WELCOME
TO

PE69002: Drilling Technology Laboratory
Spring 2024-2025

Deysarkar Centre of Excellence in Petroleum Engineering
Indian Institute of Technology Kharagpur
Kharagpur, West Bengal, INDIA - 721302

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- Introduction to Drilling Technology(DT) Laboratory
- Mandatory safety rules to be followed in the Lab
- DT Laboratory Experiments with Schedule, Evaluation Process
- Experiments:
- Design & Preparation of WBM Drilling Fluid using Hamilton Beach Mixture.

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S.I No.	Date of Event	Event of Drilling Technology Laboratory
1	16.01.2025	Introduction; Design and preparation of WBM
2	16.01.2025	Mud Balance
3	23.01.2025	pH Meter
4	30.01.2025	Preparation of WBM; 6-Speed Viscometer & Marsh Funnel
5	06.02.2025	Preparation of WBM; 6-Speed Viscometer & Marsh Funnel
6	13.02.2025	Preparation of WBM; Methylene Blue Test & Alkalinity
7	20.02.2025	**Laboratory Exam**
8	27.02.2025	Preparation of WBM; Methylene Blue Test & Alkalinity
9	06.03.2025	Preparation of WBM; Chlorides & Total Hardness
10	13.03.2025	Preparation of WBM; Total Hardness & Chlorides
11	20.03.2025	Preparation of WBM; LTLP Filter Press & Completion brine test (hydrometer)
12	27.03.2025	Preparation of WBM; LTLP Filter Press & Completion brine test (hydrometer)
13	03.04.2025	Preparation of OBM; Emulsion Stability Meter & Retort Kit
14	10.04.2025	Holiday
15	17.04.2025	Preparation of OBM; Retort Kit & Emulsion Stability Meter
16	21.04.2025	**END TERM LABORATORY EXAM**

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Serial Number	Aim of the Experiment	Equipment	Date/Day	TA
01	Design & Preparation of WBM drilling fluids	Hamilton Beach Mixer(AJD)	16.01.2025	AS/SM/MSA/AJD
02	To determine the SG/Density of the drilling fluids.	Mud Balance (AJD)	16.01.2025	
03	To determine the pH of WBM drilling fluids	Digital pH Meter (SM)	**23.01.2025**	
04	To determine the Rheology of the drilling fluid.	6 – Speed Viscometer(AKS)	30.01.2025	
05	To measure the viscosity of drilling fluid using Marsh Funnel Viscometer	Marsh Funnel(MSA)	06.02.2025	MSA/SM/AKS/AJD
06	To determine the Calcium, Magnesium & Chlorides in drilling fluid	Titration Method (AKS)	13.02.2025	
07	To find the Alkalinity in drilling fluid and in filtrate of drilling fluid	Titration Method (AKS)	27.02.2025	
08	To determine the Cation Exchange Capacity of drilling fluid	Methylene Blue Test(MSA)	06.03.2025	
09	To determine the total hardness in drilling fluid	Titration Method (SM)	13.03.2025	
10	To determine the fluid loss of the drilling fluid	LTLP API filtration apparatus(AKS/JM)	20.03.2025	
11	To measure the relative electrical strength of drilling fluid	Emulsion Stability Meter(MSA)	27.03.2025	MSA/SM/AS/AJD
12	To determine the volumes of Water, Oil and Solids in drilling fluid	Retort Kit(AJD)	03.04.2025	
13	To determine the sand content in the drilling fluid	Sand Content Kit(AKS)	17.04.2025	

EXAMINATION SCHEDULE & EVALUATION PROCESS:

S. No.	Date	Day	Examination	Examination Mode	Weightage (%)
1	20.02.2025	Wednesday	MID TERM	Viva	30
2	21.04.2025	Wednesday	END TERM	Experiment	50
Term Exam Total					80
3	Weekly Lab Record & Assignment				10
4	Attendance				10
Grand Total					100

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Group Distribution:

Group A	Group B	Group C	Group D
Adarsh Tripathi	Prashil Meshram	Sahil Katewa	Ritik Chaturvedi
Sumit Maity	Mohit Kumar Meena	Ashish Ranjan	Tapas Ghosh
Saptarsi Das	Krish Mahendra Khant	Neelarghya Kundu	Doddi Poorna Chandra
Thakre Himanshoo Rajeshkumar	Ayush Singh	Arka Prava Mandal	Sohan Dash
Mayank Sagar	Jatin Enkhia	Aakanksha Raj	Atul Kumar
			Gunupuru Lohitakshay

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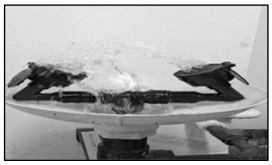
MANDATORY SAFETY RULES:

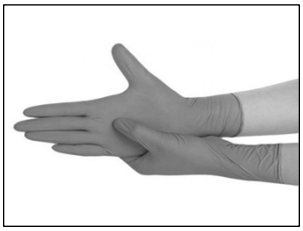
Eye Protection Goggles



Eye Shower

Apron

Fire Extinguisher



Hand Protection Safety Gloves

Safety Shoes

- **Proper safety attire is mandatory in all laboratory classes**
- **HTHP Guidelines to be followed**

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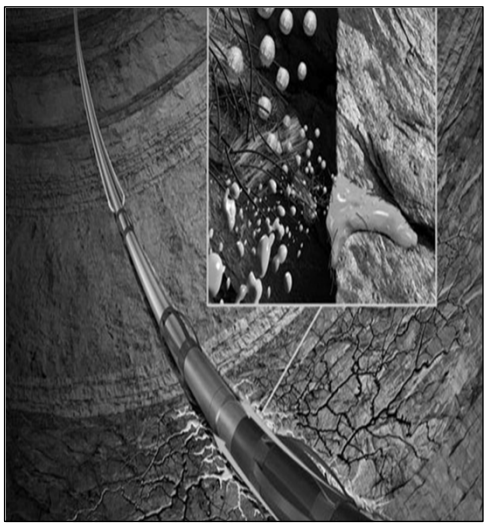
Introduction to Drilling Fluids

Definition: Drilling fluid also called drilling mud, used to aid the drilling of oil and natural gas wells and on exploration drilling rigs.



Key functions:

- Transport cuttings & caving's to surface
- Control subsurface pressures
- Help suspend weight of drill string and casing
- Cool and lubricate bit and drill string
- Provide wellbore stability
- Minimize formation damage
- Provide medium for wireline log
- Facilitate cementing & completion

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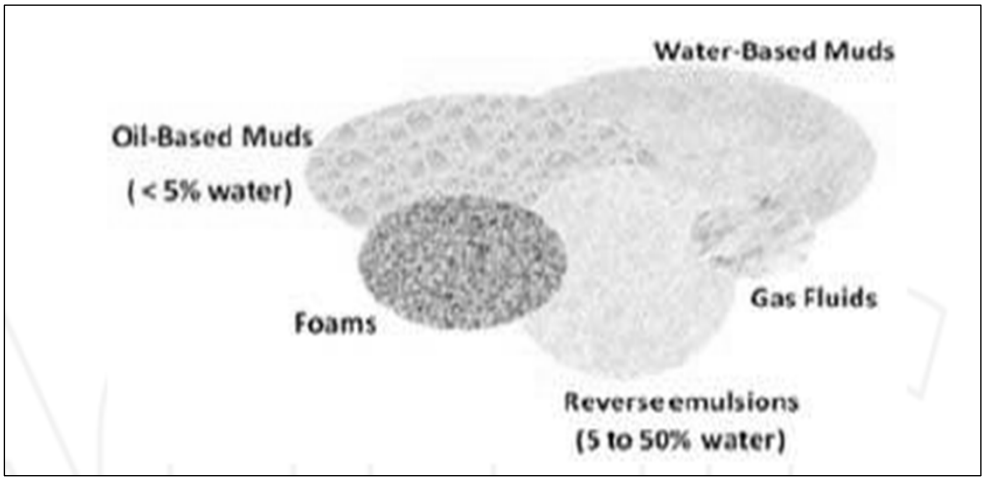

Fig1 : Drilling Fluid Composition

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Background: Drilling Fluids Additives

Water Base

- Base fluid: clear water or brines NaCl, $CaCl_2$, $CaBr_2$
- Viscosifiers: Clay (bentonite, hectorite), polymers
- Filtration control agents
- Shale stabilizers
- Weighting agents: Low gravity solids (~2.7sg) High gravity solids(~4.2 sg)

Oil Base

- Base fluid: Isomeric olefins, diesel, esters etc.
- Emulsifiers
- Water (or Brine) [Oil/water ratio: 60:40 to 95:5]
- Viscosifiers: organophilic clays, polymers
- Filtration control agents
- Weighting agents: Low gravity solids High gravity solids

We want to keep the commercial solids

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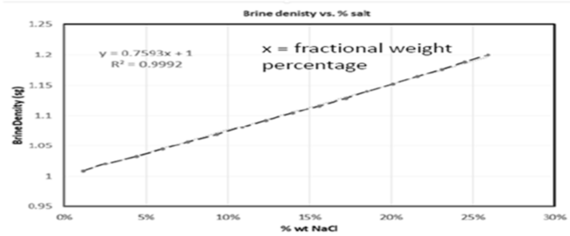
Fluid Formulation Recipe: WBM

➢ **Formulae : Density table, Volume Balance and Mass Balance, ASG**

❑ **Brine Density Correction** : e.g. NaCl

Density (ppg)	Specific Gravity	ppm NaCl	% by Weight of NaCl
8.4	1.008	11,338	1.1%
8.5	1.020	25,210	2.5%
8.6	1.032	44,297	4.4%
8.7	1.044	60,208	6.0%
8.8	1.056	75,758	7.6%
8.9	1.068	93,633	9.4%
9.0	1.080	1,08,466	10.8%
9.1	1.092	1,22,972	12.3%
9.2	1.104	1,39,752	14.0%
9.3	1.116	1,56,170	15.6%
9.4	1.128	1,72,239	17.2%
9.5	1.140	1,85,464	18.5%
9.6	1.152	2,00,893	20.1%
9.7	1.164	2,16,004	21.6%
9.8	1.176	2,30,807	23.1%
9.9	1.188	2,45,310	24.5%
10.0	1.200	2,59,524	26.0%



❑ **Brine Volume Correction: Consider 100 g of brine solution**

$$\frac{V_{Br}}{V_w} = \frac{(\frac{100}{\rho_{Br}/8.345})}{(100 - salt\_wt\%)} \quad (\rho_{Br} \text{ in lbm/gal})$$

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Fluid Formulation: WBM

➢ **Formulae : Density table, Volume Balance and Mass Balance, ASG**

❑ Brine density & volume correction

❑ $\sum V_i = V_{Br} + V_{adt} + V_{wt} = 1.$

V_{Br} , V_{adt} , V_{wt} are volume fractions of brine, additives and weighting material respectively.

❑ $\sum \rho_i V_i = V_{Br} * \rho_{Br} + V_{adt} * \rho_{adt} + V_{wt} * \rho_{wt} =$ MW (ppg)/8.345

ρ_{Br} , ρ_{adt} , ρ_{wt} are densities (g/cm³) of brine, additives and weighting material respectively.

❑ ASG (Average specific gravity of solids)

ASG = $\frac{V_{LGS}*\rho_{LGS}+V_{wt}*\rho_{wt}}{V_{LGS}+V_{wt}}$

	Field Unit	Multiplied by	Equals Metric Unit
For Fluid density →	Pounds (mass) per gallon (lb/gal)	0·120	grams/cm³
For component concentration →	1 pound per barrel (lbm/bbl)	1	g/(350 ml)

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- **Formulate** the required amount of ***Water, Salt, Viscosifier, Weighting material, Additives & LGS*** as required.
- **Clean/Wipe** the ***mechanical stirrer*** properly before inserting into mixing container.
- **Measure** all ***the liquid components*** using measuring cylinder and solid components using properly balanced weighting balance for accuracy.
- **Add** the required amount of ***wate***r into mixing container.
- **Add** the required amount of ***Salt*** into the ***water and mix @ LOW SPEED*** for ***90 seconds***.
- **Add** the required amount of ***Viscosifier, Additives, LGS & Weighting*** material in proper order with a time interval of ***5 minutes*** after every addition of single component

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- **Continue** the mixing until uniformity is obtained.
- **Start** with ***LOW*** followed by ***MEDIUM*** and increase to ***HIGH SPEED*** for proper mixing based on the thickness of the ***MUD***.
- Once uniformity is attained stop mixing and remove the contents to separate container.
- **Rinse and clean** the ***mechanical stirrer*** properly.
- **Make sure** the ***RPM*** kept to ***zero*** before turning the ***mechanical stirrer*** **OFF** and then power **OFF** the main switch.

FORMULATION EXCERCISE: DESIGN & PREPARATION OF WBM DRILLING FLUIDS

GROUP A

Design recipe of 1 lb – bbl (350 ml) water – based mud with following specifications:

- Fluid Density – 15 ppg
- Salt (NaCl) – 250,000 ppm
- Weighting material (Barite) – 4.2 SG
- Additive details (density & concentration)

Name	Specific Gravity	Concentration (g/350 ml)
Viscosifier	1	1
Filtration Control agent	1.2	2
Low Gravity Solids	2.6	15

FORMULATION EXCERCISE : DESIGN & PREPARATION OF WBM DRILLING FLUIDS

GROUP B

Design recipe of 1 lb – bbl (350 ml) oil – based mud with following specifications:

- Fluid Density – 14 ppg
- Salt ($CaCl_2$) – 256,000 ppm; 1.248 SG
- Oil/Water Ratio: 70/30
- Weighting material (Barite) – 4.2 SG
- Additive details (density & concentration)

Name	Specific Gravity	Concentration (g/350 ml)
Viscosifier	1	2
Filtration Control agent	1.5	3
Low Gravity Solids	2.6	15
Emulsifier	1	8

FORMULATION EXCERCISE : DESIGN & PREPARATION OF WBM DRILLING FLUIDS

GROUP C

- Design recipe of 1 lb – bbl (350 ml) water – based mud with following specifications:
- Fluid Density – 11 ppg
- Salt (NaCl) – 75,000 ppm
- Weighting material (Barite) – 4.2 SG
- Additive details (density & concentration)

Name	Specific Gravity	Concentration (g/350 ml)
Viscosifier	1	1
Filtration Control agent	1.2	2
Low Gravity Solids	2.6	15

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FORMULATION EXCERCISE : DESIGN & PREPARATION OF WBM DRILLING FLUIDS

GROUP D

- Design recipe of 1 lb – bbl (350 ml) water – based mud with following specifications:
- Fluid Density – 9 ppg **10 ppg**
- Salt (NaCl) – 75,000 ppm
- Weighting material (Barite) – 4.2 SG
- Additive details (density & concentration)

Name	Specific Gravity	Concentration (g/350 ml)
Viscosifier	1	1
Filtration Control agent	1.2	2
Low Gravity Solids	2.6	15

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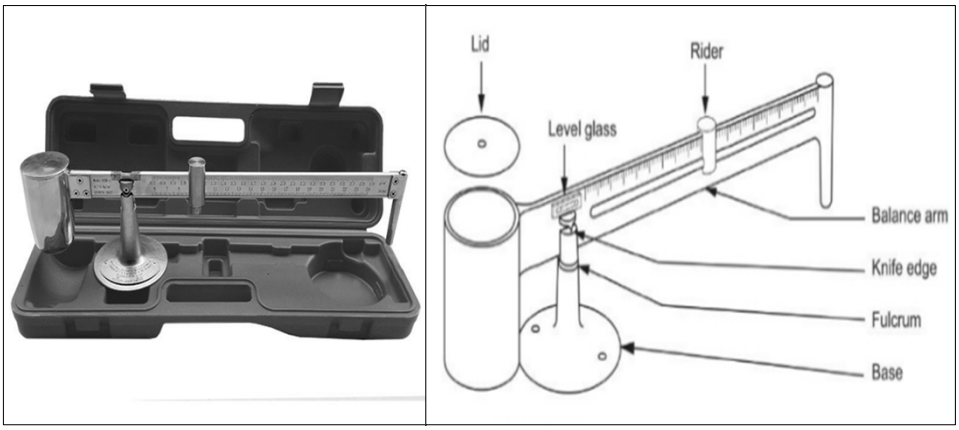
LAB EXPERIMENT: MUD BALANCE



To determine the SG/Density of a given drilling fluid sample

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WORKING PRINCIPLE OF MUD BALANCE:

- A cup of known volume and mass is attached to one end of the beam.
- Engineers fill the cup with drilling mud.
- The mass of the filled cup is balanced on the other end of the beam by a fixed countermass and a rider that can move freely along the graduated scale.

Considering balance of moments or torque, T about the fulcrum, if the distance travelled is greater, the output force is lessened.

$$T_1 = F_1 a, \quad T_2 = F_2 b$$

Where F1 is the input force to the lever and F2 is the output force. The distances *a* and *b* are the perpendicular distances between the forces and the fulcrum.

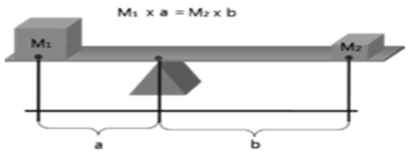

Fig 2: A Lever in balance

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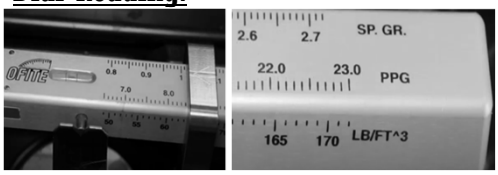
THEORY:

Density is defined as weight per unit volume. It is expressed either in pounds per gallon (lb/gal) or pounds per cubic foot (lb/ft3), or in kilograms per cubic meter (kg/m3), or compared to the weight of an equal volume of water, as specific gravity (SG). The pressure exerted by a static mud column depends on both the density and the depth. Mud Density is used to control subsurface pressures and stabilize the well bore. Mud density is commonly measured with a mud balance capable **of ±0.1 lb/gal accuracy**

Dial Reading:



Calculation:

A. Mud Weight (PSi/ft.) = Mud Weight (Sp. Gravity) * 0.433
B. Mud Weight (pcf) = Mud Weight (Psi/ft.) * 144
C. Mud Weight (kg/m3) = Mud Weight (Sp. Gravity) * 1000
D. Mud Weight (Psi/ft.) = Mud weight (ppg)*0.052

Procedure:

1. Remove the lid from the cup, and completely fill the cup with the mud to be tested
2. Put the lid on the top of the cup and rotate until firmly seated, making sure some mud is expelled through the hole in the lid.
3. Wipe the mud from the outside of the cup by using clean tissue paper.
4. Place the balance arm on the base, with the knife – edge resting on the fulcrum.
5. Move the rider until the graduated arm is level, indicated by the level bubble present on the beam. (Bubble should be in centre of the markings and steady).
6. At the left-hand edge of the rider, note down the density value with temperature without disturbing the rider.

Precautions:

1. Use separate dustbin to throw mud.
2. Clean everything after use.

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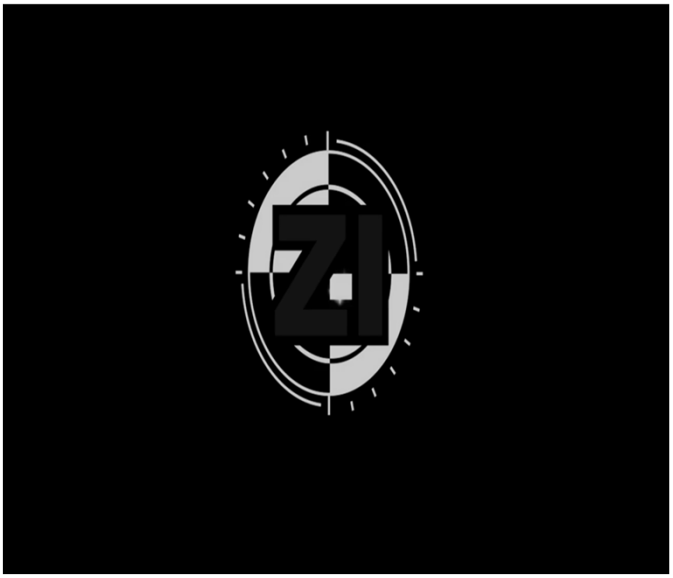
VIDEO OF MUD BALANCE EXPERIMENT:



Calibration Procedure:

The Mud Balance calibration can be checked using fresh water. At (21°C) fresh water should give a reading of 1.00 on the specific gravity scale psi/1000ft, 8.34 on the lb/gal scale, and 62.3 on the lb/cu ft scale.

- If the Mud Balance does not give the correct reading for fresh water then Replacing the lid on the balance cup with a new lid can cause the Mud Balance to be out of calibration.

Calibration frequency:

- Once a month

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ASSIGNMENT 01 (A): DESIGN & PREPARATION OF WBM DRILLING FLUIDS

Group-A Theory question	Group-B Theory question	Group-C Theory question	Group-D
1. Derive the Equation? $\frac{V_{Br}}{V_w} = \frac{(\frac{100}{\rho_{Br}/8.345})}{(100 - salt\_wt\%)}$			
2 Differentiate between water-based dispersed and non-dispersed systems?			
3.Arrange following additives in typical order of addition for a WBM formulation: Viscosifier, Salt, Weighting material			

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ASSIGNMENT 01(B): SG/DENSITY OF THE DRILLING FLUIDS

Group-A Theory question	Group-B Theory question	Group-C Theory question	Group-D
1. Which of the following is NOT a unit of density? a) Kg/m^3 b) N/m^3 c) $N.s^2/m^4$ d) g/cm^3			
2. It is necessary to mention the temperature at which specific gravity is calculated, because a) Mass of the substance changes with temperature b) Rigidity of the substance changes with temperature c) Density of the substance changes with temperature d) None of the above			
3. When measuring density of drilling/ cementing fluids, the mud-cup should NOT be tapped for removing air from the fluids. a) True b) False			
Numerical question 4. Determine the Hydrostatic pressure in Psi of well bore having 12 ppg mud weight and TVD is 11000 ft?	**Numerical question** 4. Determine the Hydrostatic pressure in Psi of well bore having 10 ppg mud weight and TVD is 7000 ft?	**Numerical question** 4. Determine the Hydrostatic pressure in Psi of well bore having 11 ppg mud weight and TVD is 9000 ft?	**Numerical question** 4. Determine the Hydrostatic pressure in Psi of well bore having 13 ppg mud weight and TVD is 10000 ft?

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