Settling of micronized barite particles in oil-based drilling fluids

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OUTLINE

1. Introduction: Oil-Based Drilling Fluid (OBDF)
2. Objective and Approach
3. Settling of micronized Barite, Barite and Clay in water (static column)
   - DP and Gamma densitometry
4. Synthesis and Rheological Properties of OBDF
5. Settling of micronized Barite (d_{50}=5-8 μm) OBDF (Static cell)
6. Settling of Barite in OBDF (Couette cell)
7. Summary

INTRODUCTION

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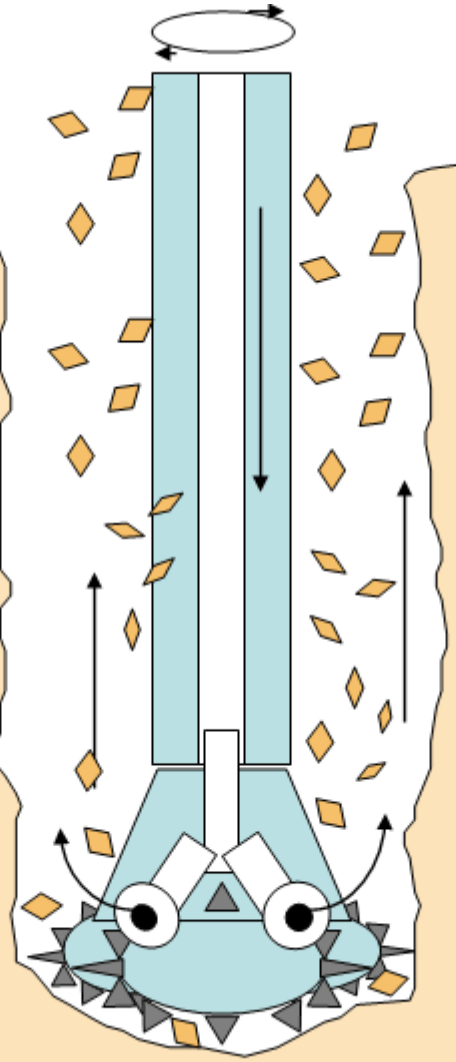
The drill string is turned at surface, which turns the bit at the bottom of the hole.

The teeth on the drill bit grind the rock into fragments, or "cuttings".



Drilling mud is pumped down the inside of the drill pipe, through jet nozzles in the bit, and into the "annulus". This is the space between the sides of the hole and the drill pipe.

The mud lifts the cuttings and circulates them back to surface where they are removed.

INTRODUCTION

- A Drilling Mud or Drilling Fluid is used while drilling oil and natural gas wells. Detailed composition data is proprietary.
- Major roles of Drilling Fluid (DF):
  - (a) Maintain wellbore stability i.e. chemical and mechanical stability,
  - (b) Remove the cuttings under the drill bit and transport them from the bottom to top of the oil well
  - (c) Lubricate and cool the drill bit and string
  - (d) Seals permeable formations thereby reducing circulation loss
- Commonly used types of DF: Water-based DF and Oil-based DF
- Important Properties: **Rheology, Density, Heavy particle settling**, fluid circulation loss, Solid content, chemical properties.

Drilling Fluid composition: reference OBDF

Name/Product name	Function	Mass fraction in reference OBDF	g/liter in reference OBDF
EDC 95-11	Base oil	0.35	501.9
CaCl2 brine	Internal phase	0.139	199.3
lime	Internal phase ingredient	0.0139	20
One-Mul NS	Emulsifier	0.0139	20
Bentone 128	Viscosifier (clay, low T)	0.00628	9
VG Supreme	Viscosifier (clay, high T)	0.00907	13
Versatrol M	Fluid loss agent	0.00697	10
VK-150	CaCO3 (simulated LGS)	0.0349	50
Barite (BaSO4)	Weighting agent	0.426	610.8

Weighting Material Sag (Settling of Barite)

- **Barite** ($BaSO_4$) is the most common **weighting material** (~4 SG) used in drilling fluids to increase the fluid density and control formation pressure.
- Advantages of Barite: • Easy to use • Fluid density increases to 2.5 S.G. • Low addition rate to achieve high densities • Improves borehole stability • Chemically inert and non-reactive • Limited particle breakdown • Not hazardous.
- **Barite Sag** is a problem of drilling process and happens when barite particles separate from the liquid phase and settle down.
- The formation of a high-density fixed bed and subsequent recirculation in the drilling fluid can lead to severe operational problems such as loss of control, lost circulation and stuck pipe, etc.

Objective

- To study and understand the drilling fluid properties such as rheology and Barite particle settling behavior

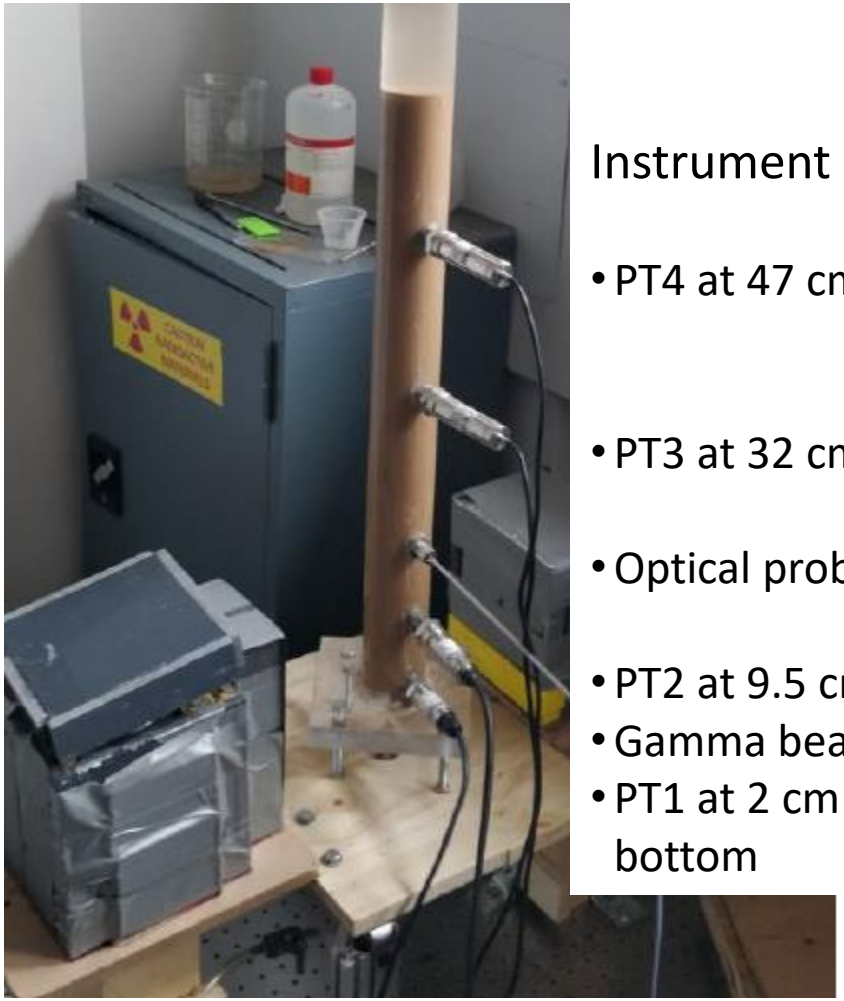
Approach

- Complex fluid: roles and effects of each component are not well understood, so use **simplified model drilling fluids** with less constituents than in an actual drilling fluid
- Measure rheological properties with a variable temperature rheometer, TA instruments: ARES-G2
- Design experimental apparatus and develop suitable measurement methods
  - Barite particle sedimentation under shear
  - Optically opaque: use DP and radiation attenuation techniques
    - X-ray and gamma ray

EXPERIMENTAL SET-UP: STATIC COLUMN

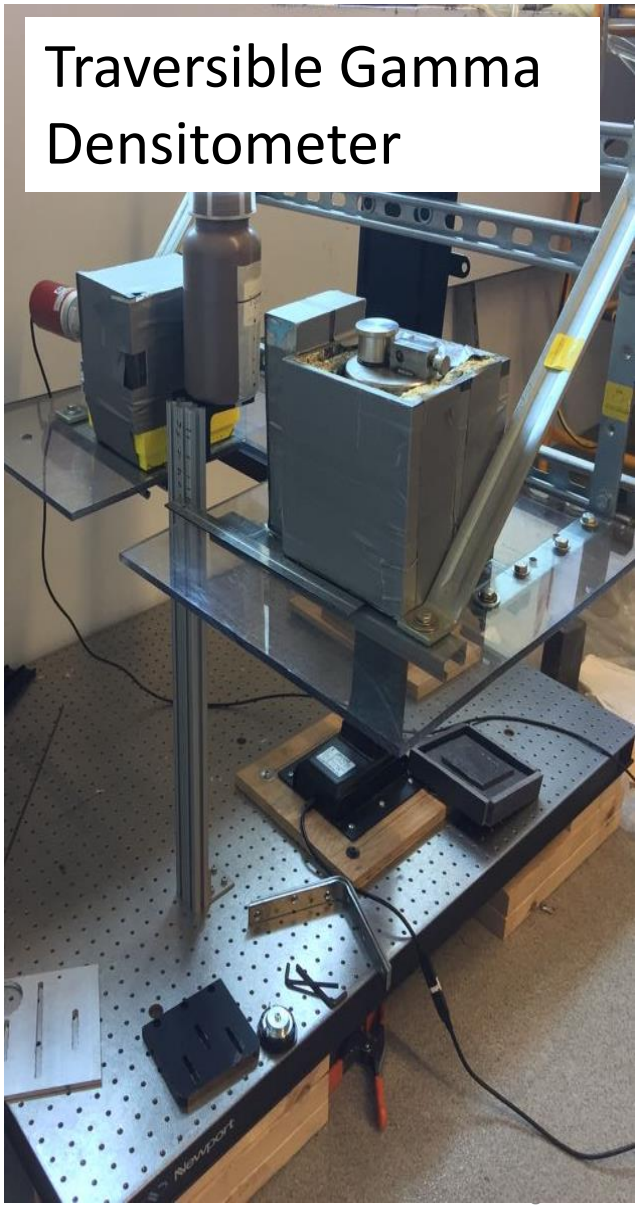
Column: 5.7 cm ID, 91 cm high

PT: Pressure Transducers



Instrument locations

- PT4 at 47 cm
- PT3 at 32 cm
- Optical probe at 17 cm
- PT2 at 9.5 cm
- Gamma beam at 5 cm
- PT1 at 2 cm from bottom



EXPERIMENTAL TECHNIQUES

Gamma Densitometry

Lambert's law for single phase

$$I = I_o e^{-\mu L}$$

Lambert's law for solid-liquid phases

$$I_0 = I e^{-(\mu_s L_s + \mu_l L_l)}$$

Volume Fraction of Solid phase

$$\epsilon_S = 1 - \frac{ln\left(\frac{I_{S-L}}{I_L}\right)}{ln\left(\frac{I_S}{I_L}\right)}$$

I_{S-L}= measured γ-counts
I_S= γ-counts settled solids
I_L= γ-counts for liquid only

Hydrostatic Pressure method

$$\epsilon_S = \frac{(\Delta P_M - \Delta P_L)}{(\Delta P_S - \Delta P_L)}$$

ε_S: *Volume averaged solid fraction*

ΔP_M = *Measured pressure difference*

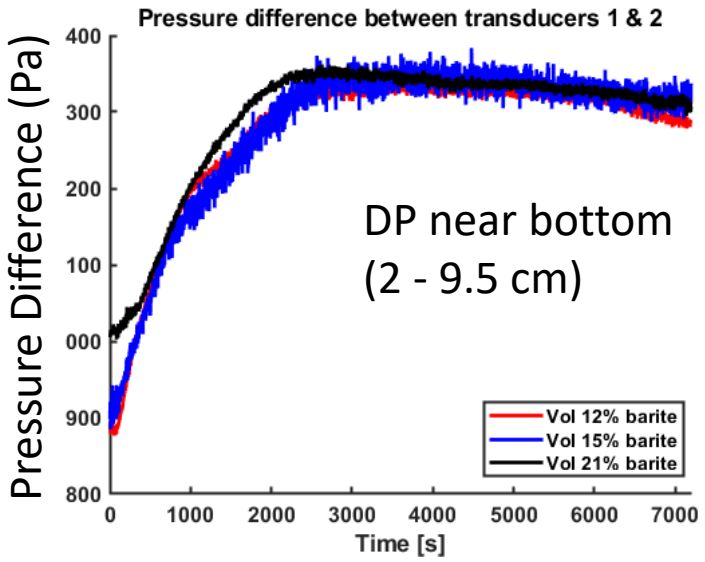
ΔP_L =*Pressure difference for liquid only*

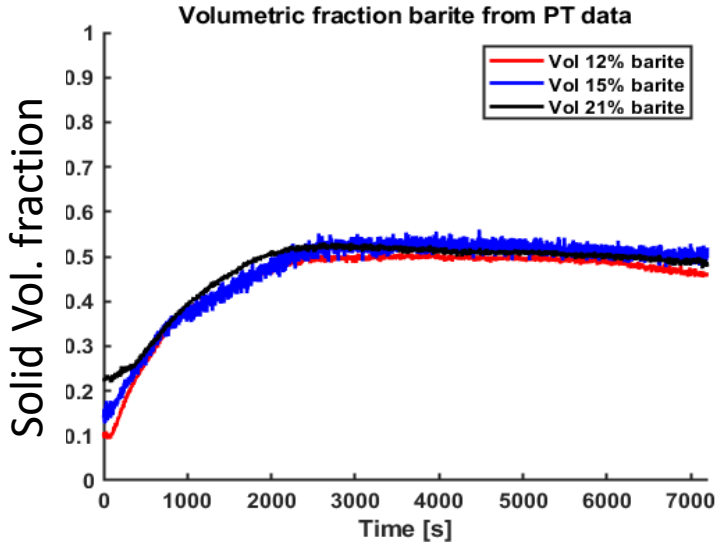
ΔP_S =*Pressure difference for a settled particle bed*

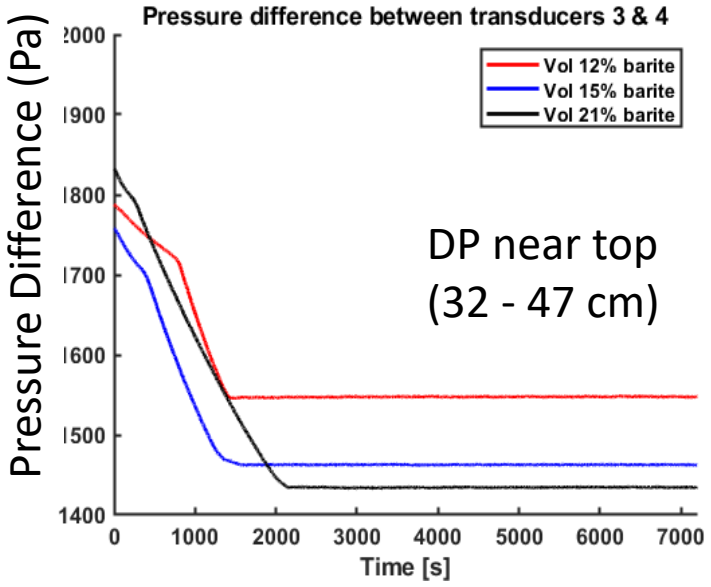
Time series data of the solid fraction and change in solid fraction with time gives settling rate

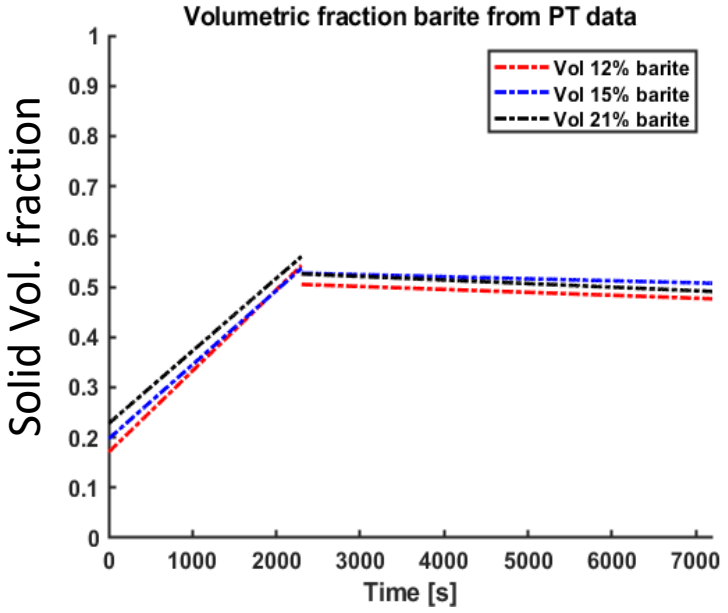
STATIC COLUMN: Barite in Water

Volume fractions: 12, 15 and 21%





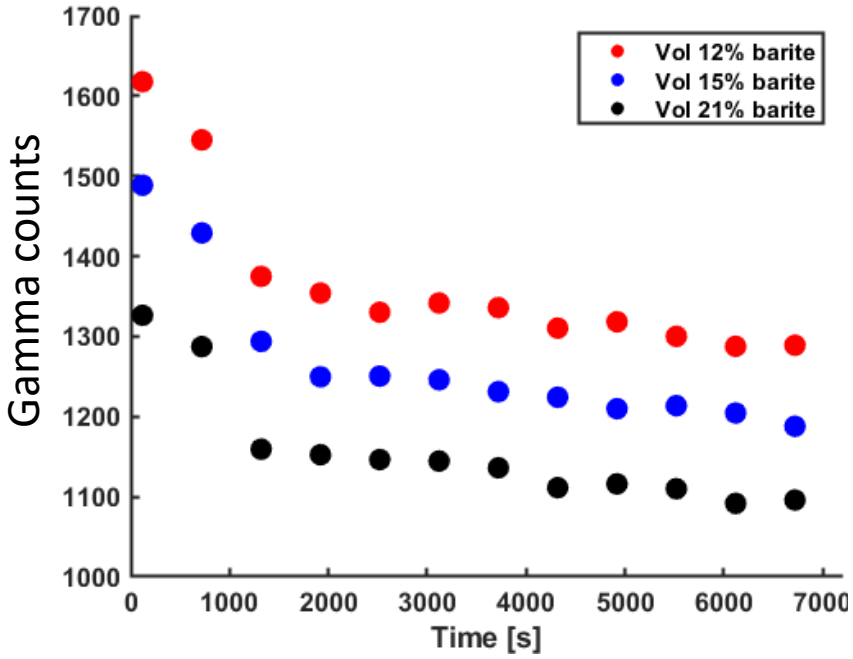


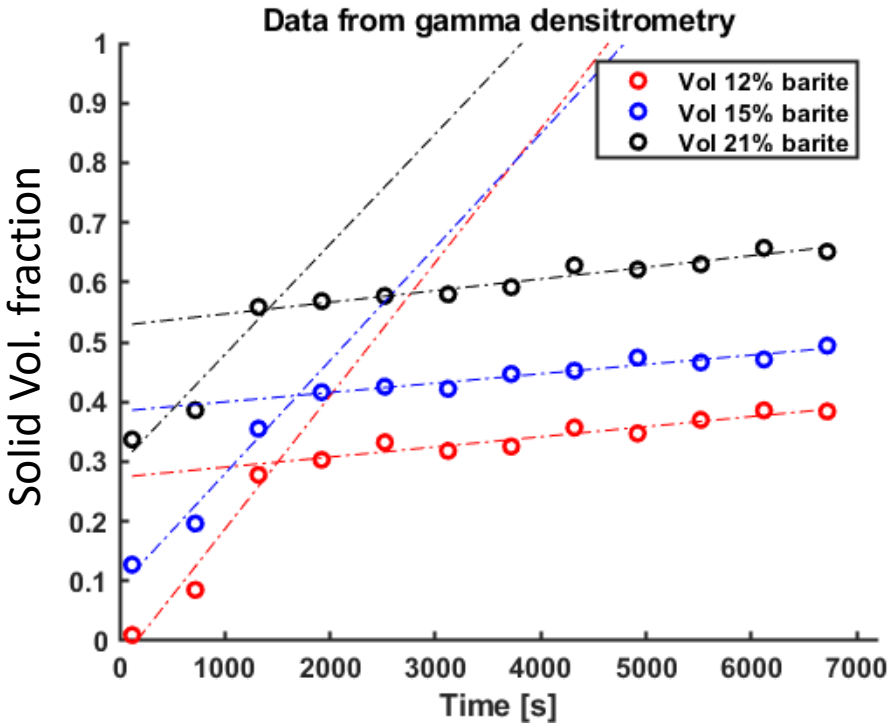


STATIC COLUMN: Barite-Water

Gamma Densitometer measurements at 5 cm from bottom

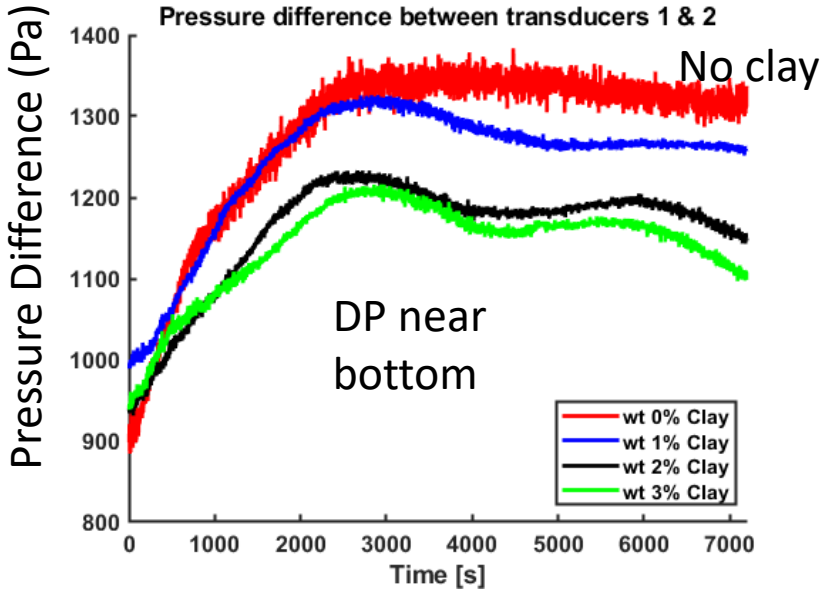
Average Solid Volume fractions:
12, 15 and 21%

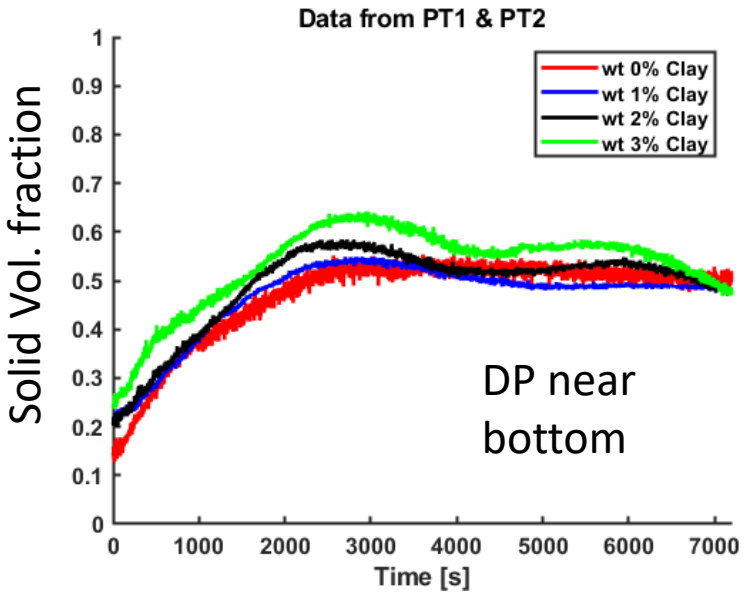


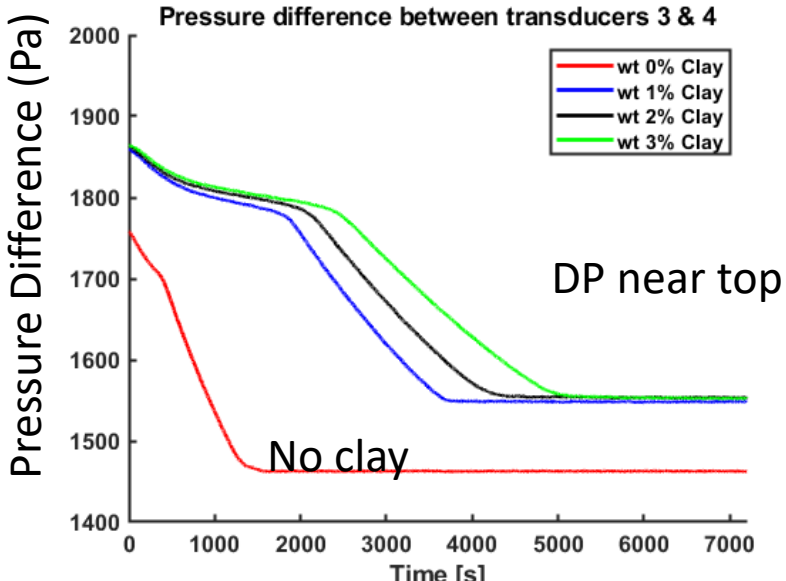


STATIC CELL: Barite-Clay-Water

Water – Barite15 V% - Clay: 1,2 & 3 wt%



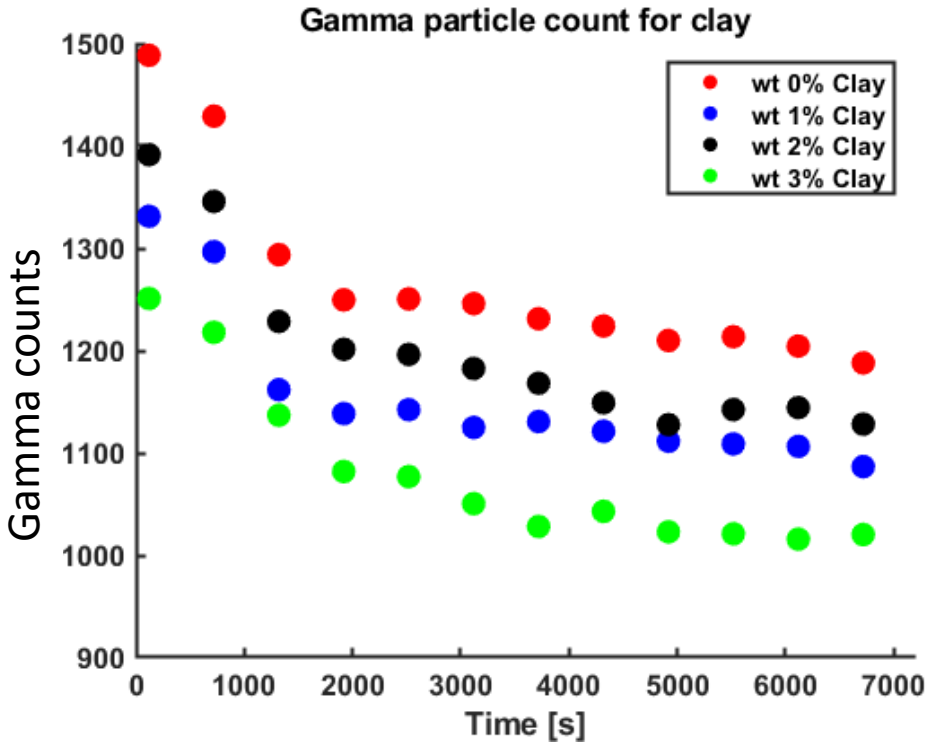


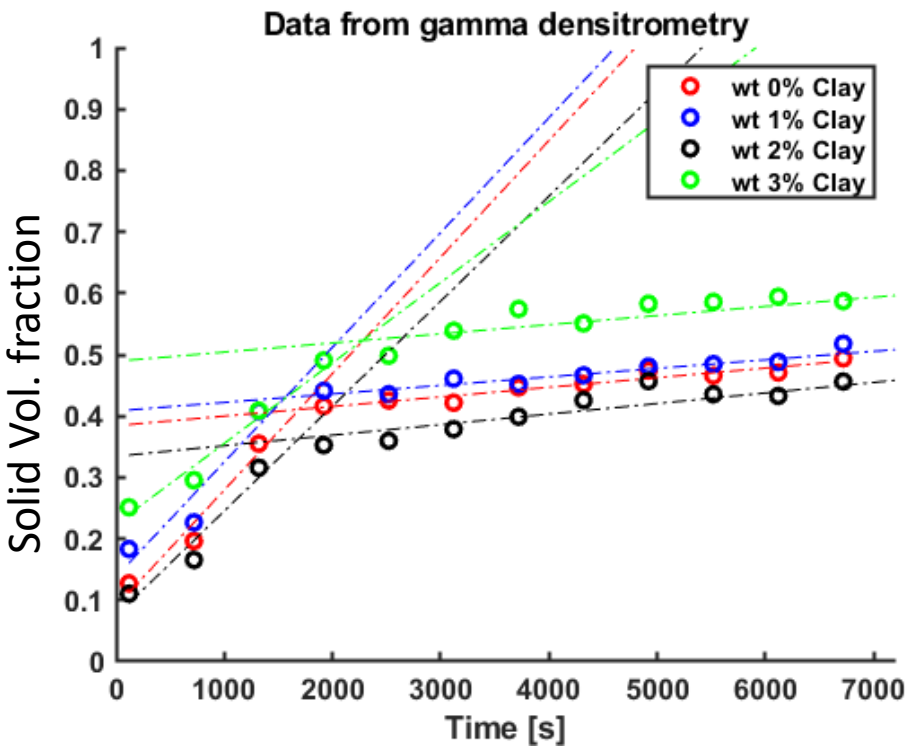


STATIC COLUMN: Barite-Clay-Water

Gamma Densitometer at 5 cm

Water – Barite15 V% - Clay: 1,2 & 3 wt%

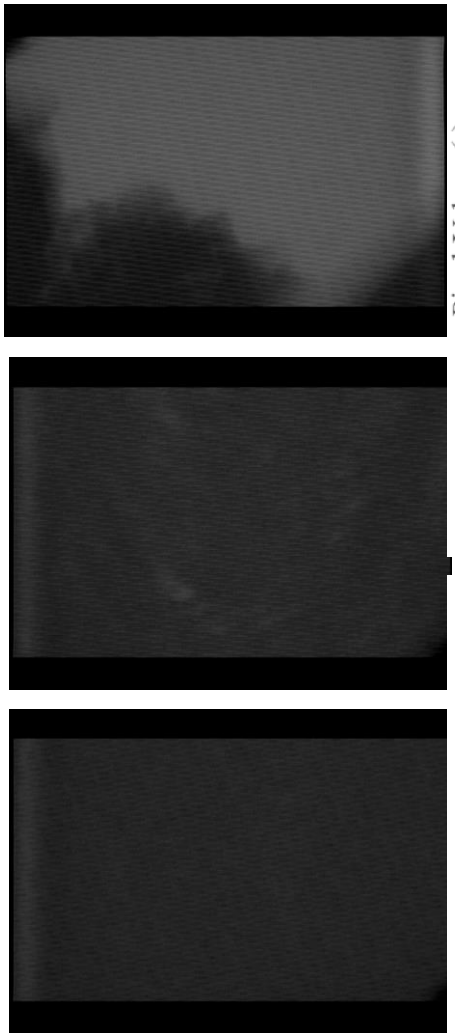


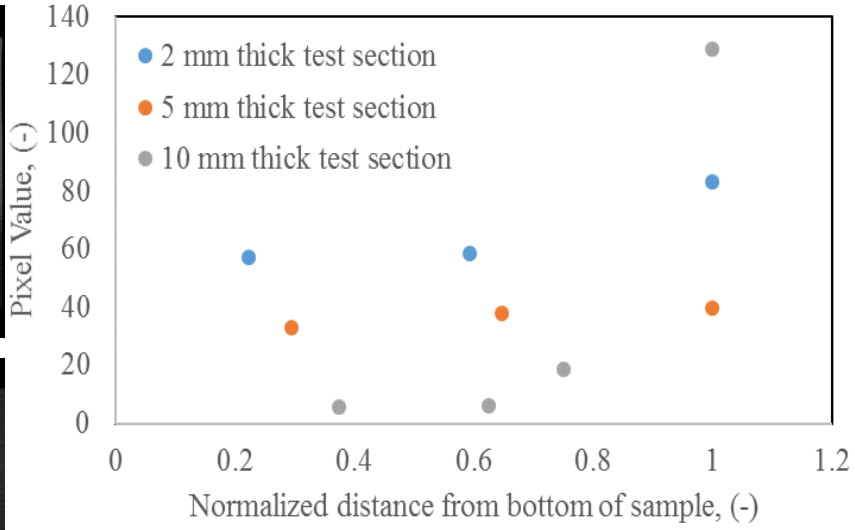


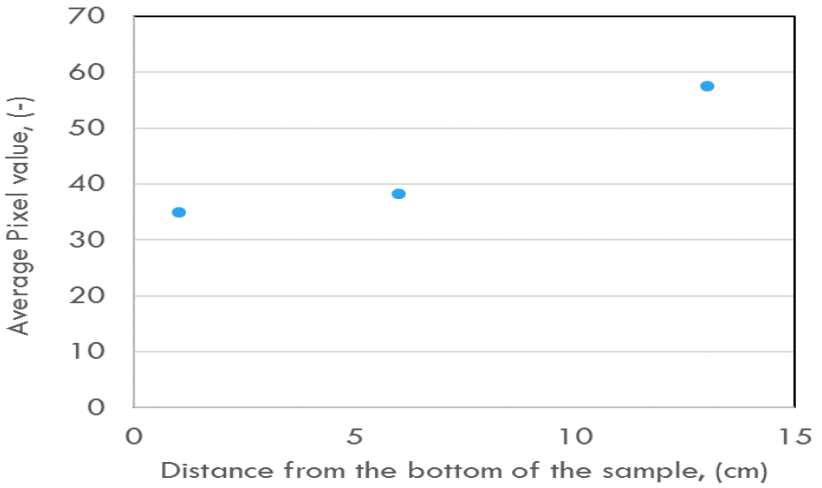
X-Ray Scan: Static Cell

Actual drilling fluid

STATIC CELL: OBDF (X-RAY after 10 days)

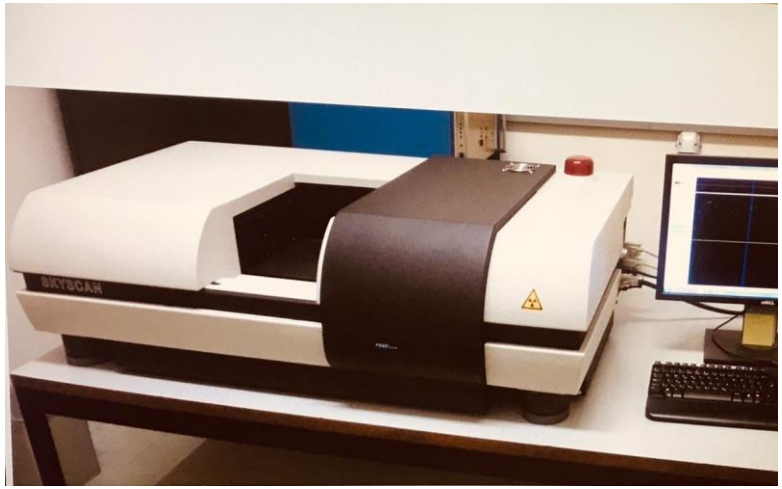


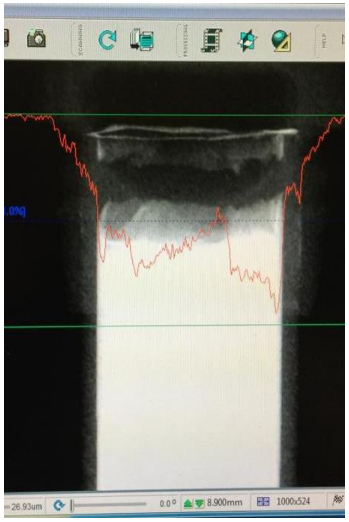


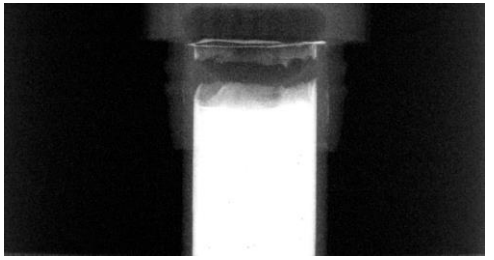


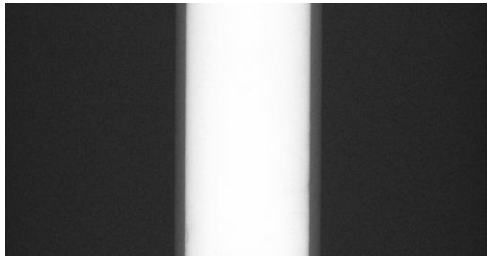
Average Pixel value α (1/local solid fraction)

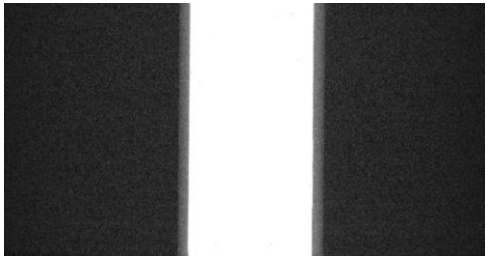
STATIC CELL: Actual DF (**Micro-CT images after 14 days**)

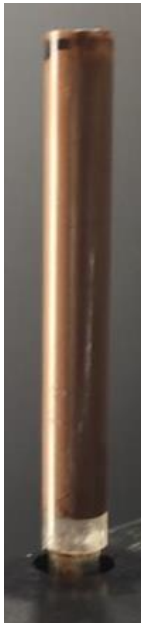


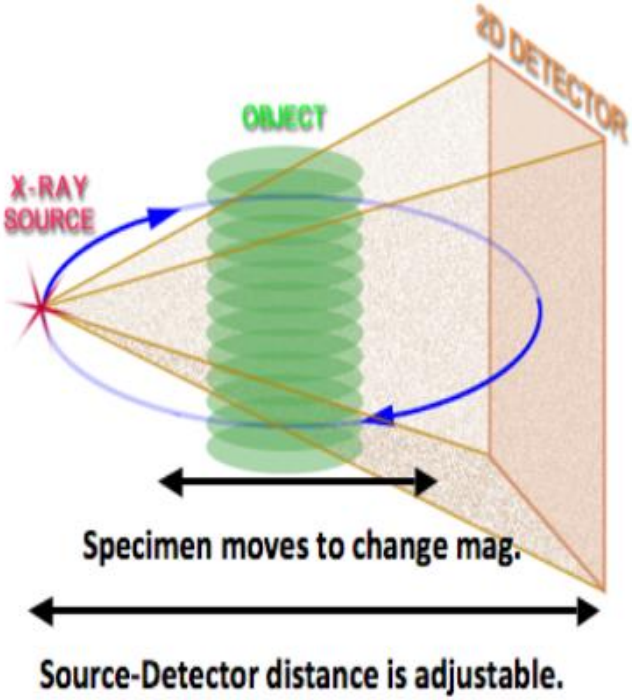






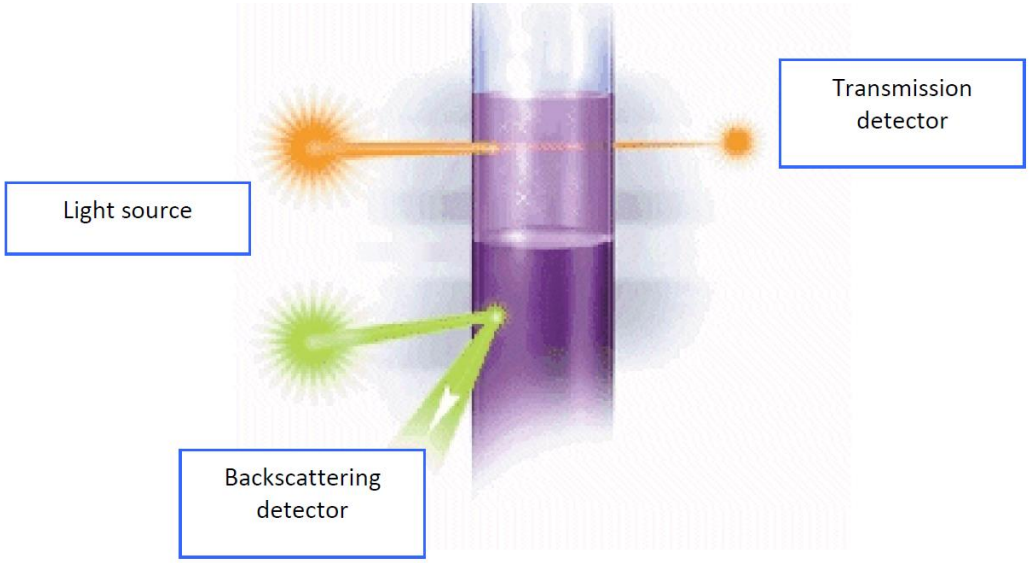




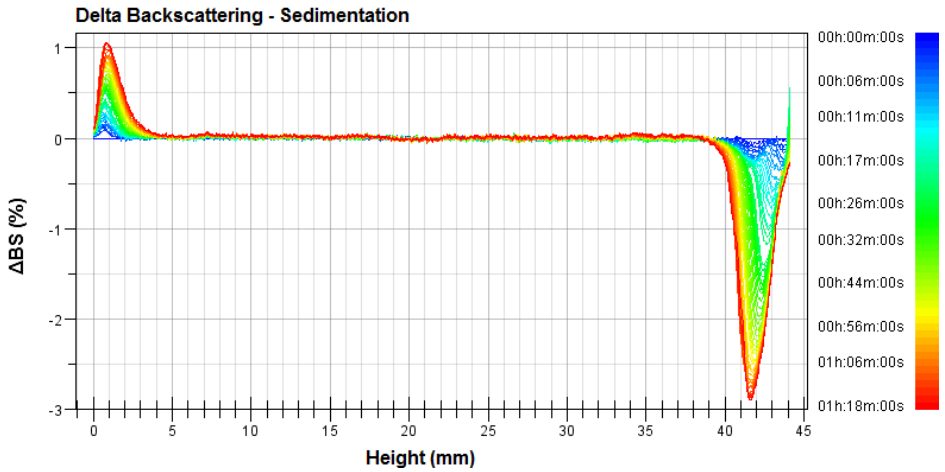


SKYSCAN 1172 MICROCT

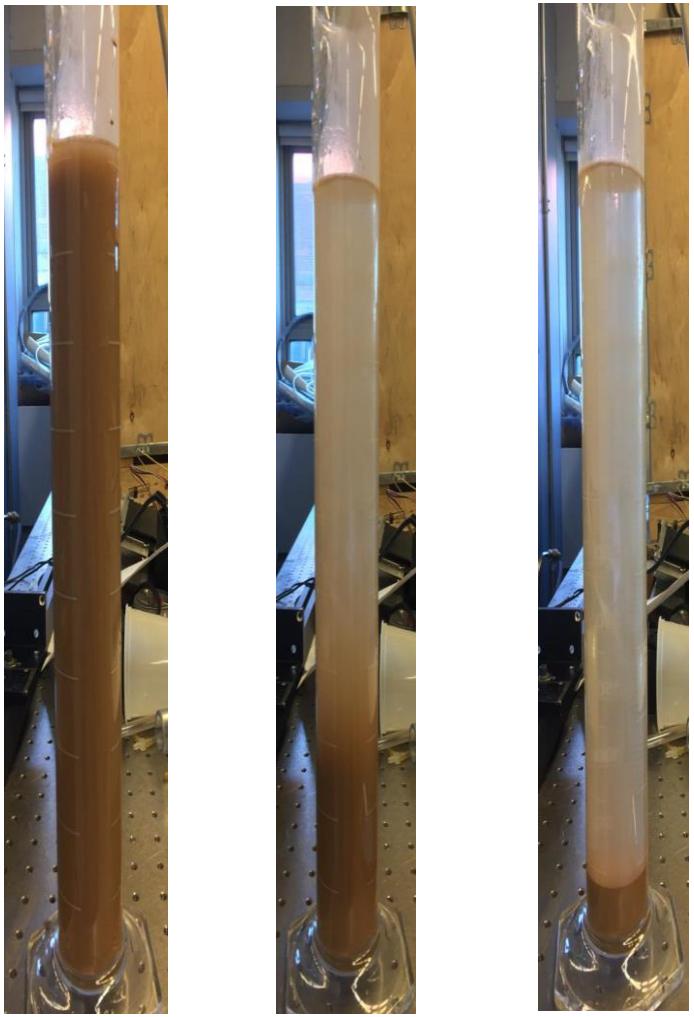
Settling in static fluid:
Multiple light scattering using Turbiscan LAB



- Infrared light λ = 880 nm
- Measure transmitted and back-scattered light
- Cylindrical cell height: ca 55 mm
- Cell diameter: ca 25 mm
- Sampling space interval: 40 µm

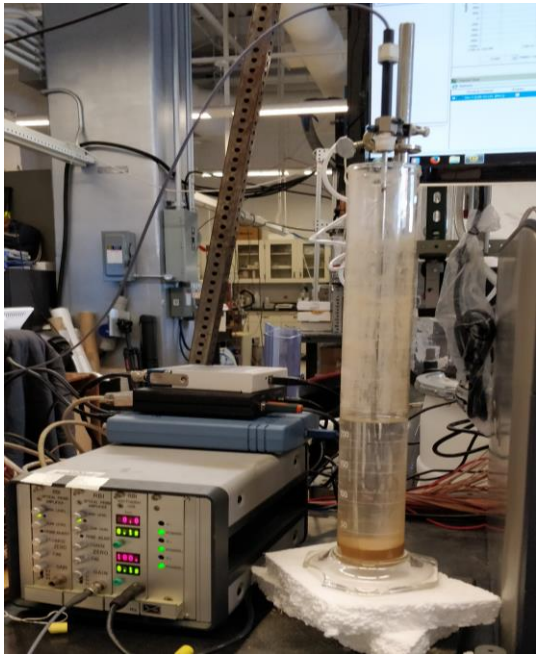


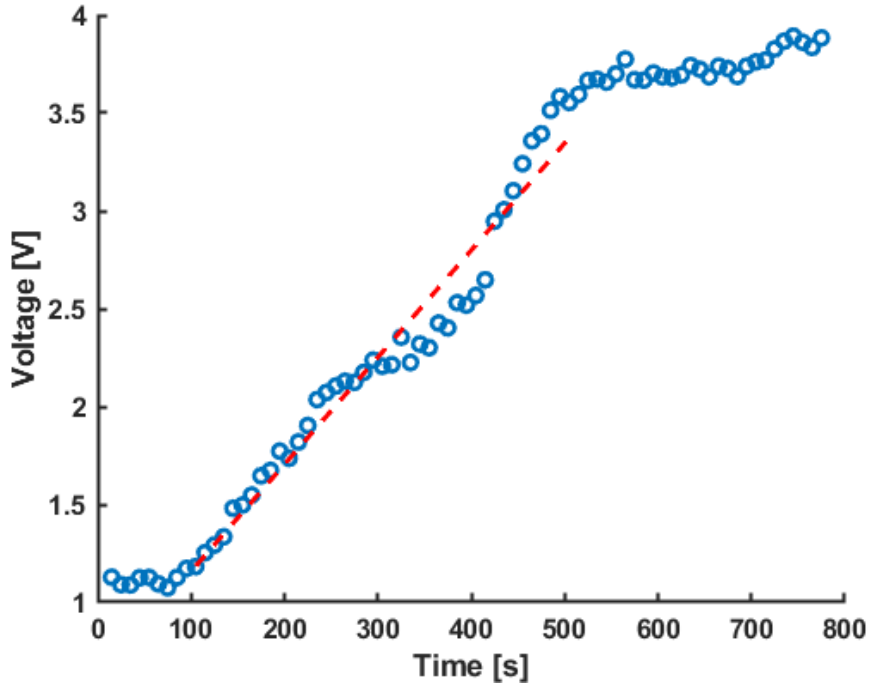
Optical Probe: local solid fraction



0 sec 300 sec 600 sec

Barite in water





OBDF: Components and Synthesis

Synthesis of 0.5 Liter sample		
Mixing volume	500 mL	
Oil-Water ratio	80-20	
Aging conditions	Dynamic_16hrs at 120C	
	g/l	**wt%**
Base Oil	501.9	35%
Internal Phase	199.3	14%
Internal Phase	20	1%
Emulsifier	20	1%
Viscosifier (Clay, low temp)	9	1%
Viscosifier (Clay, high temp)	13	1%
Fluid loss agent	10	1%
CaCO3, Simulated LGS	50	3%
Weighting Agent	610.8	43%

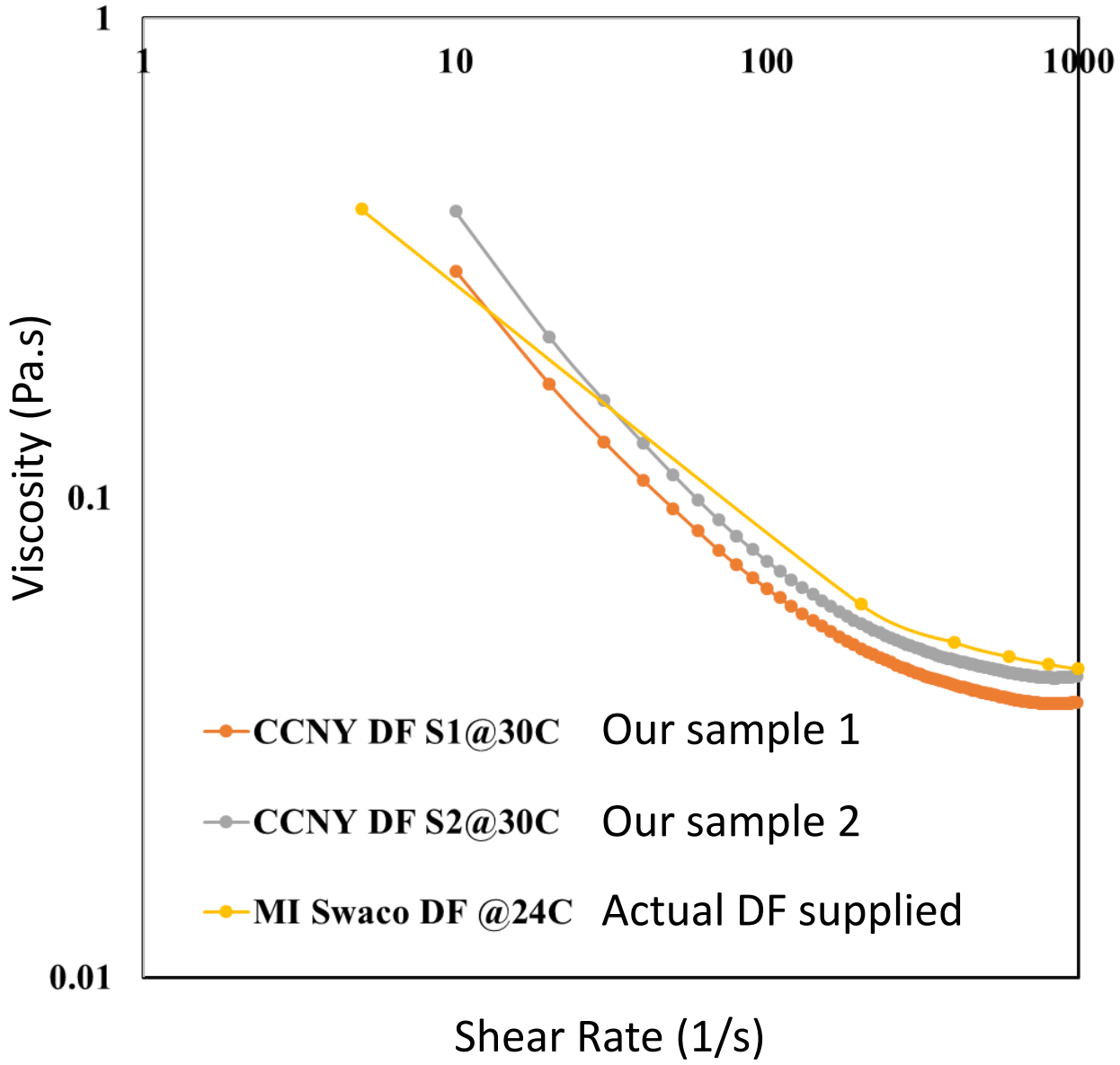
mixing order	mixing time, min
Baseoil	0
Emulsifier	2
Clay	8
Lime	5
Fluid Loss agent	5
Brine	15
Weighting agent	25
Bridging material	10 min paddle

Homogenizer at 6000 rpm

Hot roller

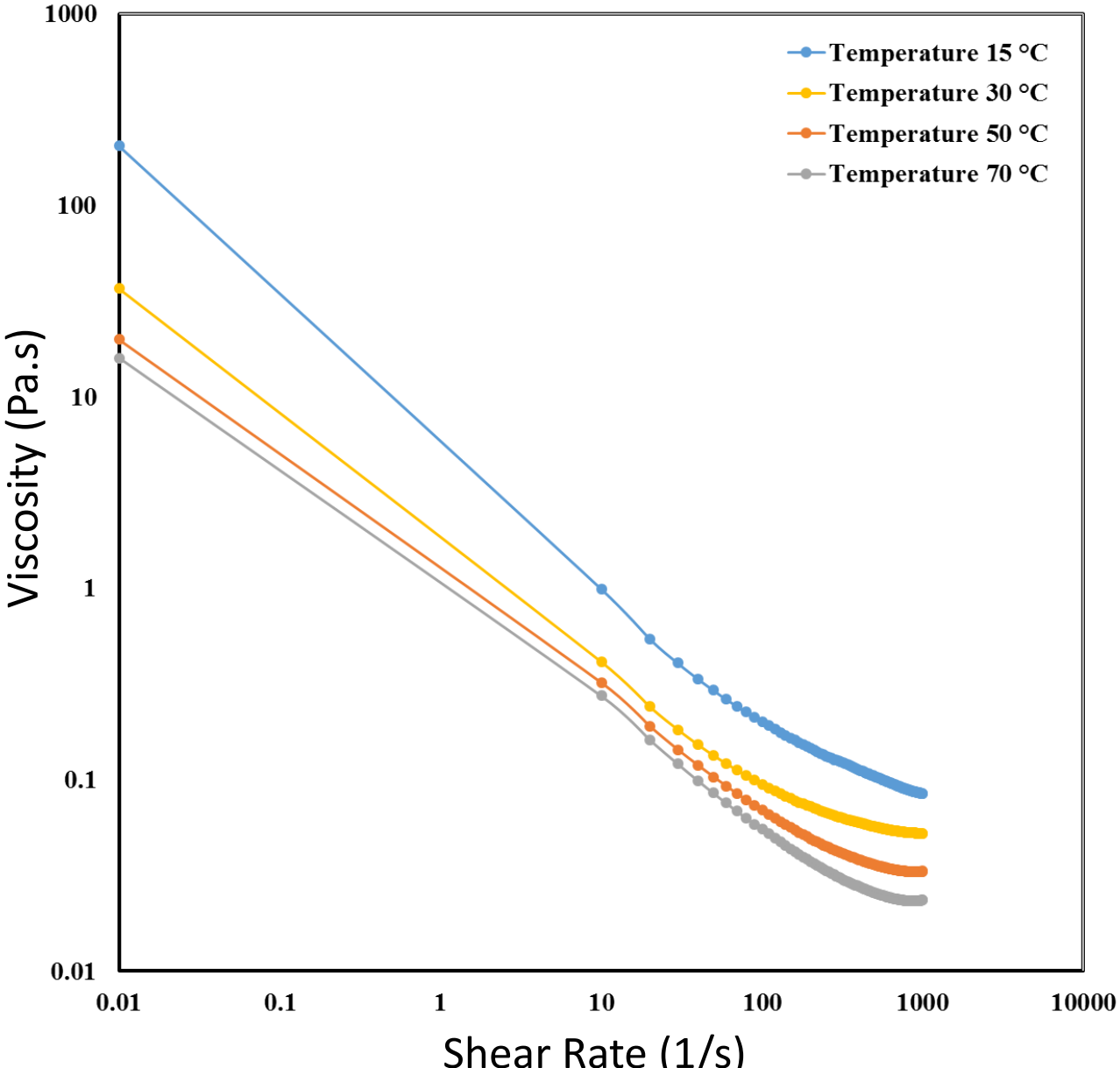
RHEOLOGICAL PROPERTIES (Actual Drilling fluids)

TA instruments: ARES-G2; Geometry: Cup and Bob

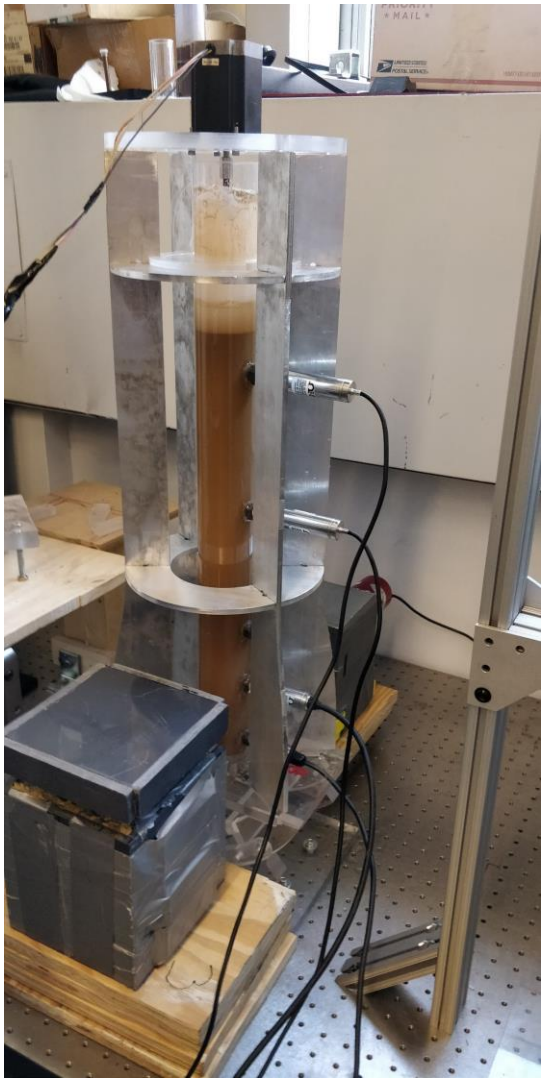


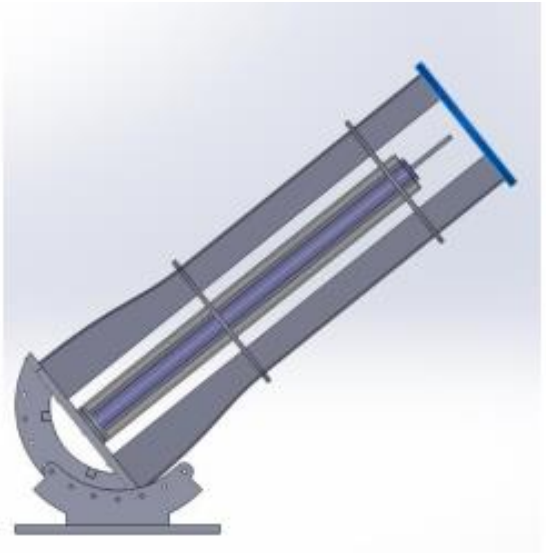
TEMPERATURE DEPENDENCE OF VISCOSITY

TA instruments: ARES-G2; Geometry: Cup and Bob



ROTATING COUETTE CELL: ROTATING INNER ROD AND STATIONARY OUTER CYLINDER





Column Height= 68 cm; I.D. = 5.7 cm;
Inner rod O.D.= 3.81 cm; RPM: 0-300.

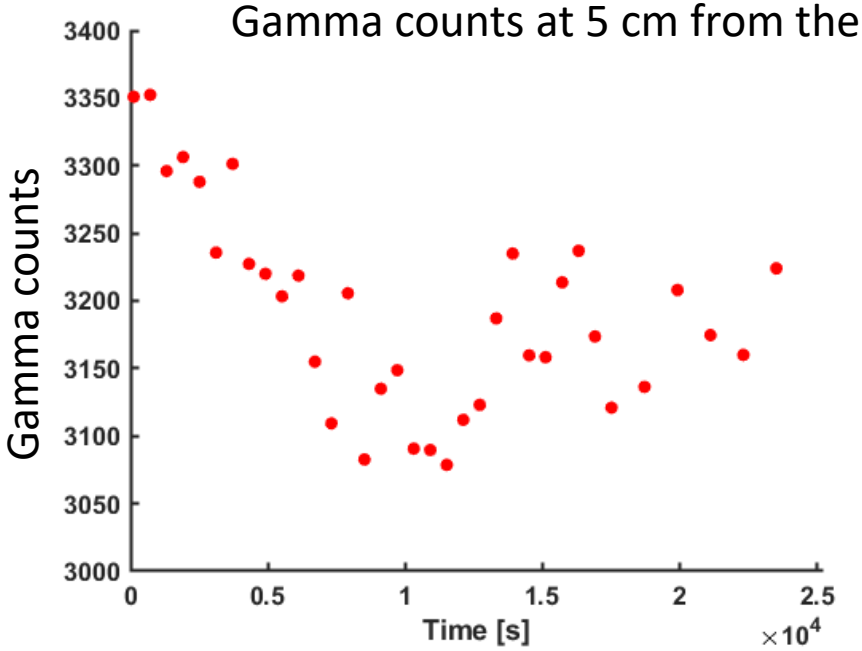
Inclination angle: 45 to 90 degrees

PT1= 2cm, PT2=9.5 cm, PT3=32 cm and PT4= 47 cm from bottom.

Gamma Measurement at 5 cm from the bottom.

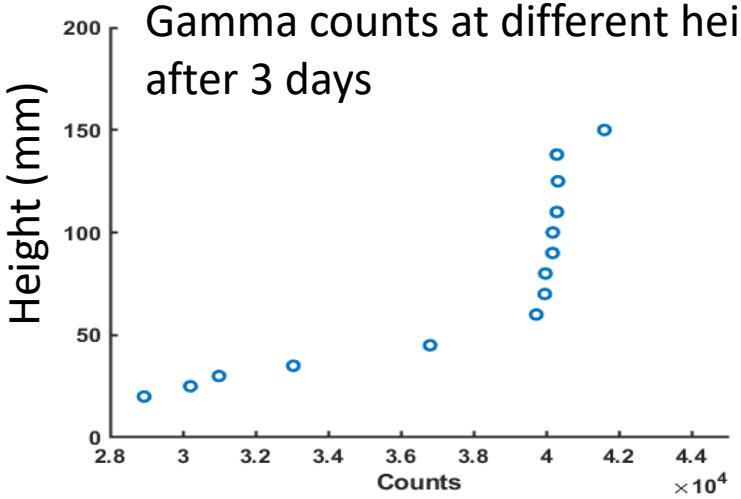
COUETTE CELL: Vertical, 300 rpm

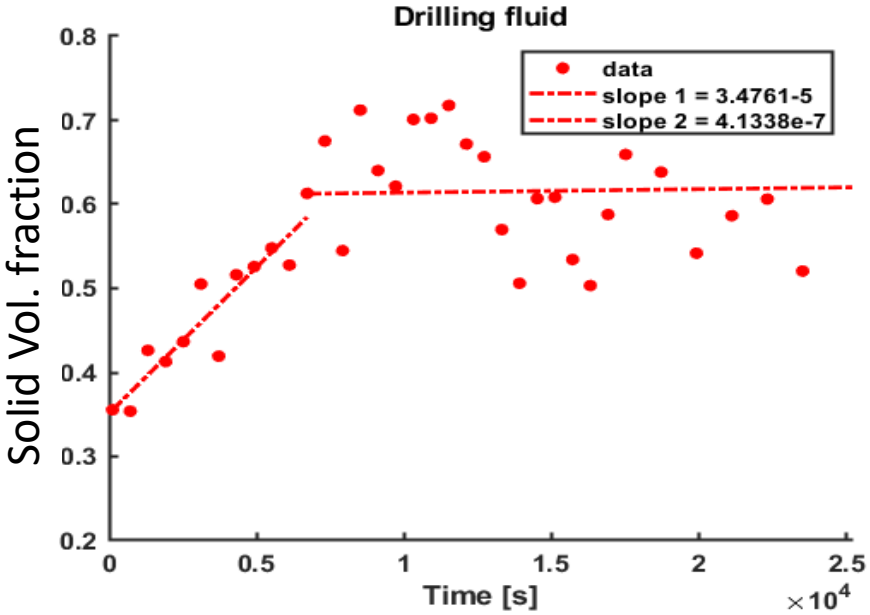
Gamma counts at 5 cm from the bottom



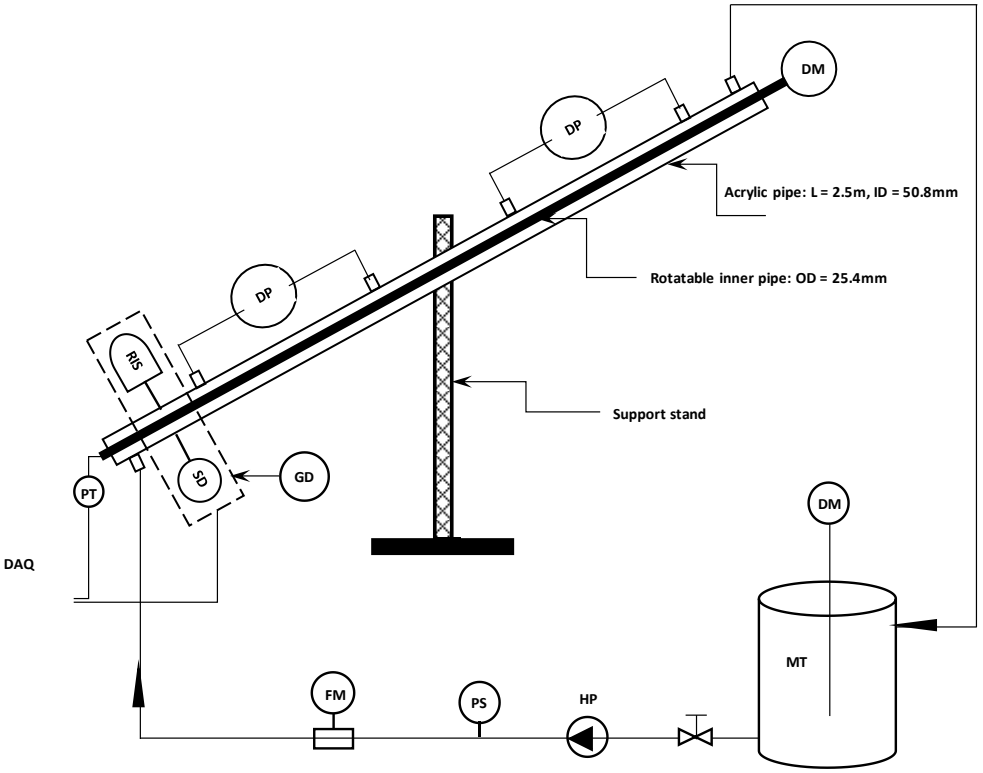
Actual Drilling Fluid

Gamma counts at different heights after 3 days





Settling in sheared fluids: Barite sag flow cell at SINTEF



Representative geometry

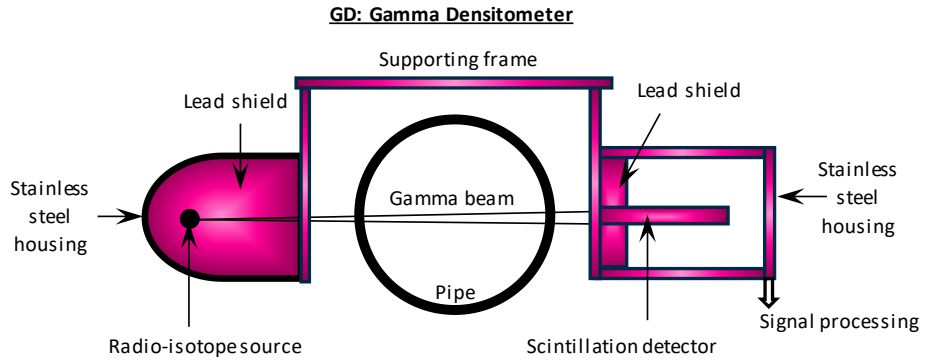
- Eccentric annulus
- Inclined pipe axis, variable

Shear induced by

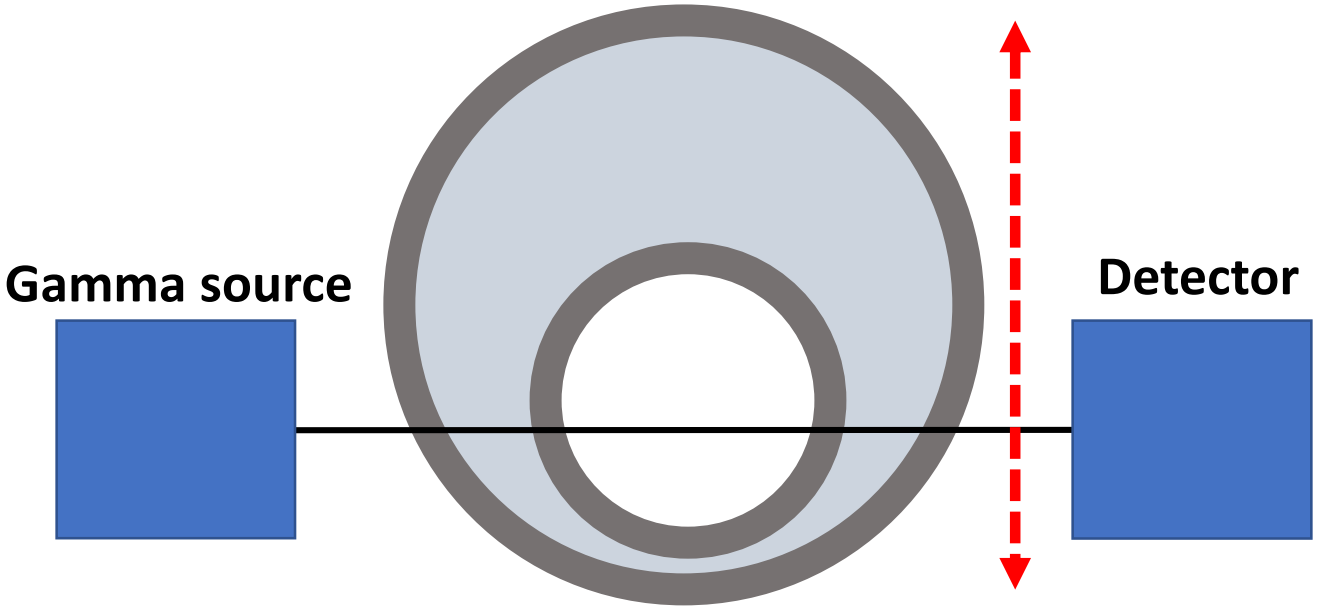
- Flow rate
- Pipe rotation

Main instrumentation

- Flow rate meter
- Pressure transmitters
- Traversing gamma densitometer



Barite sag flow cell: gamma densitometer configuration at SINTEF



Summary

- Oil Based Drilling Fluid synthesis performed successfully and preliminary rheological data obtained
- Model fluids with less components (Barite, clay and water) were synthesized and used to measure Barite particle settlement rate in a static cell/column
- Measurement techniques (DP, γD, optical probe) investigated to obtain settling rate data in static cell and column
- Rotating Couette cell constructed and used to measure Barite settling rate in OBDF

THANK YOU