength 10 sec/10 min (lbf/100 ft2)	4/6	12/25
Filtrate API (ml/30 min)	8	16.8
Filtrate HTHP (ml/30 min) @250F	17.6	40
API Cake Thickness (32nd inch)	2	4
Retort Solids Content (vol%)	17	17
Retort Liquid Content (Oil vol%/Water vol%)	0/83	0/83
Sand Content (vol%)	0.5	0.5
MBT (lb/bbl equiv)	4	4
pH (strip)	9.5	11.8
Alkalinity Mud (Pm) (ml of N50 Sulf Acid/ml mud)	1.6	6.7
Alkalinity Filtrate (Pf/Mf) (ml of N50 Sulf Acid/ml mud)	1.2/3.1	5.1/5.8
Chlorides (mg/L)	4,000	4,000
Total Hardness as Calcium (mg/L)	80	480

Cement Contamination

- **Identification**
  - API and HTHP fluid loss increase
  - pH is high
  - Pm and Pf are high
  - Calcium is high
- **Treatment**
  - Add baking soda (sodium bicarbonate, or $NaHCO_3$) to precipitate calcium. Control total hardness of the filtrate between 150 and 200 mg/L to avoid over-treatment. Note: baking soda will reduce the pH.
  - Add thinners for rheology control.
  - Add water to offset dehydration, and barite to maintain mud weight.

Contamination Examples

Anhydrite Contamination

Sample Daily Mud Check		
	Mud Properties	
Sample From	Flowline	Flowline
Time Sample Taken	06:00	09:45
Flowline Temperature (F)	120	125
Depth (ft)	8788	8999
Mud Weight (ppg)	15	15
Funnel Viscosity (sec/qt)	41	61
Plastic Viscosity (cP)	32	39
Yield Point (lbf/100ft2)	11	37
Gel Strength 10 sec/10 min (lbf/100 ft2)	4/8	12/28
Filtrate API (ml/30 min)	8	16.8
Filtrate HTHP (ml/30 min) @250F	17.6	40
API Cake Thickness (32nd inch)	2	4
Retort Solids Content (vol%)	25	24
Retort Liquid Content (Oil vol%/Water vol%)	0/75	0/75
Sand Content (vol%)	Tr	Tr
MBT (lb/bbl equiv)	4	4
pH (strip)	10.9	8.5
Alkalinity Mud (Pm) (ml of N50 Sulf Acid/ml mud)	1.6	0.7
Alkalinity Filtrate (Pf/Mf) (ml of N50 Sulf Acid/ml mud)	1.2/3.1	0.2/11
Chlorides (mg/L)	4,000	4,000
Total Hardness as Calcium (mg/L)	80	800

Anhydrite Contamination

- Identification
  - API and HTHP fluid loss increase
  - pH decreases
  - Pm and Pf decrease
  - Calcium increases
- Treatment
  - A common method of drilling anhydrite formations is to adjust the pH to 9.5 and add thinners, while maintaining a low MBT. With this method, a gyp mud can be built and its fluid loss controlled with polymers.
  - It is usually uneconomical to treat calcium out of a heavily contaminated system, but it may be controlled by adding soda ash (Na_2CO_3) if $pH < 9.5$ or bicarb ($NaHCO_3$) if $pH \geq 9.5$. After adding soda ash, a chemical dispersant is usually necessary to reduce viscosity and gel strength.

Contamination Examples

H_2S Contamination

Sample Daily Mud Check		
	Mud Properties	
Sample From	Flowline	Flowline
Time Sample Taken	06:00	09:45
Flowline Temperature (F)	120	125
Depth (ft)	8788	8999
Mud Weight (ppg)	15	15
Funnel Viscosity (sec/qt)	47	64
Plastic Viscosity (cP)	33	47
Yield Point (lbf/100ft2)	8	17
Gel Strength 10 sec/10 min (lbf/100 ft2)	4/11	17/22
Filtrate API (ml/30 min)	6	16.8
Filtrate HTHP (ml/30 min) @250F	14	24
API Cake Thickness (32nd inch)	2	4
Retort Solids Content (vol%)	25	25
Retort Liquid Content (Oil vol%/Water vol%)	0/75	0/75
Sand Content (vol%)	Tr	Tr
MBT (lb/bbl equiv)	4	4
pH (strip)	10.5	8.5
Alkalinity Mud (Pm) (ml of N50 Sulf Acid/ml mud)	1.6	0.5
Alkalinity Filtrate (Pf/Mf) (ml of N50 Sulf Acid/ml mud)	1.2/3.1	0.1/0.3
Chlorides (mg/L)	4,000	4,000
Total Hardness as Calcium (mg/L)	200	0

H_2S Contamination

- Identification
  - H_2S gas in filtrate or mud
  - API and HTHP fluid loss increase
  - All viscosity parameters may increase
  - pH decreases
  - Alkalinity decreases
  - Calcium decreases a little
- Treatment
  - Add Triazine or zinc carbonate ($ZnCO_3$):

    $$ZnCO_3 + H_2S \Leftrightarrow ZnS + H_2CO_3$$
  - Add starch or polymers to reduce fluid loss
  - Add water for dehydration
  - Add lime/caustic soda to adjust pH to > 10 and maintain Pf > 6

WBM Contamination

- Did you notice what properties increased in every example?
- Physical properties of the mud increased in all of these contamination examples
- Key to determining what kind of contamination - analyze the chemical properties of the mud to narrow down on the specific type of contamination
- MBT level typically has large affect on contamination severity

Summary of Contaminant Effects & Treatment

Contaminant		WT	FV	PV	YP	Gels	FL	pH	P_m	P_f	M_f	Cl^-	Ca^{2+}	Solids	Treatment
Cement		—	↑	—	↑	↑	↑	↑	↑	↑	↑	—	↑pH↓ 11.5	—	Bicarb, or SAPP, or thinner, bicarb and citric acid
Gypsum or anhydrite		—	↑	—	↑	↑	↑	↓	↓	↓	↓	—	↑	—	Caustic, dilution water and thinner, or soda ash (plus fluid-loss polymer)
Salt		—	↑	—	↑	↑	↑	↓	↓	↓	↓	↑	↑↗	—	Caustic, dilution water, thinner and fluid-loss polymer
Carbonate or bicarbonate		—	↑	—	↑	↑	↗	↓	↓	↗→	↑	—	↓	—	pH <10.3: lime pH 10.3 to 11.3: lime and gyp pH >11.3: gyp
H_2S		—	↑	—	↑	↑	↑	↓	↓	↓	↓	—	↗	—	Caustic, lime and zinc source (zinc oxide)
Solids	Old	↗	↗	↗	—	↗	—	—	—	—	—	—	—	↑	Dilution water and solids-removal equipment
	New	↗	↗	↗	↗	↗	↗	↘	↘	↘	↘	↗	↗	↑	Dilution water, solids-removal equipment and thinner

↑ *Increase* ↓ *Decrease* — *No change* ↗ *Slight increase* ↘ *Slight decrease*

Additional Details of Treatments for Contaminants

Contaminant	Contaminating Ion	Treatment	Treating Concentration (lb/bbl)
Carbon dioxide	Carbonate Bicarbonate	Gyp to reduce pH Lime to raise pH Lime to raise pH	mg/l x F_W x 0.00100 mg/l x F_W x 0.000432 mg/l x F_W x 0.00424
Gypsum and anhydrite	Calcium	Soda ash SAPP Sodium bicarbonate	mg/l x F_W x 0.000928 mg/l x F_W x 0.000971 mg/l x F_W x 0.00735
Lime or cement	Calcium and hydroxyl	Sodium bicarbonate SAPP Citric acid	lb/bbl excess lime x 1.135 lb/bbl excess lime x 1.150 lb/bbl excess lime x 1.893
Hard or seawater	Calcium and magnesium	Caustic soda	mg/l x F_W x 0.00116
Hydrogen sulfide	Sulfide (H_2S, HS^-, S^{2-})	Zinc oxide* plus sufficient caustic soda to maintain the pH above 10.5	mg/l x F_W x 0.00091

*Other zinc compounds such as chelated zinc or zinc carbonate may also be used. An excess should always be maintained in the system.
NOTES:
1. F_w is the fractional % of water from retort.
2. Excess lime = 0.26 (P_M – (P_f x F_w)).

Non-Aqueous Drilling Fluids

Contamination

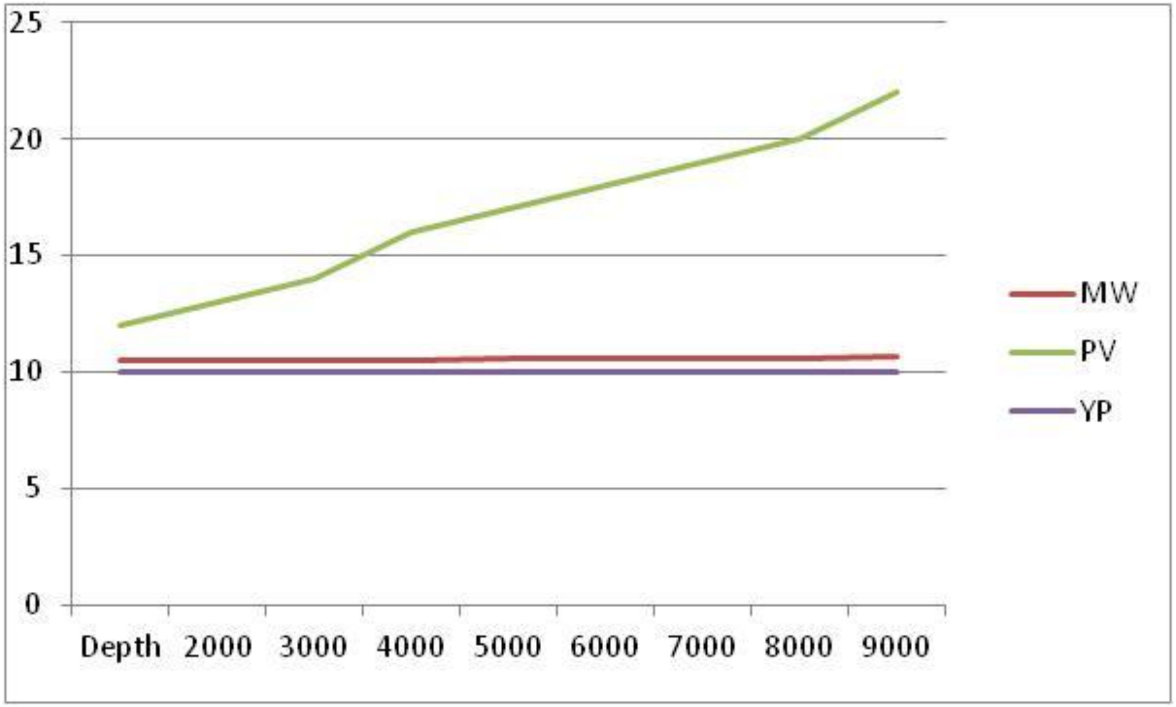
Major Contaminants of NADF

- Solids
- Salt Water
- Fresh Water
- CO_2

Contamination Examples

What contamination caused this?

Ultra-Fines Build-up



Solids Contamination

- Identification
  - Total Solids increase
  - Viscosity parameters increase
  - ES changes
- Treatment
  - Optimize or reconfigure Solids Control Equipment
  - Add emulsifier and/or oil-wetting agent
  - Dilute with base fluid

Contamination Examples

Salt Water Contamination

Sample Daily Mud Check		
	Mud Properties	
Sample From	Day 1	Day 2
Flowline Temperature (F)	120	128
Depth (ft)	8788	8999
Mud Weight (ppg)	12	11.6
Funnel Viscosity (sec/qt)	65	97
Plastic Viscosity (cP)	32	53
Yield Point (lbf/100ft2)	18	29
Gel Strength 10 sec/10 min (lbf/100 ft2)	7/11	9/19
Filtrate HTHP (ml/30 min) @250F	4	6.5
Retort Oil Content (vol%)	54	47
Retor Water Content (vol%)	18	28
Retort Solids Content (vol%)	28	25
Alkalinity (Pom) (ml)	2.1	1.8
Chlorides (Clom) (mg/L)	38,000	27,000
Calcium (mg/L)	18,500	10,200
Electrical Stability (v)	485	136

Saltwater Contamination

- Identification
  - O/W ratio decreases
  - Chlorides decrease
  - Viscosity parameters increase
  - ES decreases
  - HTHP Fluid Loss increases
  - Whole mud alkalinity (Pm) may drop
- Treatment
  - Add base fluid to adjust O/W ratio back to spec
  - Increase concentration of solute – usually $CaCl_2$ – in internal phase to raise Water Phase Salinity (WPS)
  - Add lime to adjust Pm upward
  - May need to add emulsifier

Contamination Examples

Fresh Water Contamination

Sample Daily Mud Check		
	Mud Properties	
Sample From	Day 1	Day 2
Flowline Temperature (F)	120	128
Depth (ft)	8788	8999
Mud Weight (ppg)	12	11.6
Funnel Viscosity (sec/qt)	65	97
Plastic Viscosity (cP)	32	53
Yield Point (lbf/100ft2)	18	29
Gel Strength 10 sec/10 min (lbf/100 ft2)	7/11	9/19
Filtrate HTHP (ml/30 min) @250F	4	6.5
Retort Oil Content (vol%)	54	47
Retor Water Content (vol%)	18	28
Retort Solids Content (vol%)	28	25
Alkalinity (Pom) (ml)	2.1	1.8
Chlorides (Clom) (mg/L)	38,000	18,200
Calcium (mg/L)	18,500	9,418
Electrical Stability (v)	485	136

Fresh Water Contamination

- Identification
  - O/W ratio decreases
  - Chlorides decrease substantially, along with Ca^{2+} (if $CaCl_2$ is used in internal phase)
  - Viscosity parameters increase
  - ES decreases
  - HTHP Fluid Loss increases
  - Whole mud alkalinity (Pm) may drop
- Treatment
  - Add base fluid to adjust O/W ratio back to spec
  - Add $CaCl_2$ to raise the Water Phase Salinity (WPS)
  - Add lime to increase Pm
  - May need to add emulsifier

Contamination Examples

CO_2 Contamination

Sample Daily Mud Check		
	Mud Properties	
Sample From	Day 1	Day 2
Flowline Temperature (F)	120	128
Depth (ft)	8788	8999
Mud Weight (ppg)	12	12
Funnel Viscosity (sec/qt)	65	66
Plastic Viscosity (cP)	32	34
Yield Point (lbf/100ft2)	18	19
Gel Strength 10 sec/10 min (lbf/100 ft2)	7/11	7/11
Filtrate HTHP (ml/30 min) @250F	4	6.5
Retort Oil Content (vol%)	54	54
Retor Water Content (vol%)	18	18
Retort Solids Content (vol%)	28	28
Alkalinity (Pom) (ml)	2.1	0
Chlorides (Clom) (mg/L)	38,000	38,000
Calcium (mg/L)	18,500	18,400
Electrical Stability (v)	485	319

CO_2 Contamination

- Identification
  - Whole mud alkalinity (Pom) (excess lime) drops to zero
  - ES decreases
  - HTHP Fluid Loss increases
- Treatment
  - Add lime to increase Pom

Troubleshooting OBM/SBM (NADF)

Insufficient Viscosity

Cause	Treatment
Undertreatment of viscosifier	Add organophilic clay
Lack of proper particle size distribution	Add rheology modifiers
Low Water Content	Add water (brine)
New mud, lack of shear	Shear through bit or shear unit
Gas stripping	Increase mud weight
	Add wetting agent
	Add primary emulsifier and lime

Troubleshooting OBM/SBM (NADF)

Excessive Viscosity

Cause	Treatment
High water content (saltwater flow)	Dilute with base fluid
	Add primary emulsifier and lime
	Add wetting agent
	Add OBM thinner/dispersant
Incorporated drill solids	
1. High solids (% volume)	Centrifuge/solids control
	Use dilution
	Add wetting agent
	Add OBM thinner/dispersant
2. Fines solids problem	Centrifuge/solids control
	Use dilution
	Add wetting agent
	Add OBM thinner/dispersant
3. Water-wet solids	Add wetting agent and primary emulsifier
	Decrease water content
	Reduce solids content
High-temperature instabililty	Add wetting agent and primary emulsifier
	Decrease water content
	Reduce solids content
Acid gases	Add lime (conventional system)
	Add primary emulsifier and wetting agent
	Increase mud weight
	If H2S, add H2S scavenger
Overtreatment	Dilute with base fluid

Troubleshooting OBM/SBM (NADF)

Increase in HTHP Fluid Loss

Cause	Treatment
Weak emulsion	Add primary emulsifier
	Add lime (conventional system)
Lack of proper particle size distribution	Add fluid loss additive
	Add organophilic Clay
	Add weight material or bridging agent
High-temperature instability	Add primary emulsifier and wetting agent
	Add lime (conventional system)
	Add fluid loss additive

Water in HTHP Filtrate

Cause	Treatment
Weak emulsion	Add primary emulsifier and wetting agent
	Add lime (conventional system)
High-temperature instability	Add primary emulsifier
	Add lime (conventional system)
	Add fluid loss additive

Troubleshooting OBM/SBM (NADF)

Water-Wet Solids

Cause	Treatment
Super-saturation	Add emulsifier and wetting agent
	Add OBM thinner/dispersant
	Add water sparingly
Excessive solids	Use soids control and dilution with base fluid
	Adding wetting agent
	Add OBM thinner/dispersant
Undertreatment	Add primary emulsifier and wetting agent
	Add OBM thinner/dispersant

Troubleshooting OBM/SBM (NADF)

Shaker Screen Blinding

Cause	Treatment
Water-wet solids	Add wetting agent
	Add primary emulsifier
	Add OBM thinner/dispersant

Water Flow

Cause	Treatment
Decrease in OWR (water intrusion)	Increase mud weight
Decrease in mud weight	Increase mud weight
	Add primary emulsifier and wetting agent
	Add lime (conventional system)
	Add base fluid to adust OWR
	Add salt to adjust brine salinity

Troubleshooting OBM/SBM (NADF)

Carbon Dioxide Contamination

Indicator	Treatment
P_{OM} decrease	Increase mud weight
	Add lime
Rheology increase	Add primary emulsifier and wetting agent
	Add base fluid for dilution
	Increase mud weight
	Add lime

Hydrogen Sulfide Contamination

Indicator	Treatment
P_{OM} decrease	Increase mud weight
or Foul odor	Add lime
or Mud turns black	Add primary emulsifier and wetting agent
or Drill pipe turns black	Add H_2S scavenger


Thank You