Spacer Design for Invert Emulsion Mud Displacements

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Displacement Technology

Good displacement design practices account for:

- Conditioning the drilling fluid for removal
- Logistics maintenance and pre-planning
- Appropriate use of casing-cleaning tools
- Pipe movement during pumping operation
- Rational spacer design

Displacement Design

Hydraulics

- Pump Output (Horsepower)
- Friction Pressure
- Pump Direction
- Density difference between mud & brine

Spacers

- Flow rate
- Contact Time
- Cleaning Efficiency
- Mud Contamination

Mechanical Aids

- Tools (Scrapers, brushes, circulating ports, debris removal tools)
- Pipe Movement

Deepwater Displacement Design

Single Stage Displacement

- Direct displacement mud-to-brine in entire wellbore (incl riser)
- Allows pipe movement in casing
- May be important in deviated wellbores

2 Stage Displacement

– Indirect for Riser

Mud-to-seawater-to-brine

– Indirect or Direct for Casing

Mud-to-seawater-to-brine or mud-to-brine

– No pipe movement in casing

- in GoM new permits may require balanced displacements

Spacer Design

- Every displacement pumped includes a spacer 'system'
- The functions and objectives of the spacer system as a whole are the same in all cases.
- However, preferences differ from one operator to another and from one service company to another.
- Weighted spacers, viscous pills, base fluids, surfactant type and concentration, solvents, spacer sequence, contact time, volume and effective flow regime are among the many questions that must be addressed by the completion engineer.

Spacer Design

Weighted spacers

Viscous pills

Base fluids

Surfactant Type / Concentration

Solvents

Spacer sequence

Contact time

Volume

Effective flow regime

Typical Spacer Design

OBM	Function	Size(2)
Base Oil(1)	**Thin Mud**	250 – 500 ft
Weighted Viscous Pill	**Transition OB -> WB** **Remove whole mud**	10% hole volume
Wash Pill	**Clean Mud film, Water-wet pipe**	Modeled for OBM
Viscous Pill	**Carry Solids , Separate from brine**	500 – 1000 ft
Brine	**Complete Well**	Wellbore

(1) : Important when doubt about condition of mud
(2) : In widest annulus

1st Viscous Push Pill ("Transition Spacer")

Follows immediately after OBM or Base Oil

Prepared in drill water, seawater or brine*

+ Polymer (XC or HEC) for viscosity/suspension

    - prefer XC when possible

+ Barite or brine* for density (1-2 ppg > mud ppg)

+ "Chemistry" for compatibility with OBM

  – Surfactant and solvent

* Compatibility between Mud and Completion brine may be compromised and may need added "chemistry"

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Transition Spacer Qualities

Designed to remove whole mud

Compatible with Drilling Fluid

- Provides a ‘smooth transition’ from Mud-to-Spacer
- Prevents large, emulsified interface

Viscosity > mud viscosity

- Take advantage of pipe rotation to overcome yield stress of mud in small annulus
- Exceed yield stress of mud by friction forces

Density > mud density

- Overcome lack of (or insufficient) pipe rotation
- Exceed yield stress of mud by gravitational force

1st Viscous (Transition) Spacer

Requires a <u>Chemical</u> & <u>Physical</u> ‘Transition’ from Oil Based Mud to Water Based Spacer

100% OBM

100% WB Viscous Spacer

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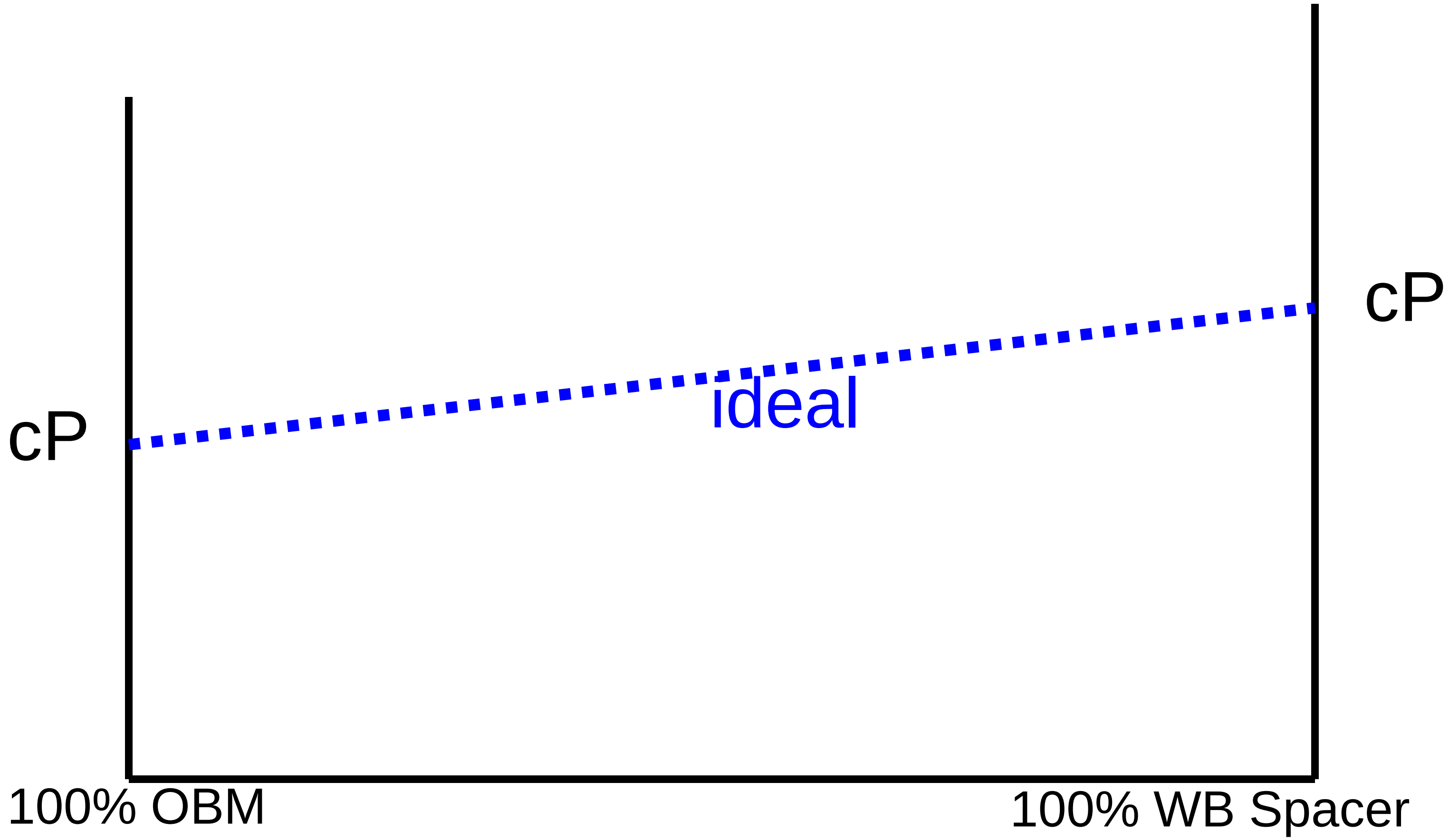
1st Viscous (Transition) Spacer



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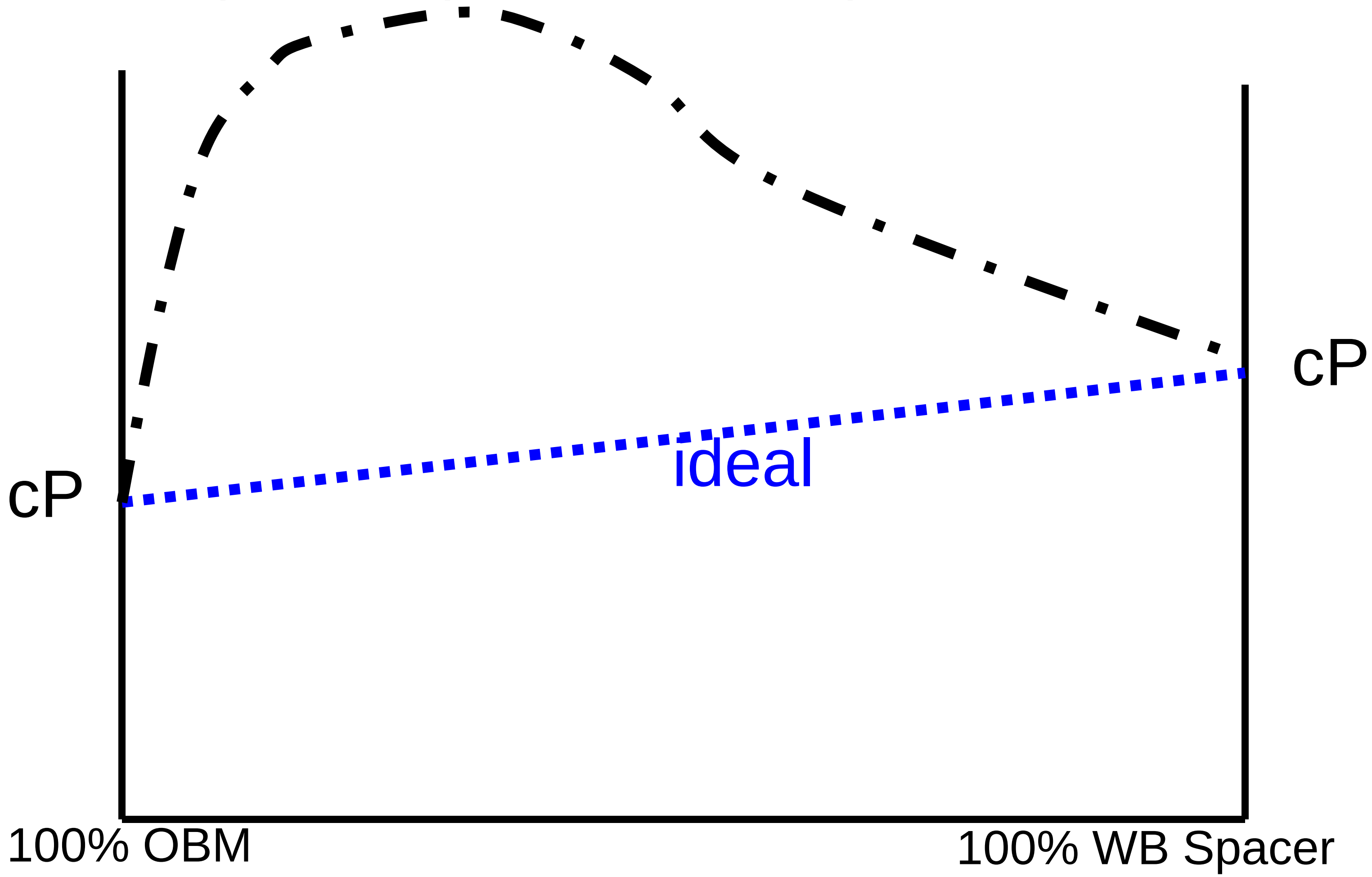
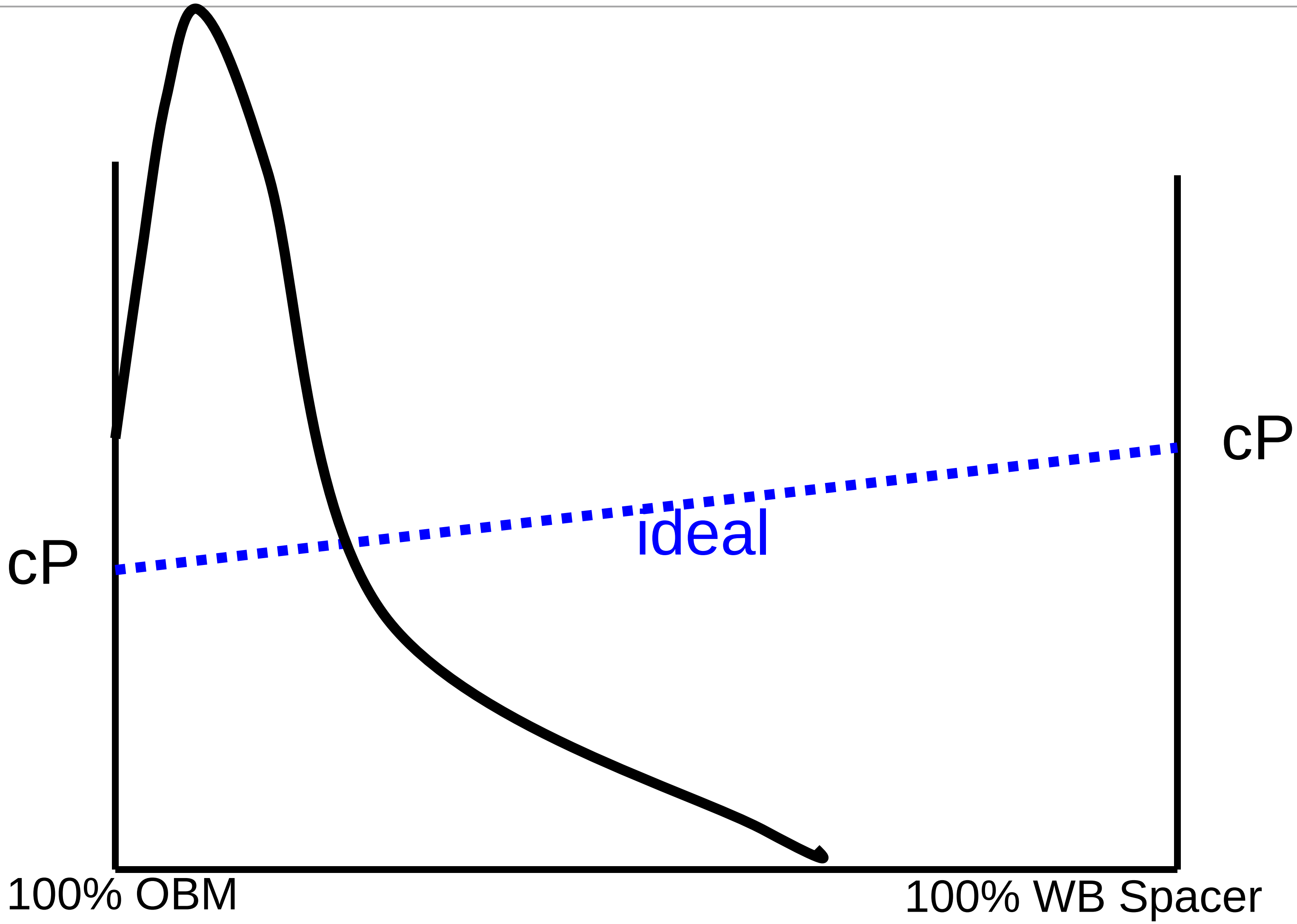
1st Viscous (Transition) Spacer

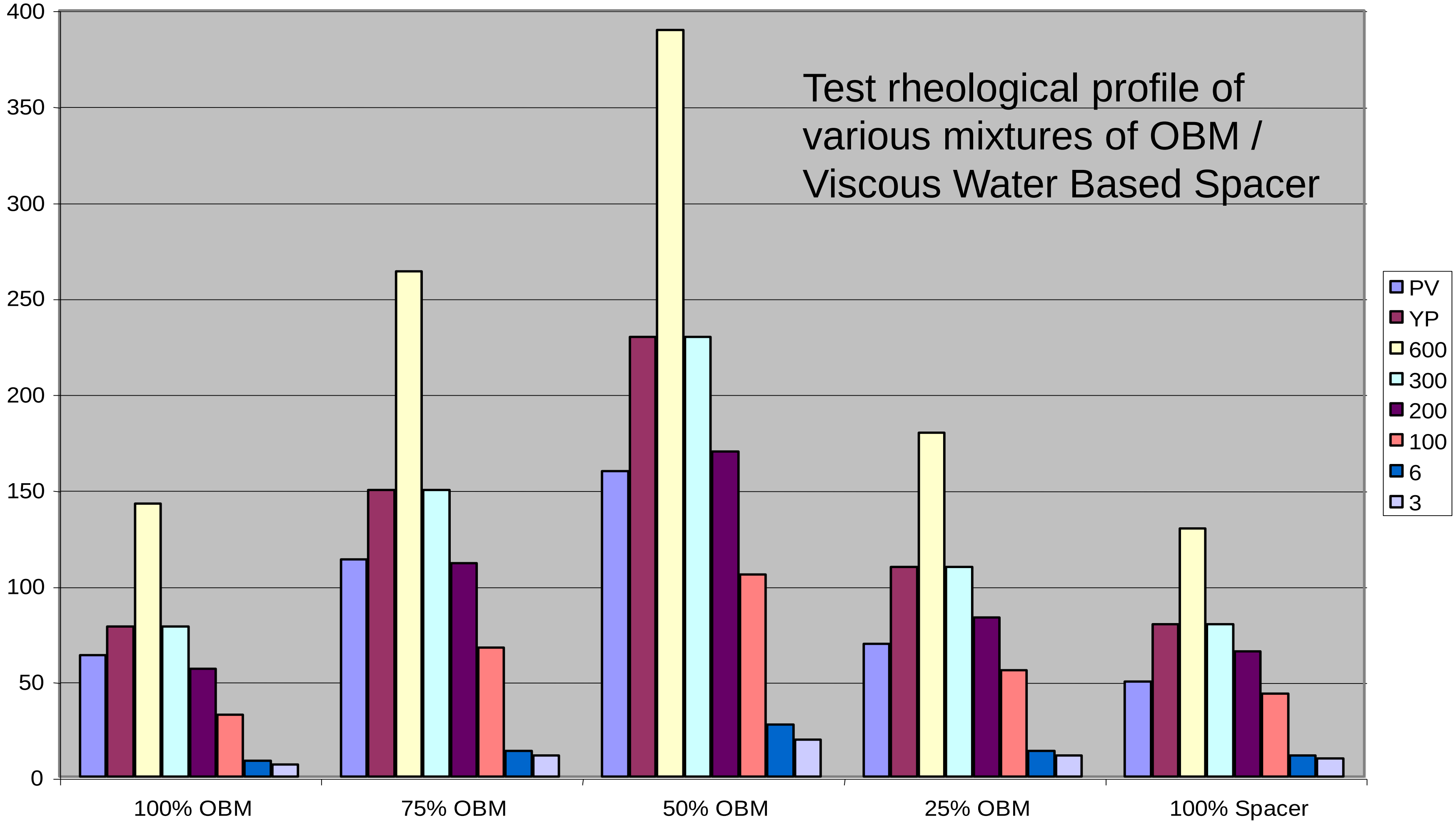
Incompatible Spacer (for example, Brine + HEC/XC)



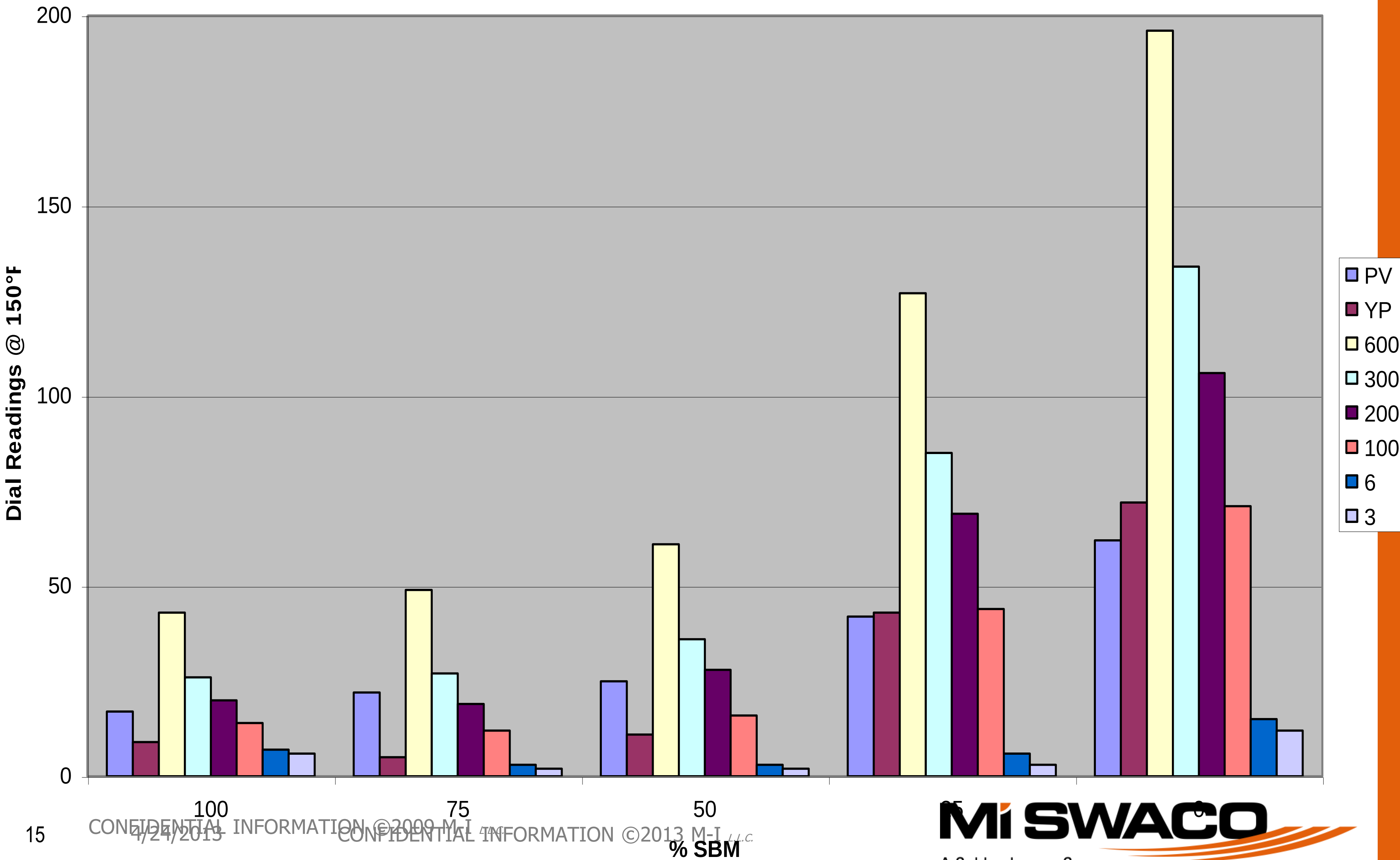
1st Viscous (Transition) Spacer



"Incompatible" Viscous Spacer



“Compatible” Transition Spacer



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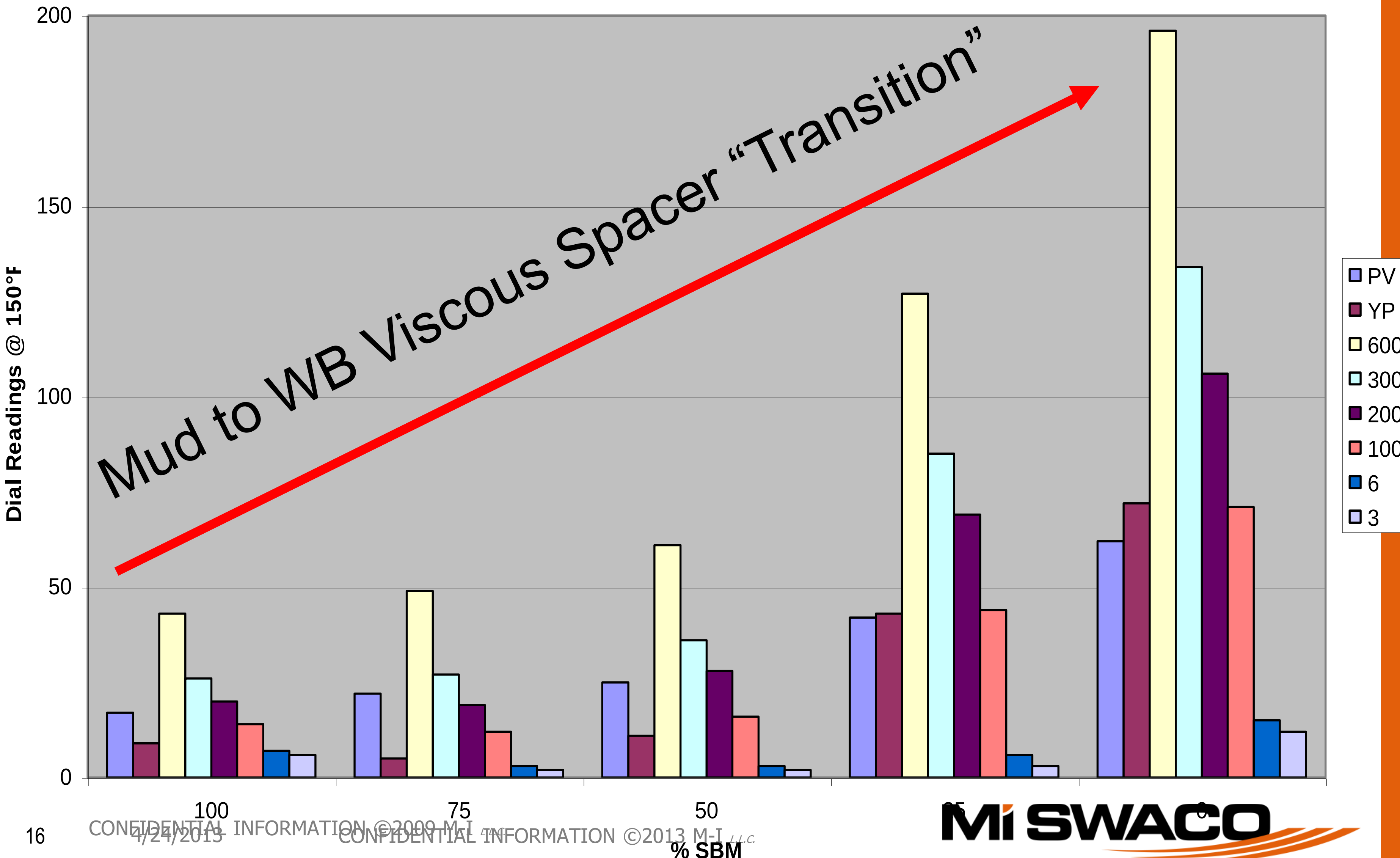
"Compatible" Transition Spacer



Chemical Wash Spacer

The ONLY spacer designed to Clean the Mud from the Pipe Surface!

Leave Entire Pipe Surface

- Free of Whole Mud
- Free of Oil-Film
- Water-Wet

Designed for Largest Annulus

- Contact time, Volume, Flow Rate

What is the Efficiency???

- Contact Time / Spacer Volume / Flow Rate are directly related
- What about efficiency when spacer is contaminated with mud?

Optimize Spacer Composition & Sizing

Size:

500 ft in the largest annulus?

1500 ft in the largest annulus?

5 minutes contact time?

10 minutes contact time?

3 ft/sec in the largest annulus?

Composition:

Concentration versus Volume?

Is 100 bbl of 10% better or worse than 50 bbl of 20%?

How effective is it as it circulates and picks up mud?

Fann 35 Cleaning Test (X-Clean)

Cleaning test is performed to determine….

- Cleaning agent type
- Cleaning agent concentration
- Velocity required for effective mud removal
- Contact time required for effective mud removal

Fann 35 Cleaning Test (X-Clean)

Cleaning test is performed to determine….

- Cleaning agent type
- Cleaning agent concentration
- Velocity required for effective mud removal
- Contact time required for effective mud removal

Cleaning test is repeated with mud contamination

Fann 35 Rheometer with Capped C-Sleeve

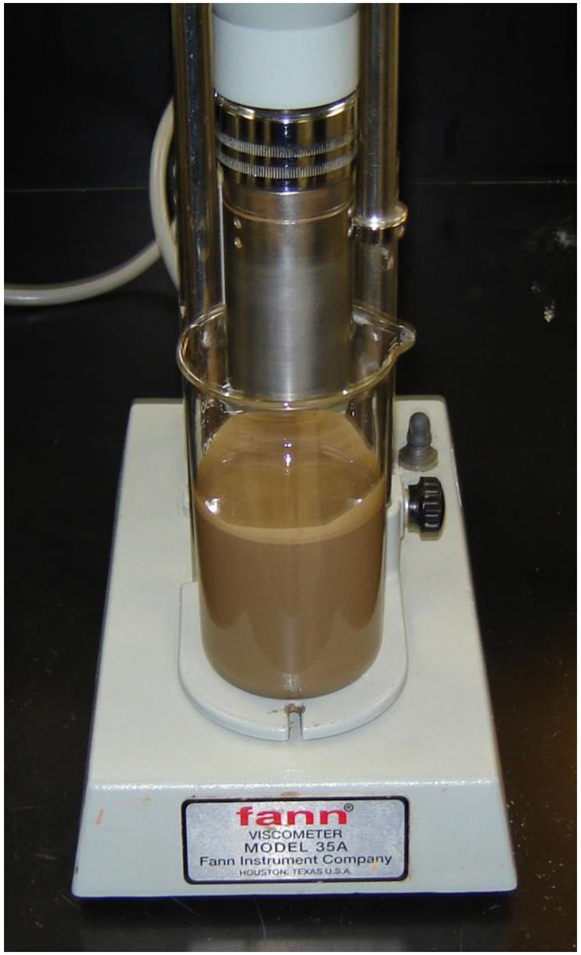
Carbon Steel Sleeve

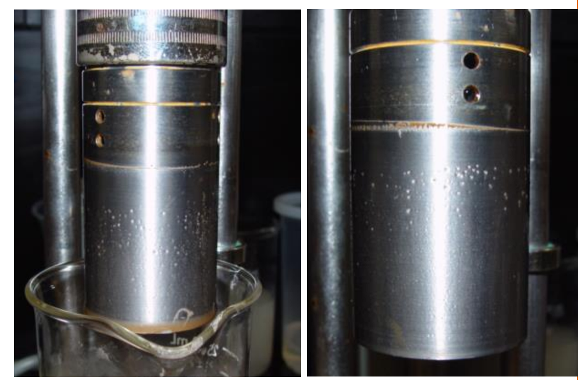
RPM / ft/min

600 / 240
300 / 120
200 / 80
100 / 40

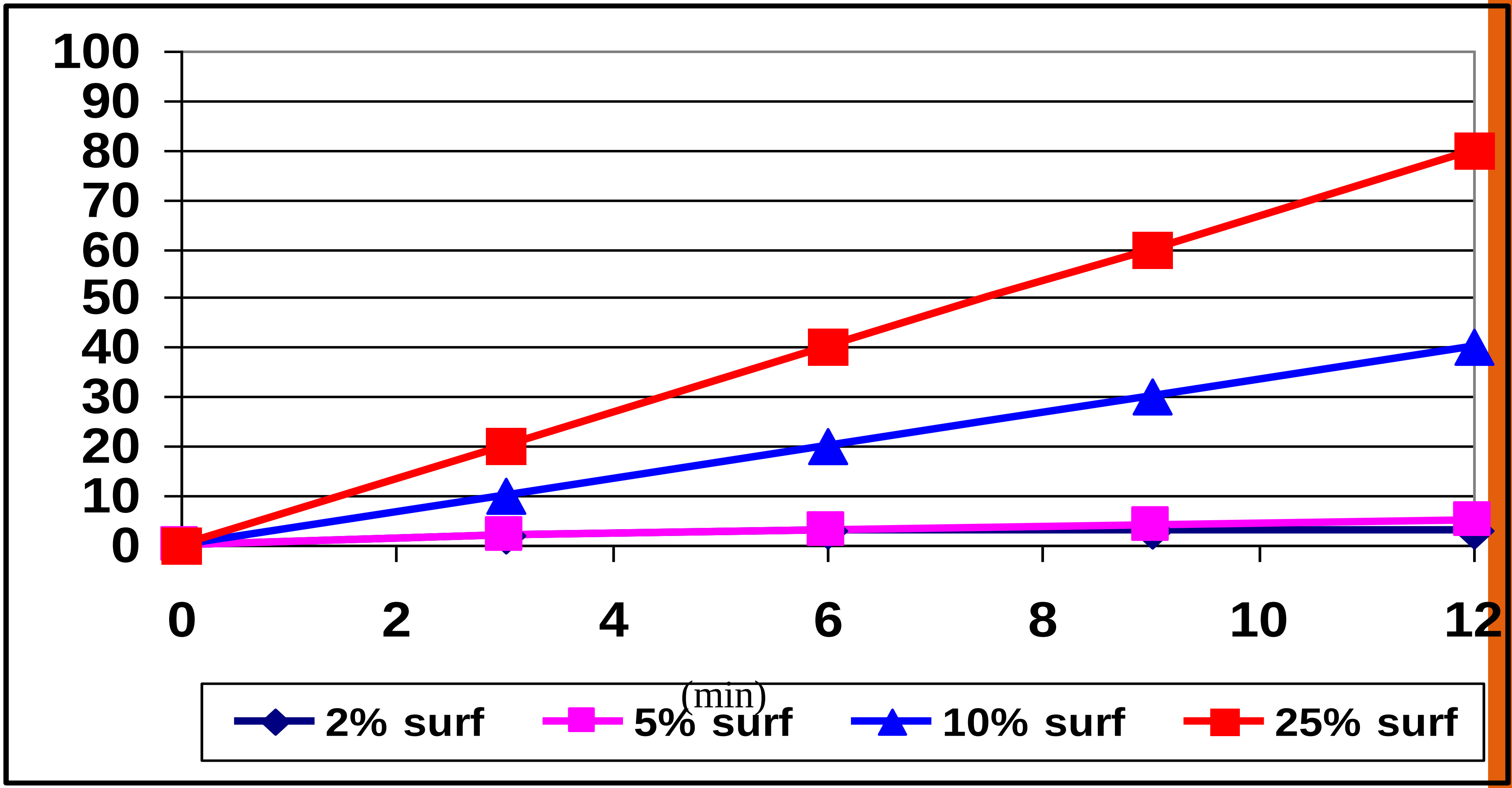
40F - ~150F

X-Clean Test

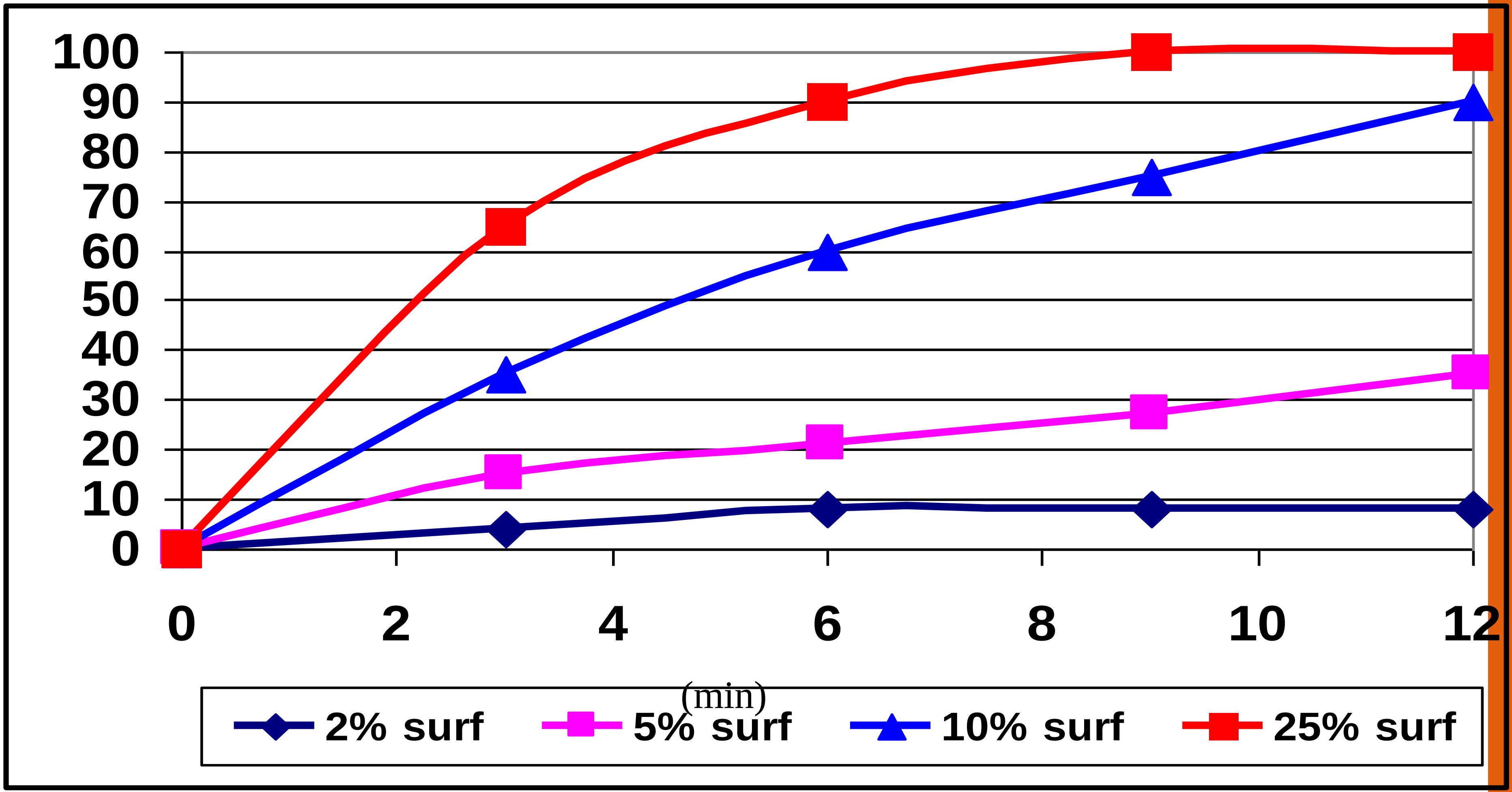

fann
VISCOMETER
MODEL 35A
Fann Instrument Company
HOUSTON, TEXAS U.S.A.



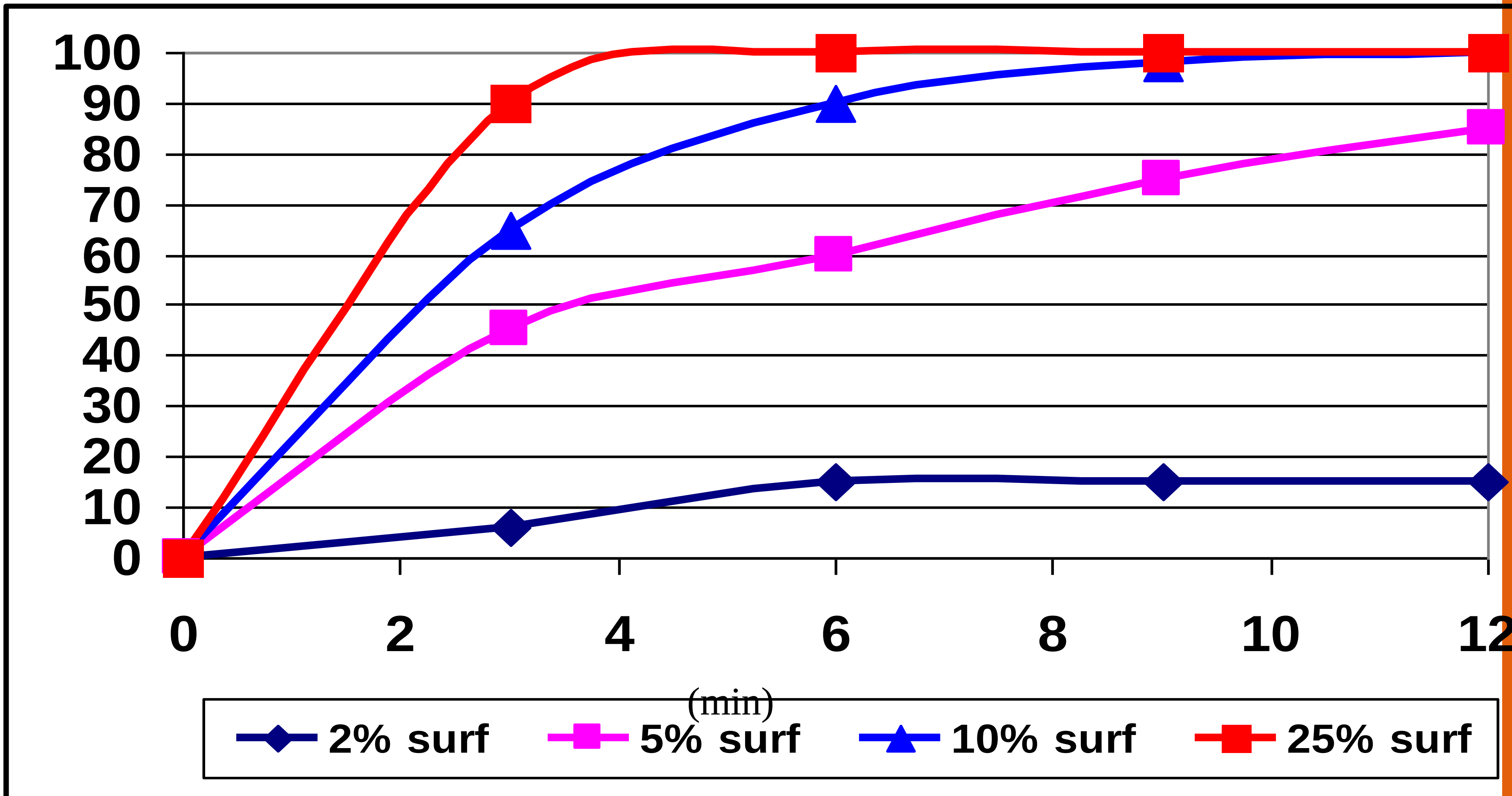
Chemical Spacer Efficiency vs. Contact Time at 50 ft/min.



Chemical Spacer Efficiency vs. Contact Time at 100 ft/min.



Chemical Spacer Efficiency vs. Contact Time at 200 ft/min.



Cleaning Efficiency

How is the Cleaning Efficiency of the Chemical Wash Spacer affected by its Circulation around the wellbore??

i.e., How is the Cleaning Efficiency affected by its continual 'contamination' by mud??

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Cleaning Efficiency Testing 14 pt Matrix

Test Data			
Test Temp.	°F	Pre-soak	
#	Concentration (%)	Contamination (%)	Sleeve RPM (rpm)
1	20	0	100
2	10	8	100
3	5	15	100
4	10	0	300
5	10	8	300
6	10	15	300
7	20	0	300
8	20	8	300
9	20	15	300
10	20	0	600
11	20	15	600
12	5	0	600
13	5	15	600
14	0	0	600
15			

Cleaning Efficiency Testing 14 pt Matrix

Test Data									
Test Temp.		°F	Pre-soak						
#	Concentration (%)	Contamination (%)	Sleeve RPM (rpm)	Test Time (mins)					
				1	2	4	6	10	
1	20	0	100	2.75	2.00	1.25	1.00	1.00	
2	10	8	100	3.25	3.00	2.75	2.75	2.75	
3	5	15	100	4.75	4.50	3.50	3.25	2.50	
4	10	0	300	1.50	1.25	1.00	1.00	1.00	
5	10	8	300	1.75	1.25	1.00	1.00	1.00	
6	10	15	300	1.75	1.00	1.00	1.00	1.00	
7	20	0	300	1.25	1.00	1.00	1.00	1.00	
8	20	8	300	1.75	1.00	1.00	1.00	1.00	
9	20	15	300	1.75	1.00	1.00	1.00	1.00	
10	20	0	600	1.00	1.00	1.00	1.00	1.00	
11	20	15	600	1.00	1.00	1.00	1.00	1.00	
12	5	0	600	1.25	1.00	1.00	1.00	1.00	
13	5	15	600	1.25	1.00	1.00	1.00	1.00	
14	0	0	600	1.50	1.50	1.50	1.50	1.50	
15									

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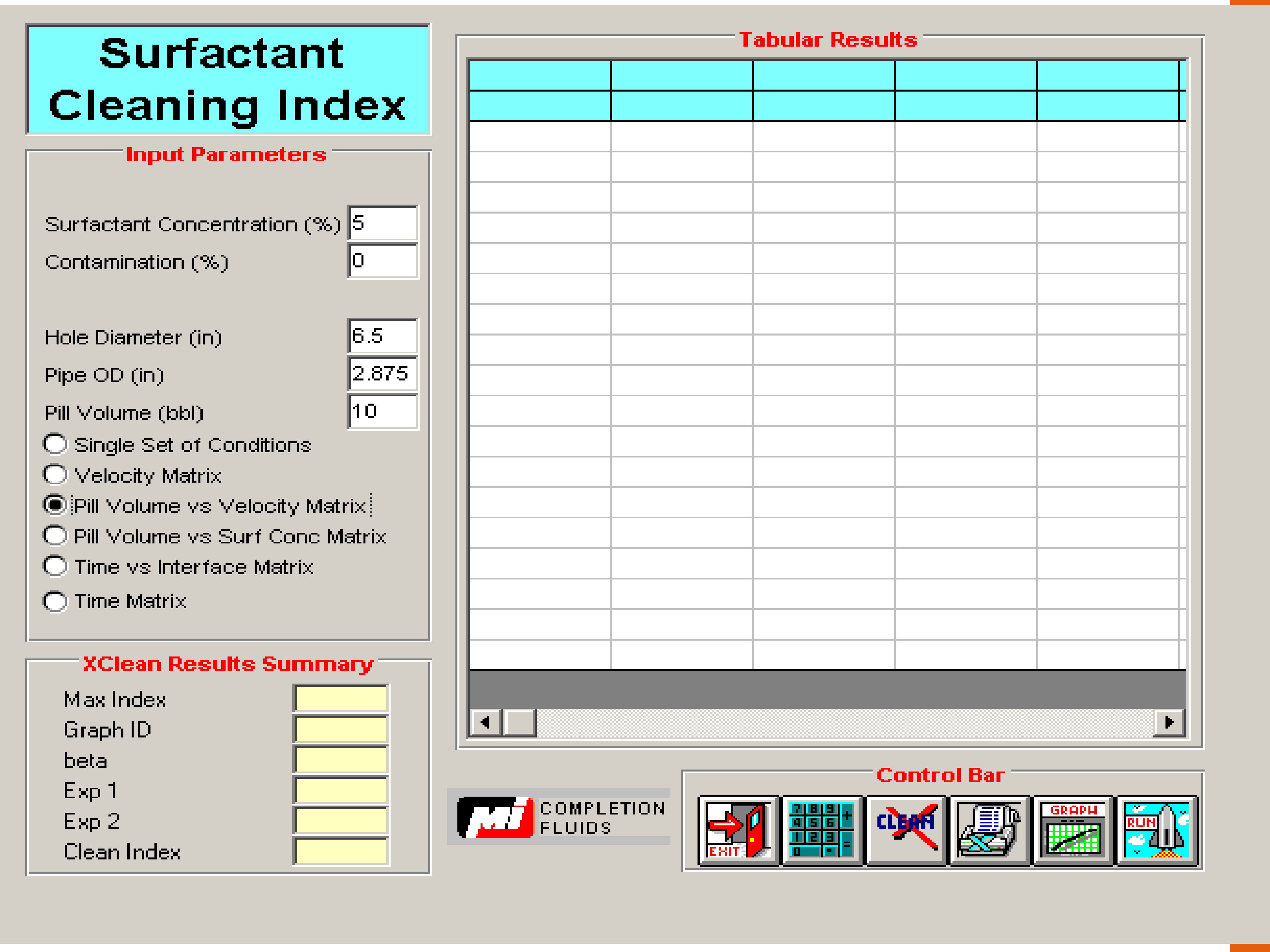
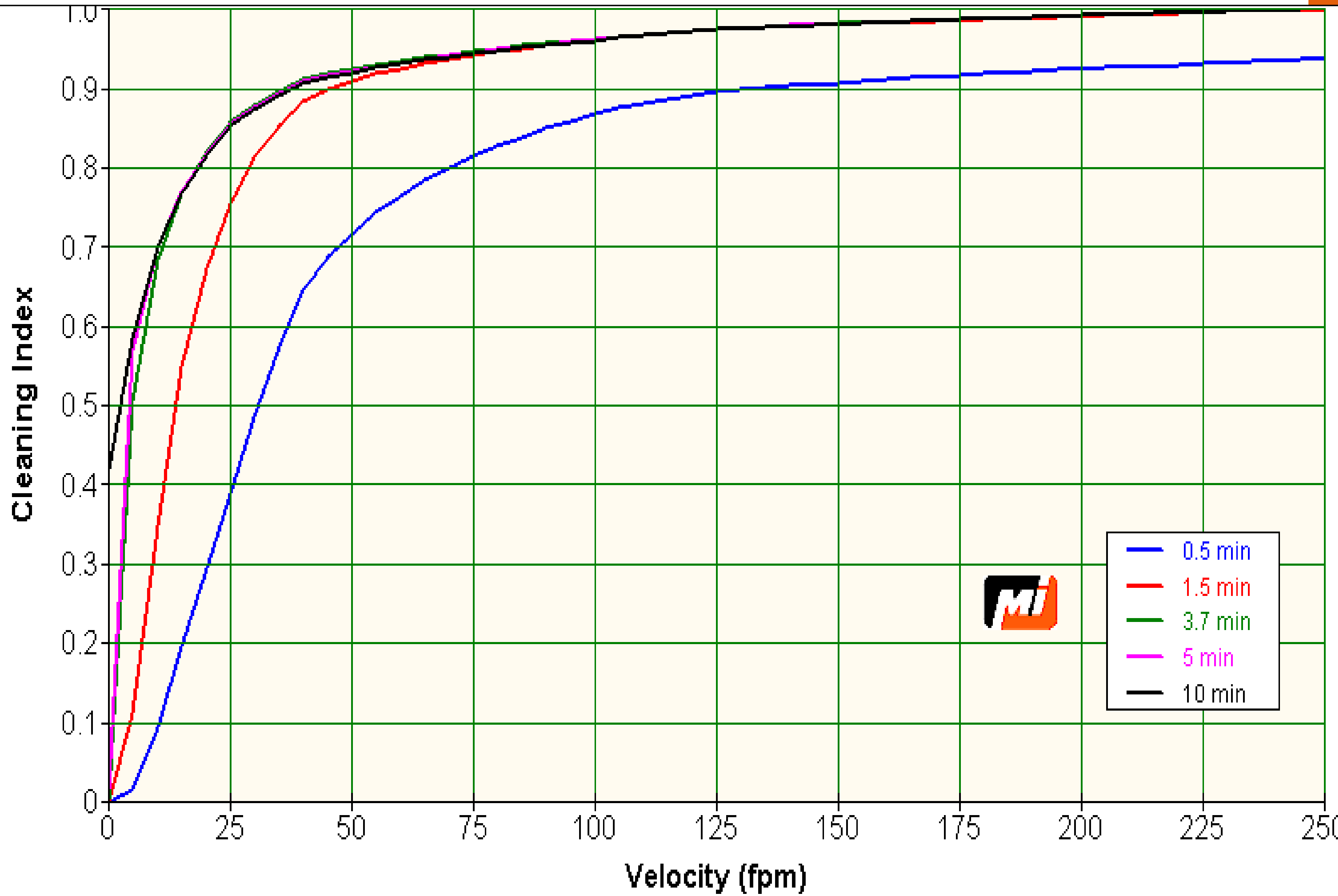
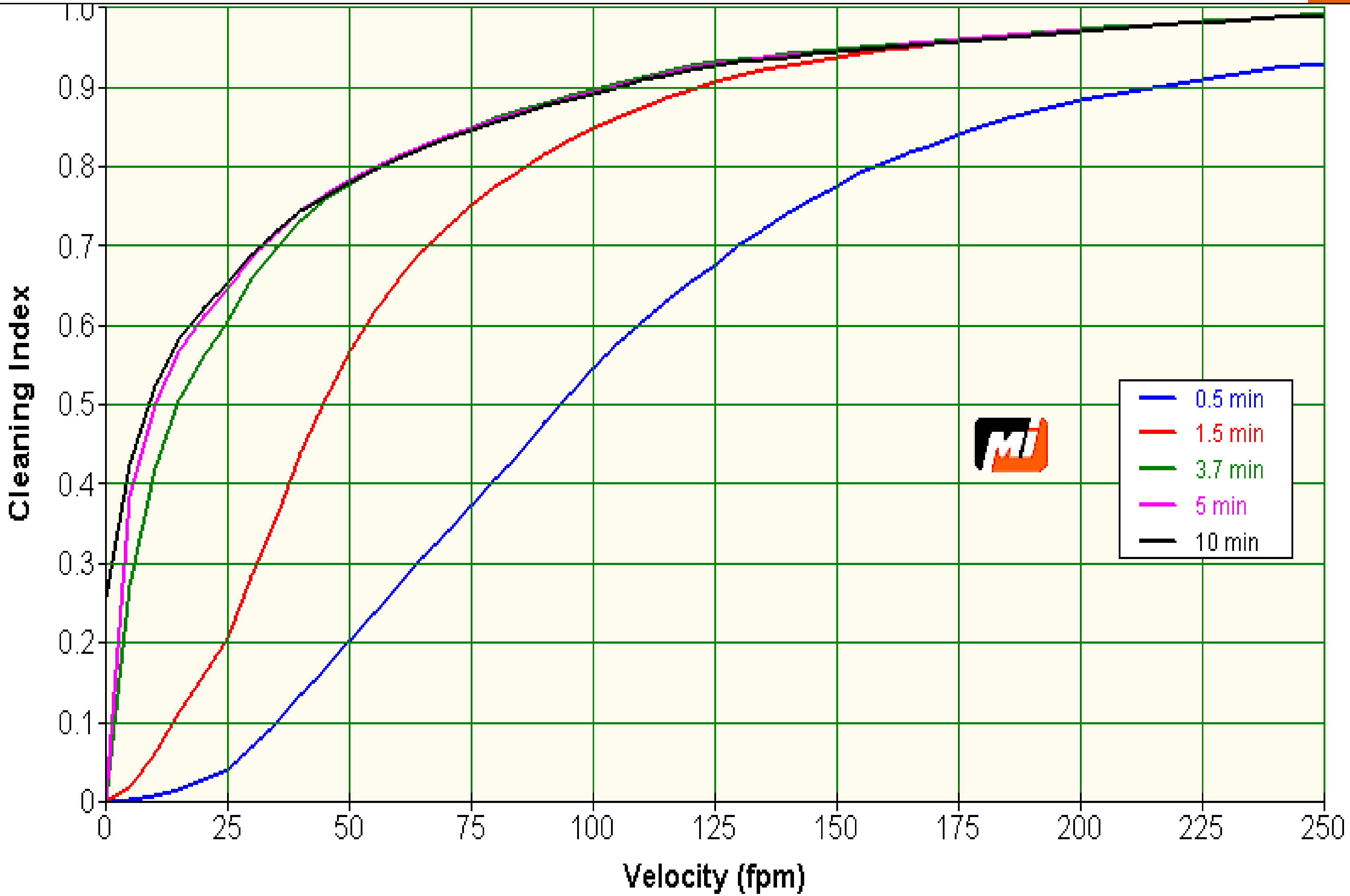

Surfactant Cleaning Index
Input Parameters
Surfactant Concentration (%) 5
Contamination (%) 0
Hole Diameter (in) 6.5
Pipe OD (in) 2.875
Pill Volume (bbl) 10
Single Set of Conditions
Velocity Matrix
Pill Volume vs Velocity Matrix
Pill Volume vs Surf Conc Matrix
Time vs Interface Matrix
Time Matrix
XClean Results Summary
Max Index
Graph ID
beta
Exp 1
Exp 2
Clean Index
Tabular Results
COMPLETION FLUIDS
Control Bar
EXIT
CLEAN
GRAPH
RUN

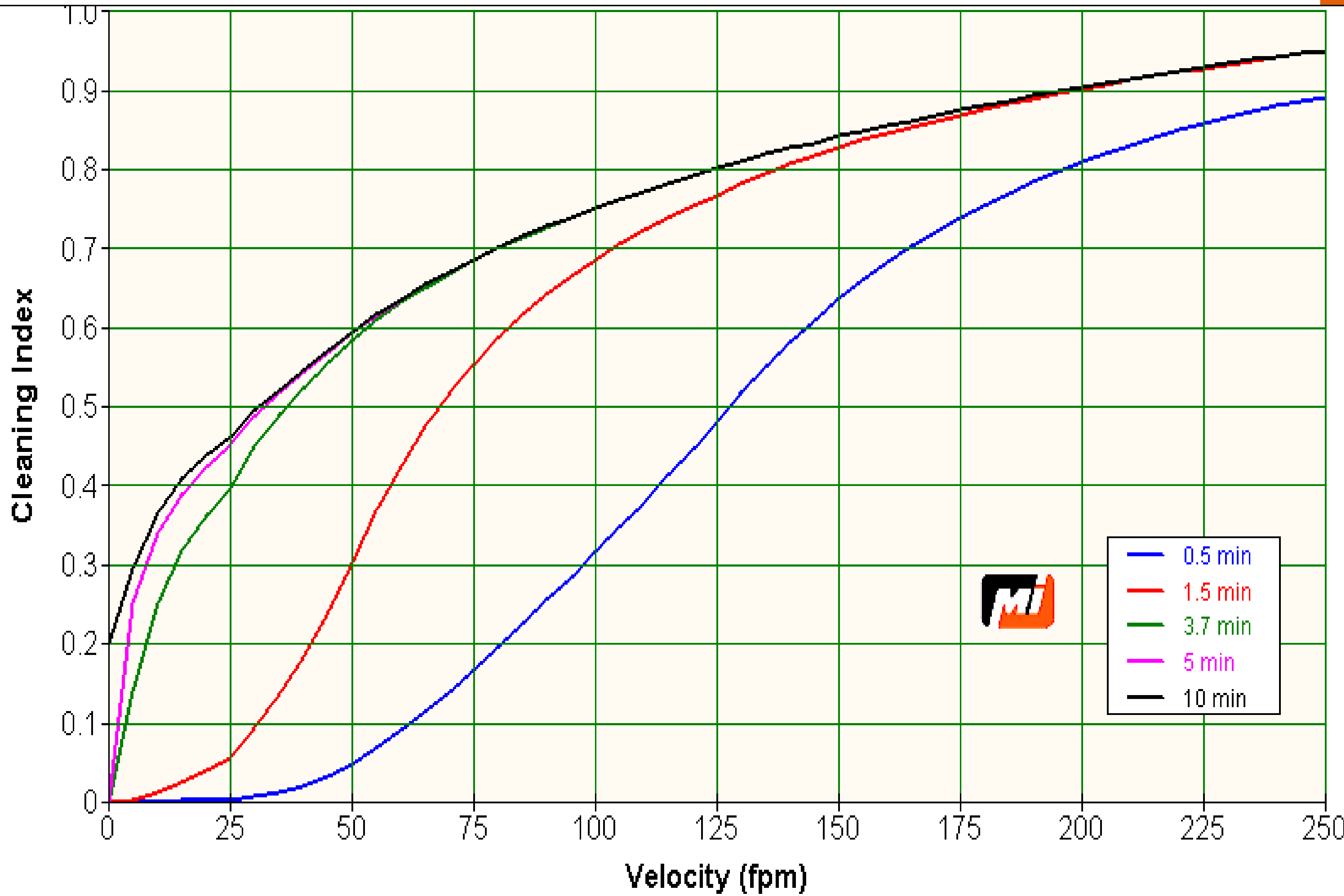
5% Surfactant w/ 0% OBM



5% Surfactant w/ 10% OBM



5% Surfactant w/ 20% OBM



This spreadsheet calculates the volume of mud cake film left on tubulars

The total bbl of mud film should be at least matched by the chemical spacer volume

Company	**Well Info**
Offshore Producing Co	**Nexen GC 243 #3 (Aspen #3)**

	input	Bbl of mud cake
film thickness (in)*	0.01	
I.D. of Casing I (in)	9.56	3.90
Length (ft)	10500	
I.D. of Casing II (in)	8.605	3.39
Length (ft)	10150	
I.D. of Casing III (in)		0.00
Length (ft)		
I.D. of Casing IV (in)		0.00
Length (ft)		
O.D. of Tubing I (in)	5.5	2.19
I.D. of Tubing I (in)	4	1.59
Length (ft)	10250	
O.D. of Tubing II (in)	5.865	2.37
I.D. of Tubing II (in)	4.25	1.72
Lenth (ft)	10400	
O.D. of Tubing III (in)		0.00
I.D. of Tubing III (in)		0.00
Length (ft)		

Total Volume in Tubing	**3.31**
Total Volume in Casing	**11.85**

DESIGN CRITERIA

Mud Cake Volume	**Bbls =**		**15.17 bbl**	
Linear Coverage (Annular):	**15**	**bbl will cover**	**255**	**ft in Widest Annulus**

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Evaluation Metrics

Brine Clarity (NTU or TSS)

Presence of drilling fluid on drill pipe

Drilling fluid or brine interface volume

Filtration media cycles

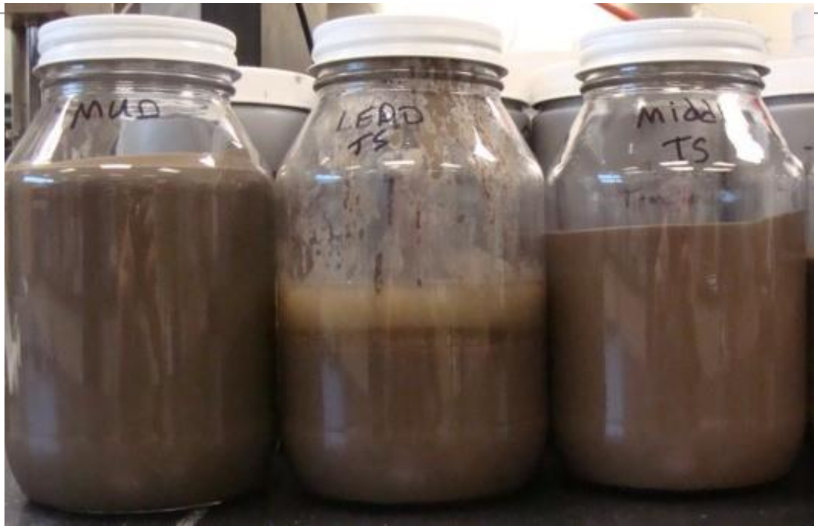
Time required for filtration

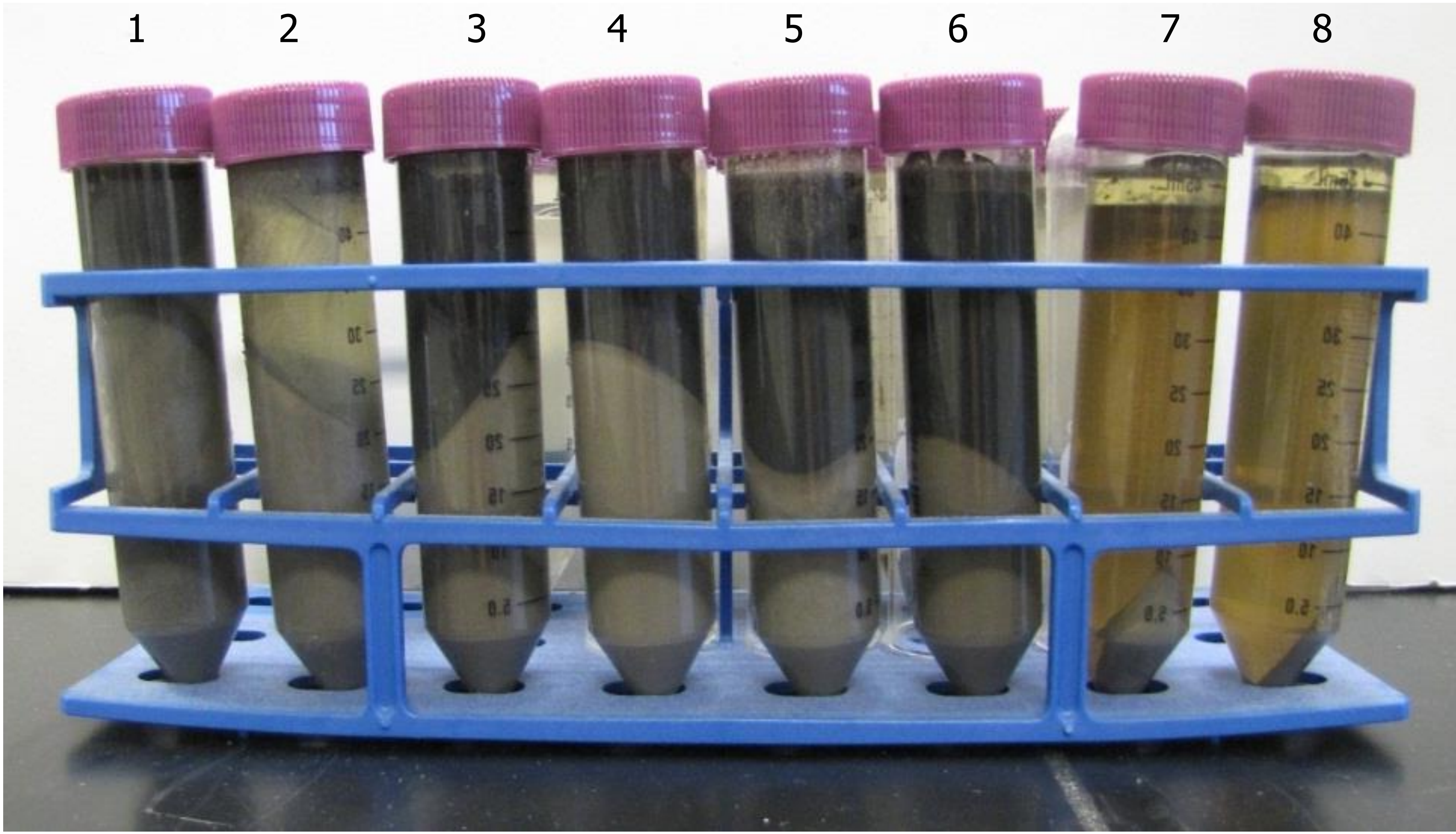
OBM and Surfactant


H2O
A
B
C
D
E
F

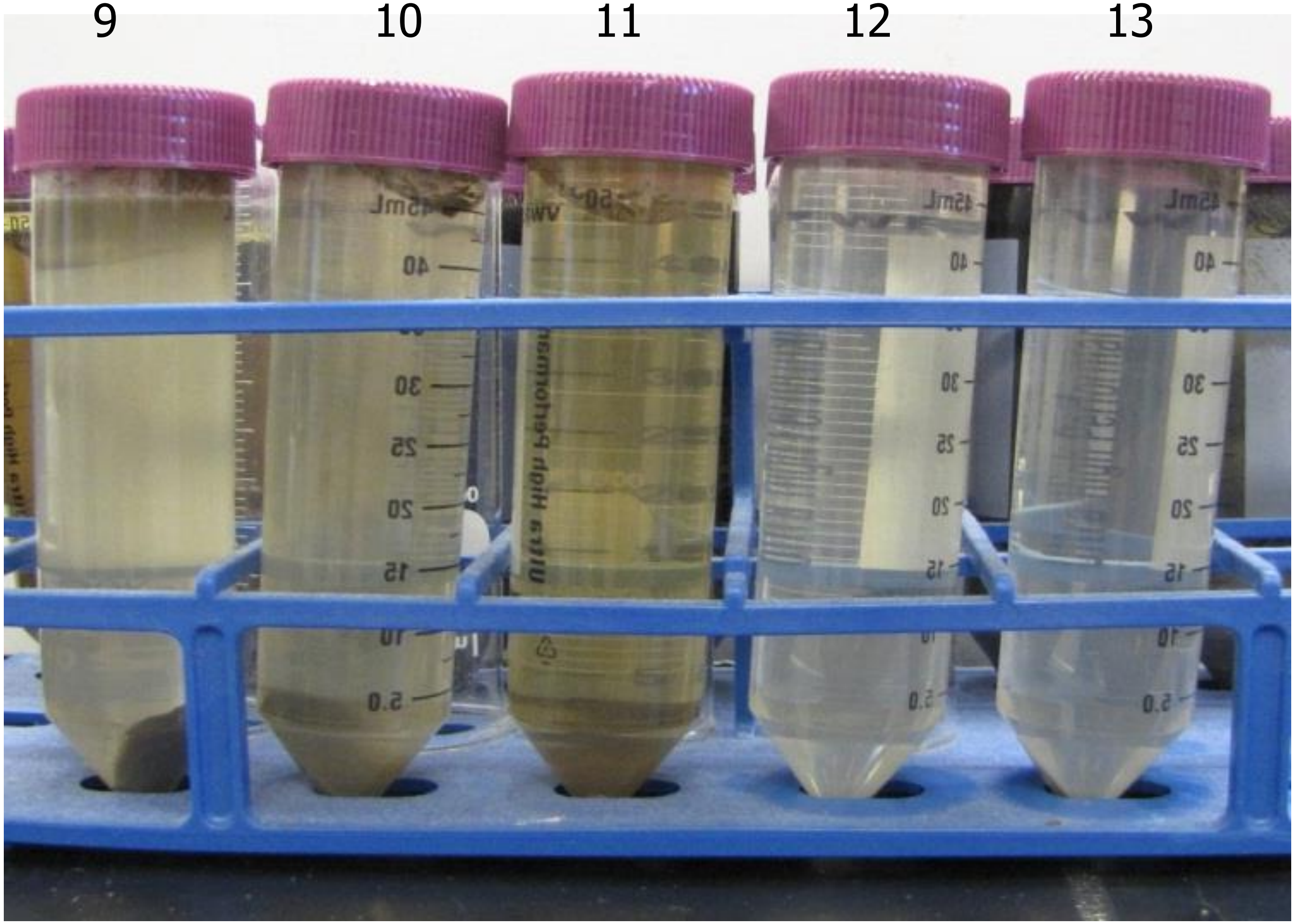
Displacement Analyses: Samples from Rig

Displacement Analyses: Samples from Rig

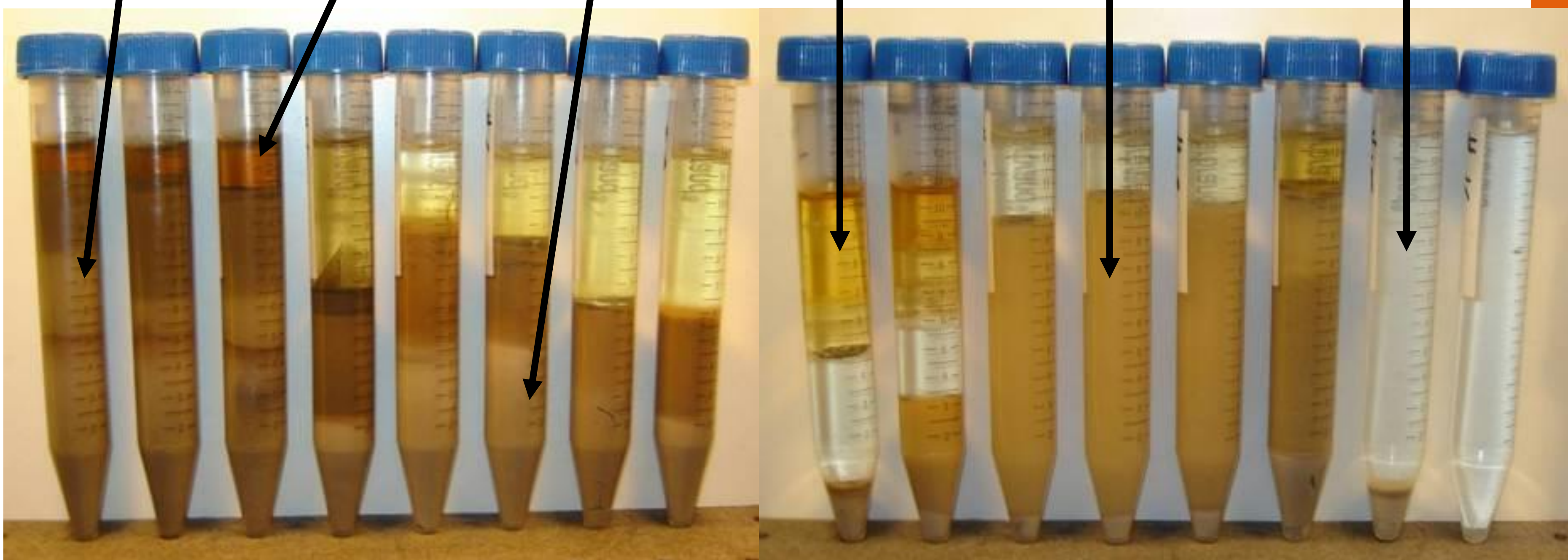



1
2
3
4
5
6
7
8

9 10 11 12 13

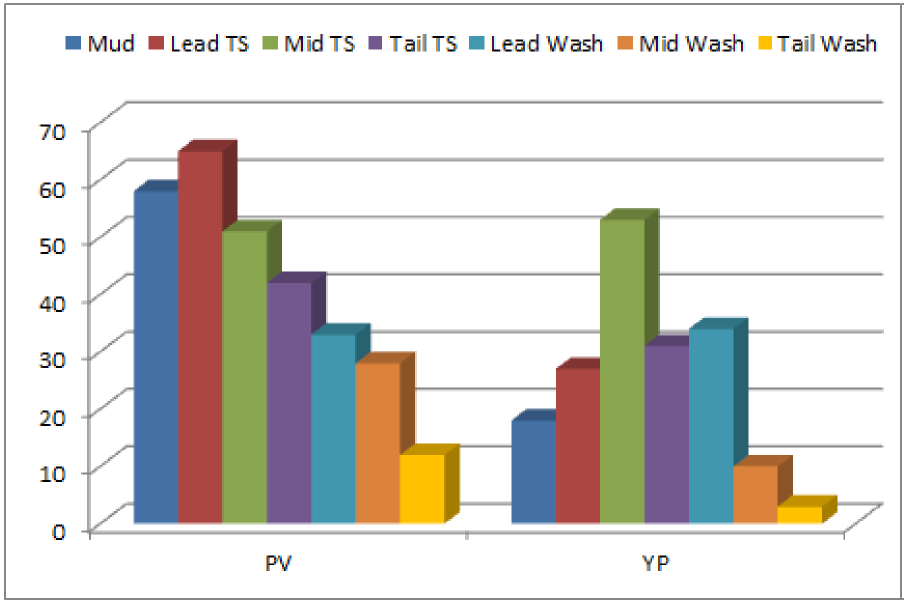


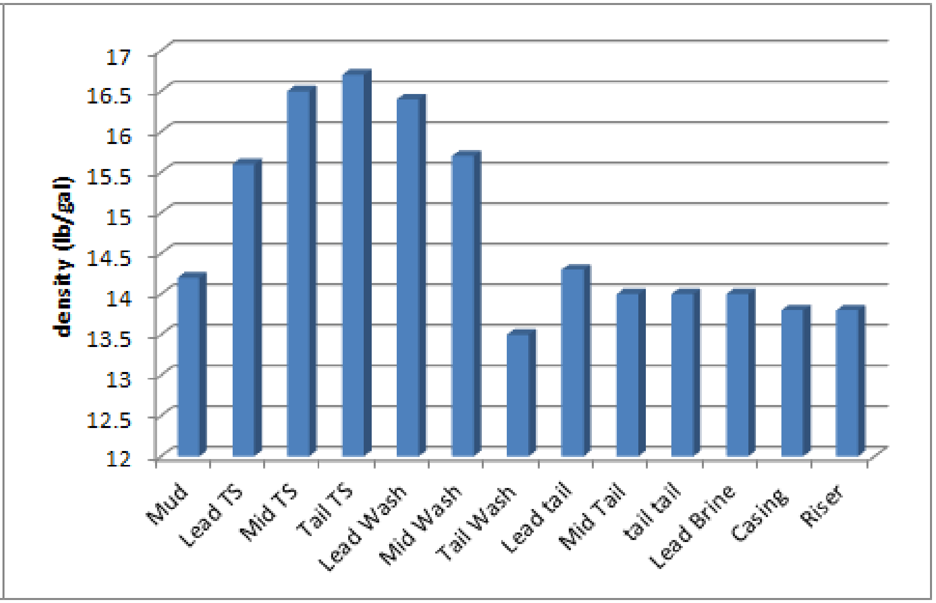
Post-Displacement Analysis

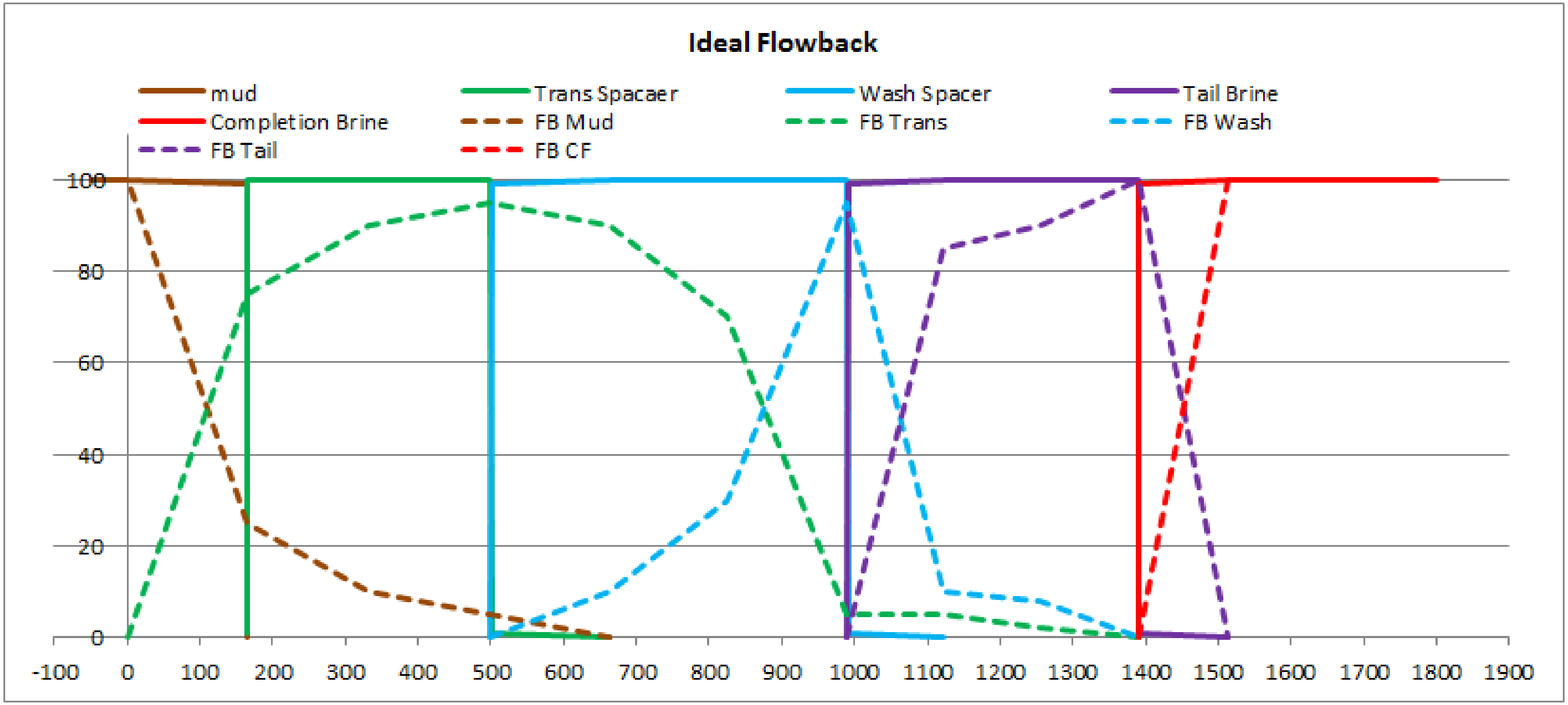


Ref: “Validating the Quality of Mud-to-Brine Displacements”

AADE 04-DF-HO-39 2004 Drilling Fluids Tech Conference, Houston, TX


Mud
Lead TS
Mid TS
Tail TS
Lead Wash
Mid Wash
Tail Wash
70
60
50
40
30
20
10
0
PV
YP


density (lb/gal)
17
16.5
16
15.5
15
14.5
14
13.5
13
12.5
12
Mud
Lead TS
Mid TS
Tail TS
Lead Wash
Mid Wash
Tail Wash
Lead tail
Mid Tail
tail tail
Lead Brine
Casing
Riser



 4/24/2013

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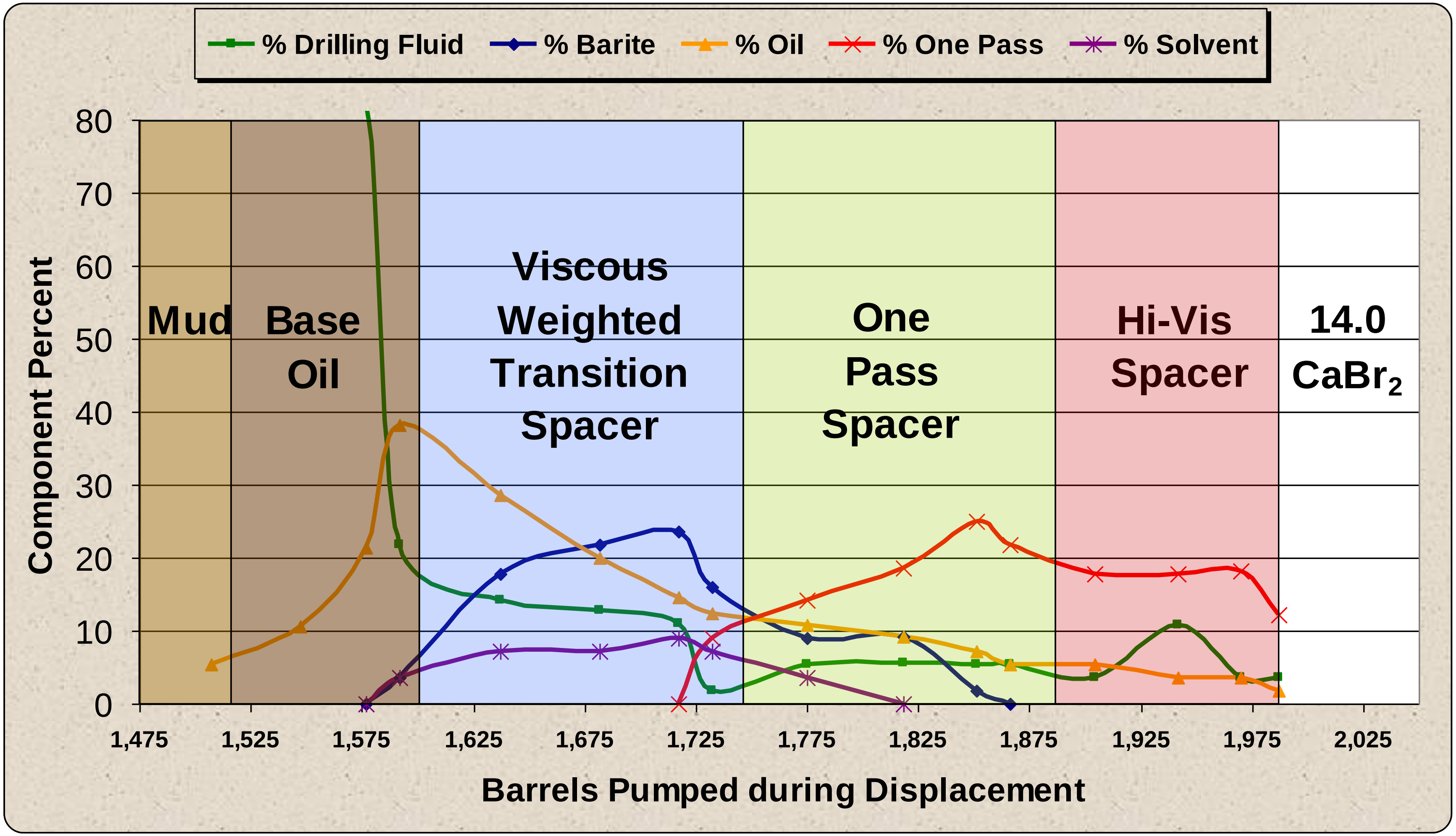
Displacement FlowBack Plot



A couple of Lessons Learned

Spacer design criteria which emphasize the wash spacer without regard to the transition spacer are mistaken.

- Transition spacer appears to do most of the whole mud removal.
- Success by the wash spacer depends upon the work of the transition spacer.

3/64 ^{inch} is typical for a sheath of mud removed in aqueous spacers.

- Wash spacer size can be calculated from this using results from spindle cleaning test (X-Clean).

Transition spacer can be appropriately sized according to hole volume.

- Recommended 10% of hole-volume-with-pipe appears to correlate with optimized mud removal volume.

Results published as SPE 110589 and presented at 2007 ATCE at Anaheim, CA.

Thank you for your attention