Gas Flotation Tanks (GFT) – A Comparison of 2 chamber Vs 4 Chamber Design Performance

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Outline:

- Significant Design Feature of Micro-Bubble Flotation (MBF):
- Application of Induced gas flotation in an API tank
- Benefits of Sequential Oil removal
- 2 chamber and 4 chamber designs
- Comparative Performance Evaluation of 2 Vs 4 Chamber design
- Conclusions

Significant Design Feature of Micro-Bubble Flotation (MBF):

1. Shift from Single to multi chamber design
2. Recycle gas & pressurized system
3. Adjustable weirs to optimize skimming
4. Hydraulic skimming, eliminate paddles.
5. CFD to optimize internal design and hydraulics.
6. Bubble generation -outside.
7. Use of smaller bubbles
8. Fully isolated (discrete) chamber.
9. Pressure vessel to API tank/vessel retrofit.

APPLICATION OF INDUCED GAS FLOTATION IN AN API TANK.

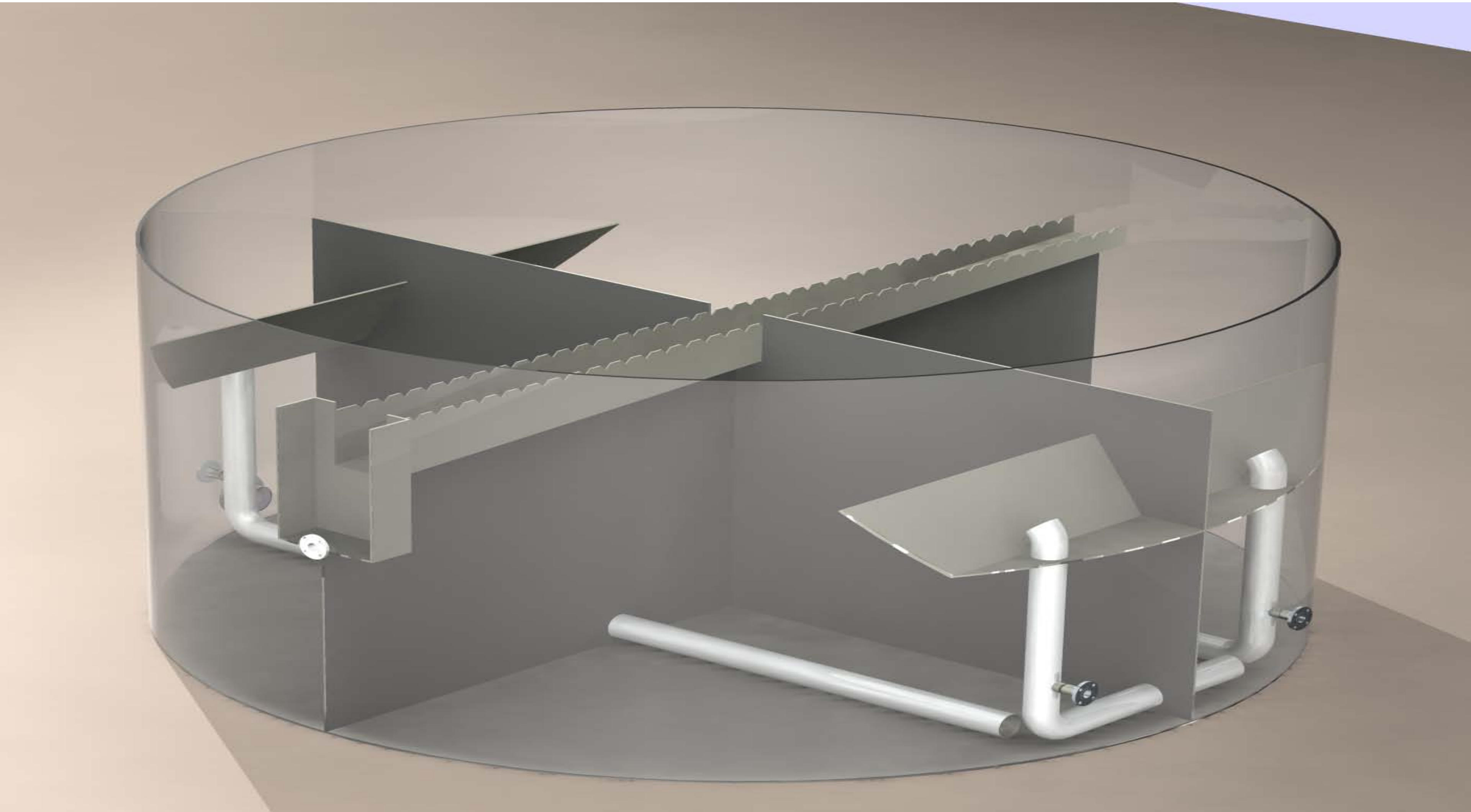

Figure A. Two Chamber GFT with GLR reactor Installation.

Benefits of Sequential Oil Removal

Rate of oil removal is based on rise velocity of oil and gas, which depends on size, gravity, water viscosity.
The equation below give oil concentration in the nth chamber. Theoretically all that is needed is time.

$$\frac{C_n}{C_{in}} = \left(\frac{1}{e^{k\theta t}}\right)^n \quad \text{or} \quad \frac{C_n}{C_{in}} - \left(\frac{1}{e^{nk\theta t}}\right)$$

- Where C is the oil concentration at inlet and in the nth chamber
- t is residence time per chamber,
- K is an oil removal constant,
- θ is a chamber cell constant related to how efficient any one chamber is at removing oil.

In the above expression if you double the number of chambers (n) and half time (t) then the result is same ie no difference in performance. However lab results and commercial scale gas flotation units conflicts with this conclusion and prove that the oil removal efficiency does improve with increased number of chambers.

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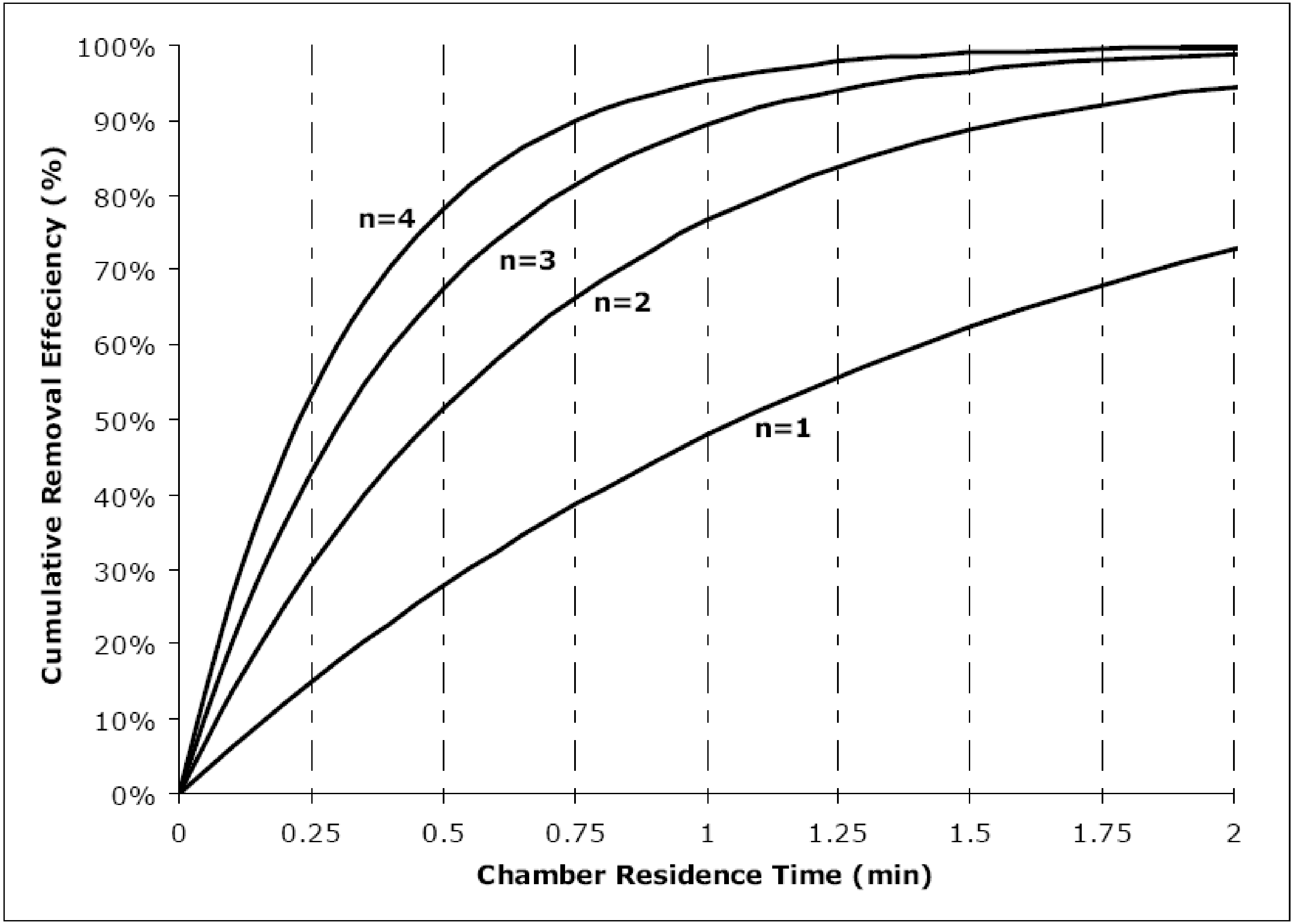
- Expression above assumed perfect hydraulic conditions (no impact from walls or other internal structures), such that k and θ remains the same.
- Most oil is skimmed in chamber one and lesser in subsequent chambers. This impacts value of k in each chamber.
- Further oil removal efficiency in each chamber reduces as residual oil decreases.
- To counter this fresh bubbles are introduced in each chamber, this further improves k
- To account for the above, the equation can be modified as follows:

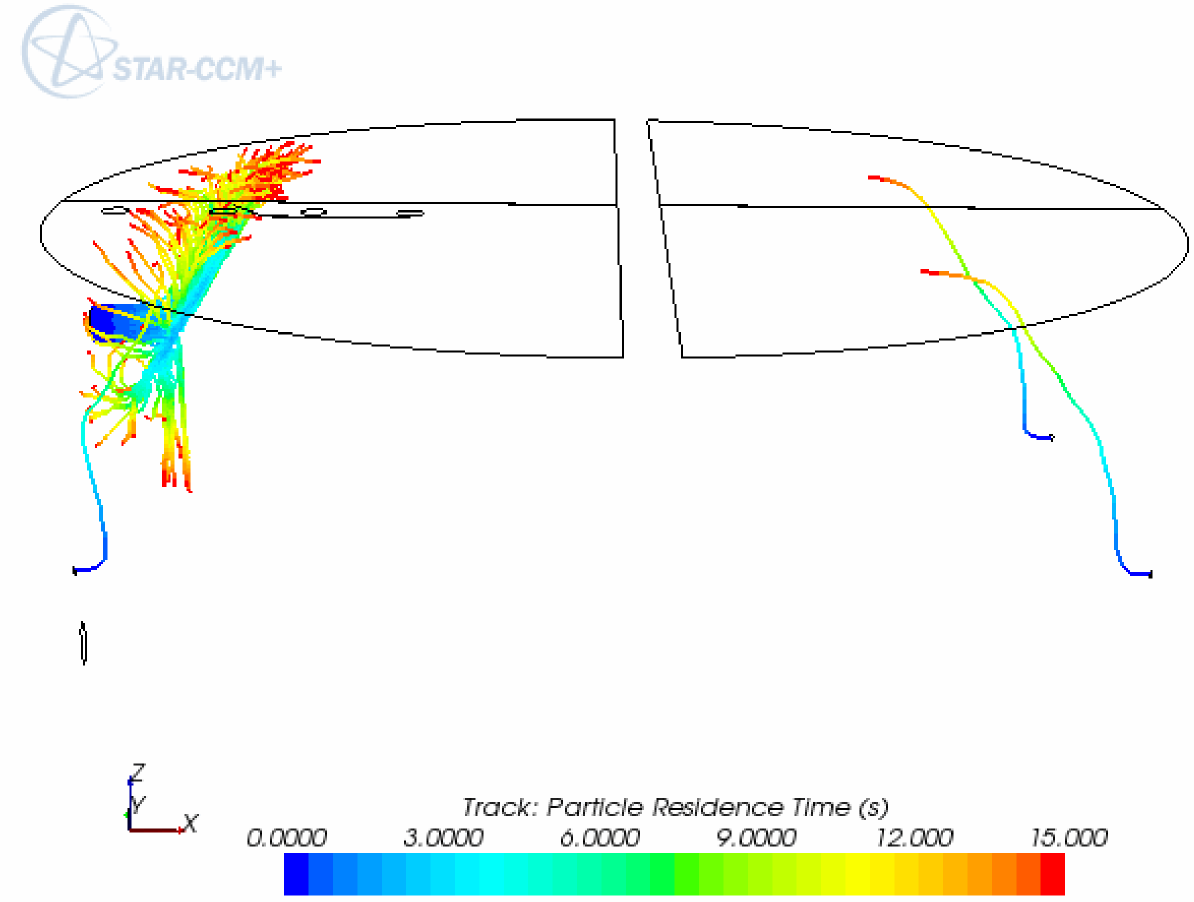
$$\frac{C_n}{C_{in}} = \prod_{i=1}^{n} exp(-k_i \theta_i t)$$

Alternatively cumulative removal efficiency (CRE) is

$$CRE = 1 - \prod_{i=1}^{n} \exp(-k_i \theta_i t)$$



100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Cumulative Removal Effeciency (%)
n=4
n=3
n=2
n=1
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
Chamber Residence Time (min)



Animation depicting progress in time (step size = 15 sec) of the 'Combined' phase particles evolving at the different inlets.

PERFORMANCE EVALUATION OF 2 CHAMBER DESIGN VS 4 CHAMBER DESIGN

CASE #1 2 CHAMBER GFT

	Site I	Site II
Designed Flow rate (BWPD)	52,000	208,000
Oil density	872	932
Water density	1003	1005
Operating temperature (Deg C)	60	50
No of chambers	2	2
Designed Retention time (Min.)	60	60
Micro-bubble Generator	MB Pump	GLR reactor

Figure D. 2 Chamber Inlet Process Conditions

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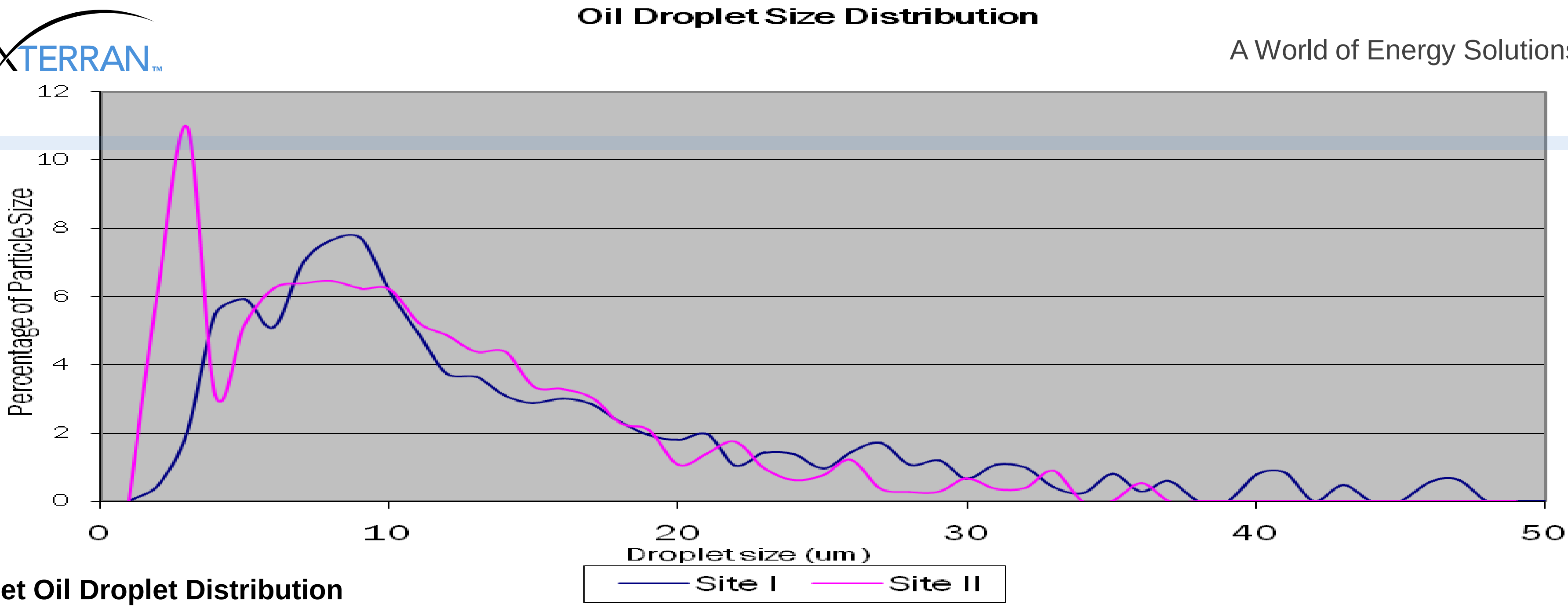
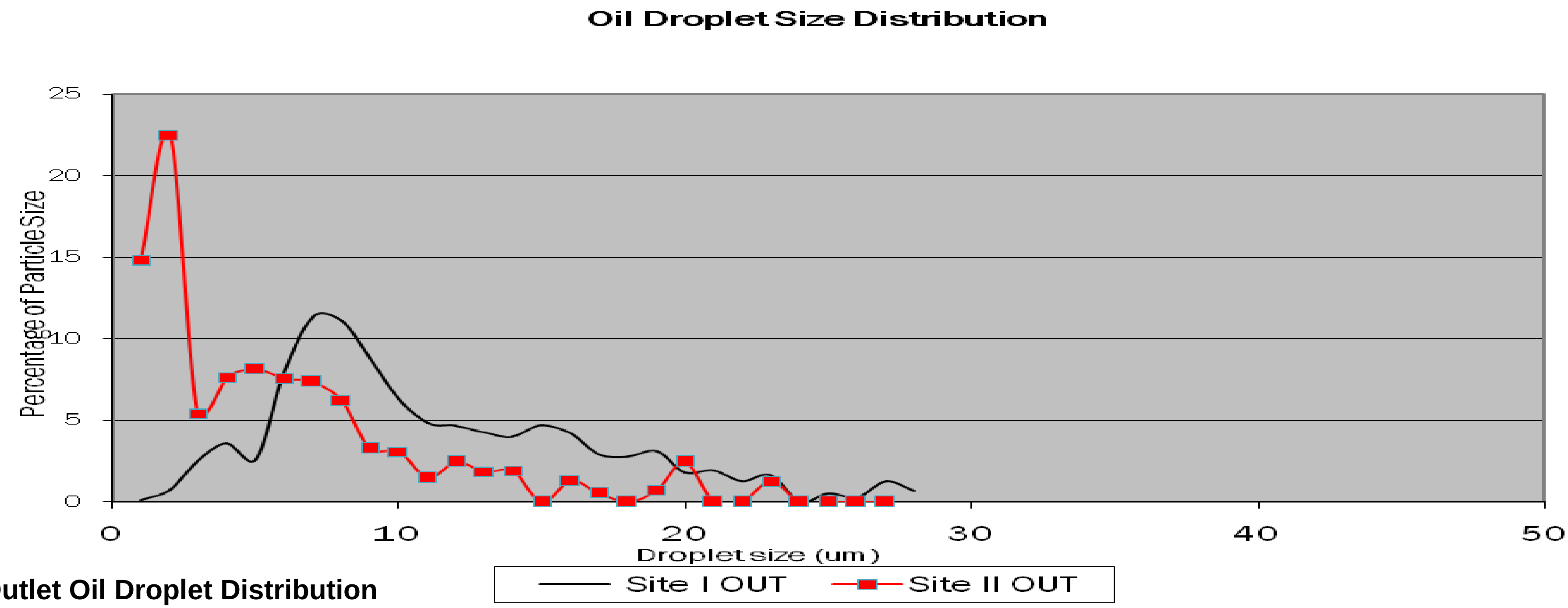


Inlet Oil Droplet Distribution



Outlet Oil Droplet Distribution

Case #2. 4 Chamber GFT

	Client 1	Client 2
Designed Flow rate (BWPD)	85,000	44,000
Oil density	876	910
Water density	1000	1002
Operating temperature (Deg C)	50	80
No of chambers	4	4
Designed Retention time (Min.)	60	60
Micro-bubble Generator	MB Pumps	MB Pumps

Figure G. 4 Chamber Inlet Process Conditions

Figure H. Oil concentration at the outlet of each chamber

	Client 1 (oil ppm)		Client 2 (oil ppm)	
	Day 1	Day 2	Day 1	Day 2
Inlet	159	135	515	205
Chamber 1	35	27	144	64
Chamber 2	22	22	121	66
Chamber 3	15	12	25	21
Outlet	14	13	5	3

4 Chamber GFT, Client 1

Cumulative Chamber Removal Efficiency				
	Client 1		Client 2	
	Day 1	Day 2	Day 1	Day 2
Inlet	0	0	0	0
Chamber 1	78%	80%	72%	69%
Chamber 2	86%	84%	77%	68%
Chamber 3	91%	91%	95%	90%
Outlet	91%	90%	99%	99%

Figure I.
Cumulative Oil Removal Efficiency by Chamber

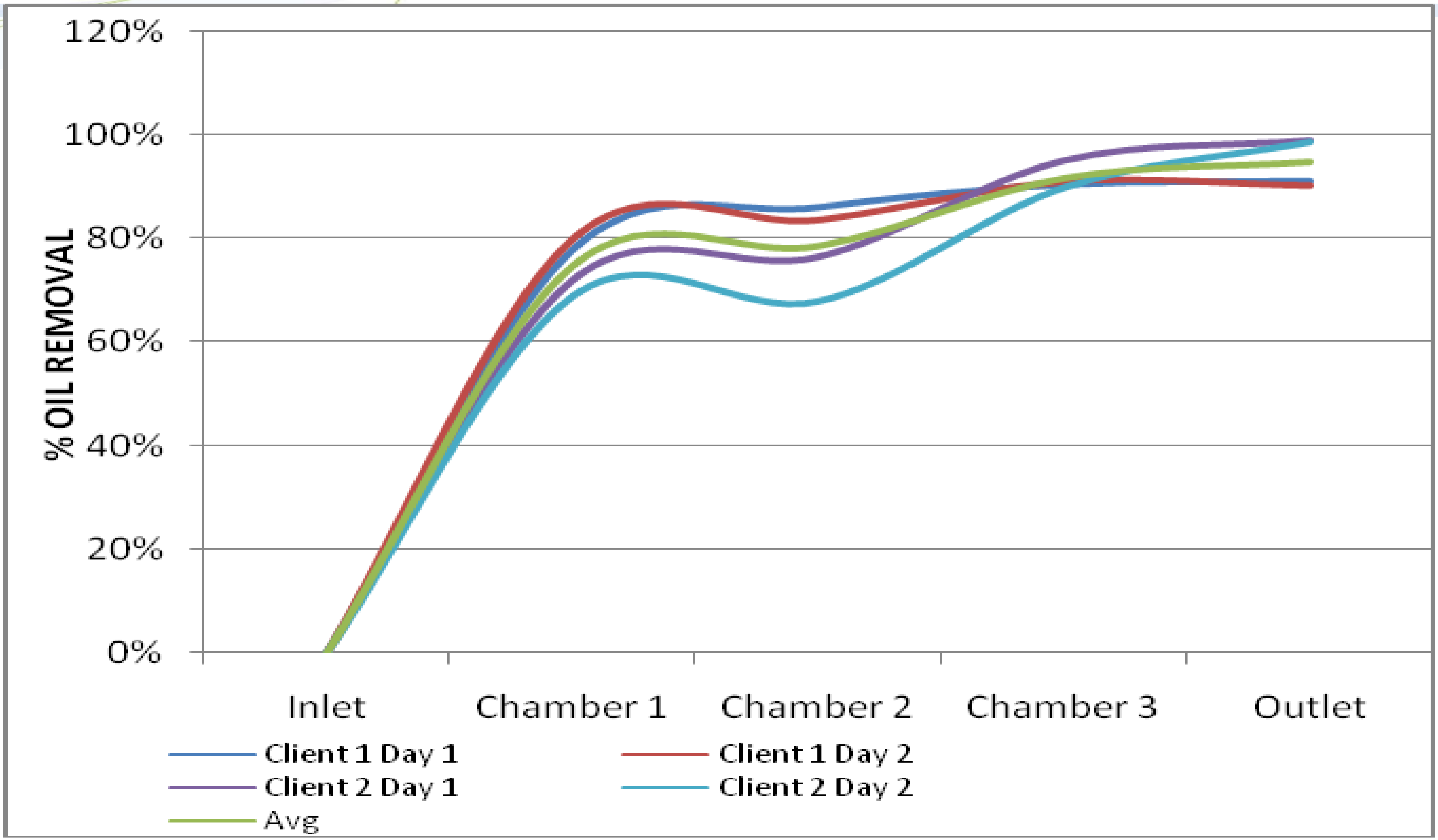
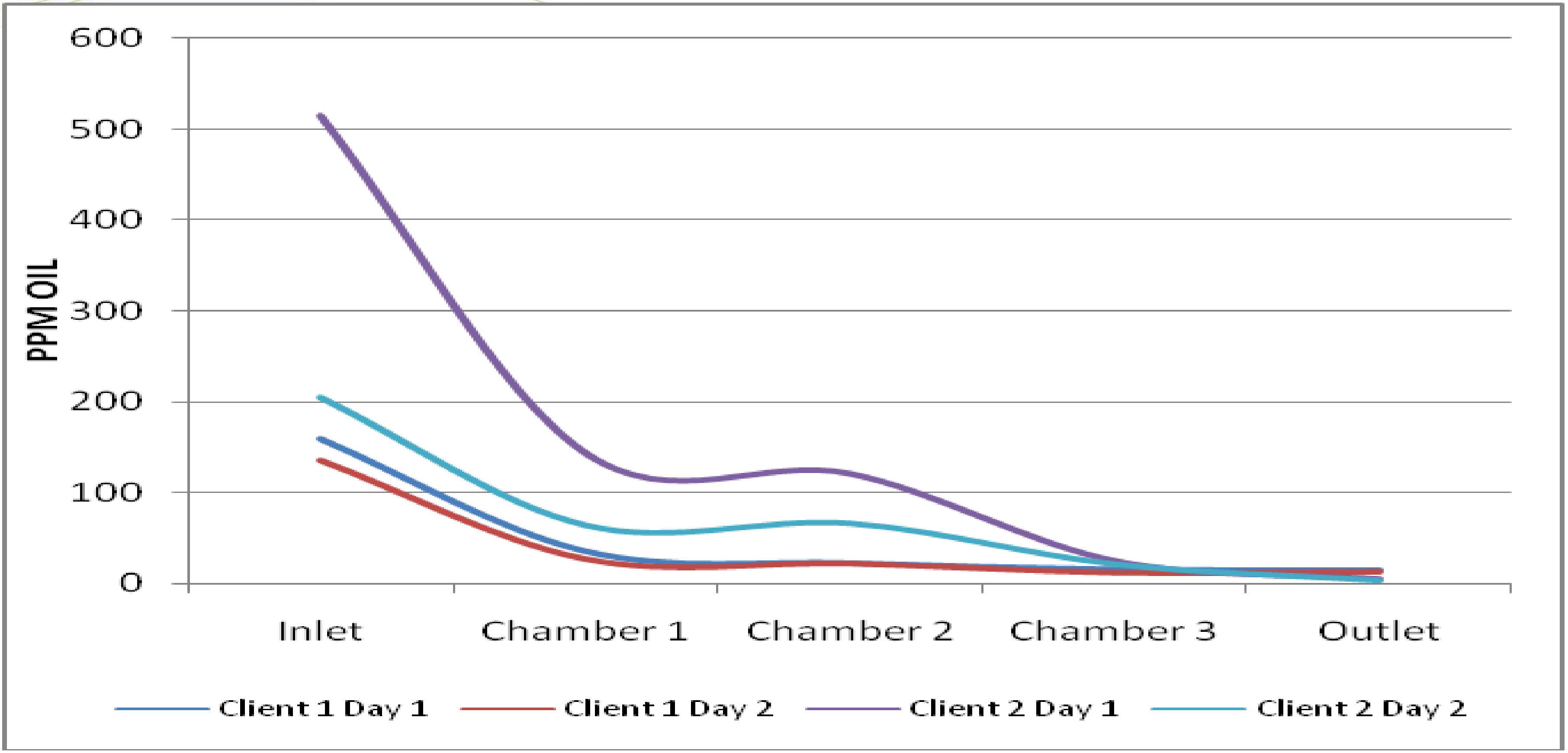


Figure J.
Cumulative Oil Removal Efficiency by Chamber



- Client 2 experienced an upset on day one, inlet oil went up to 500 ppm.
- However outlet was still maintained.
- Demonstrates the ability for the first chamber to absorb large upsets.
- This characteristic of buffered upsets has been observed in many other GFT installations.

Figure L. Water Samples at the outlet of each chamber collected for Client 1.

Figure M. Water Samples at inlet and outlet of GFT, Client 2.

Water Samples at the outlet of each chamber collected for Client 1.

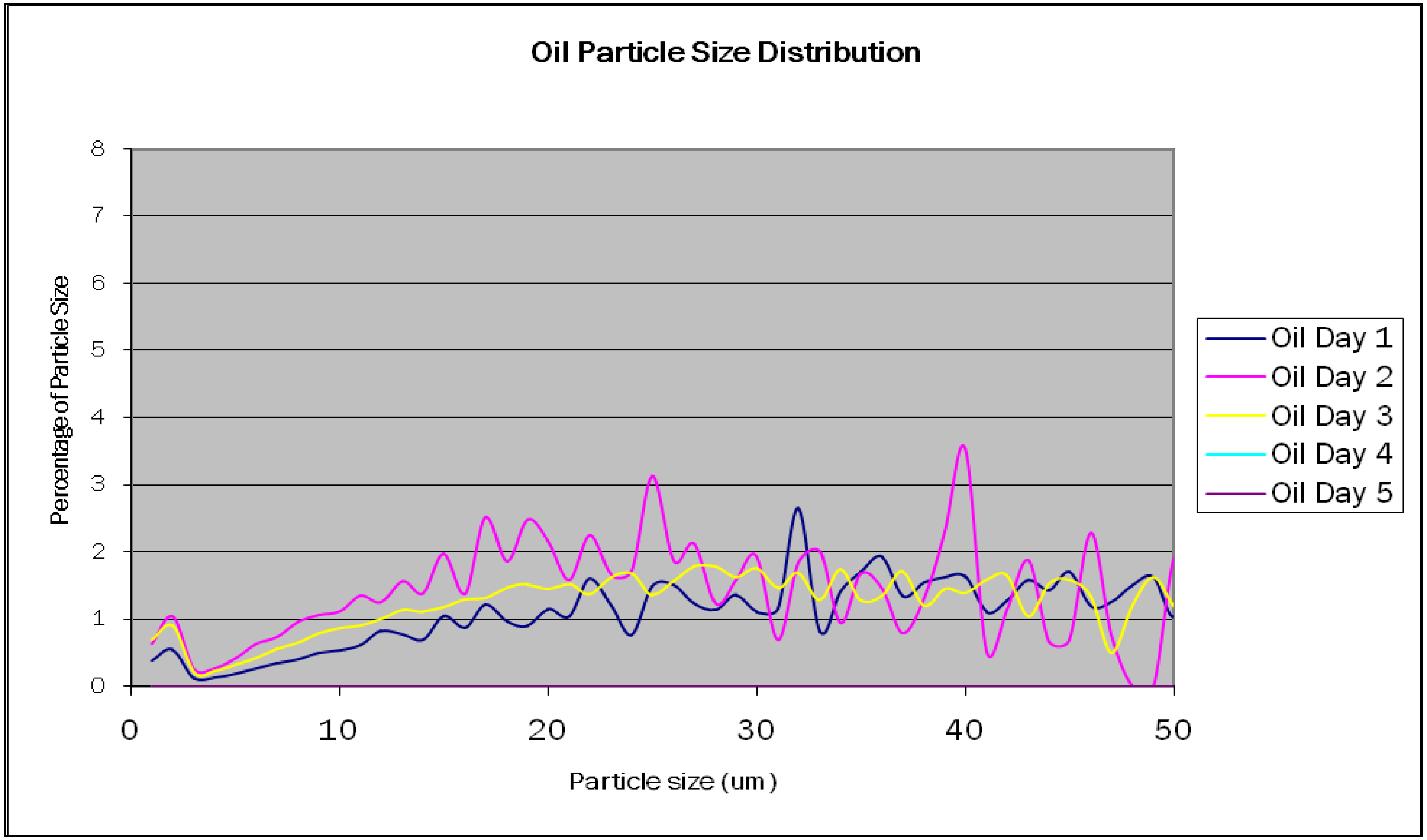


Figure N. Chamber 1

Water Samples at the outlet of each chamber collected for Client 1.

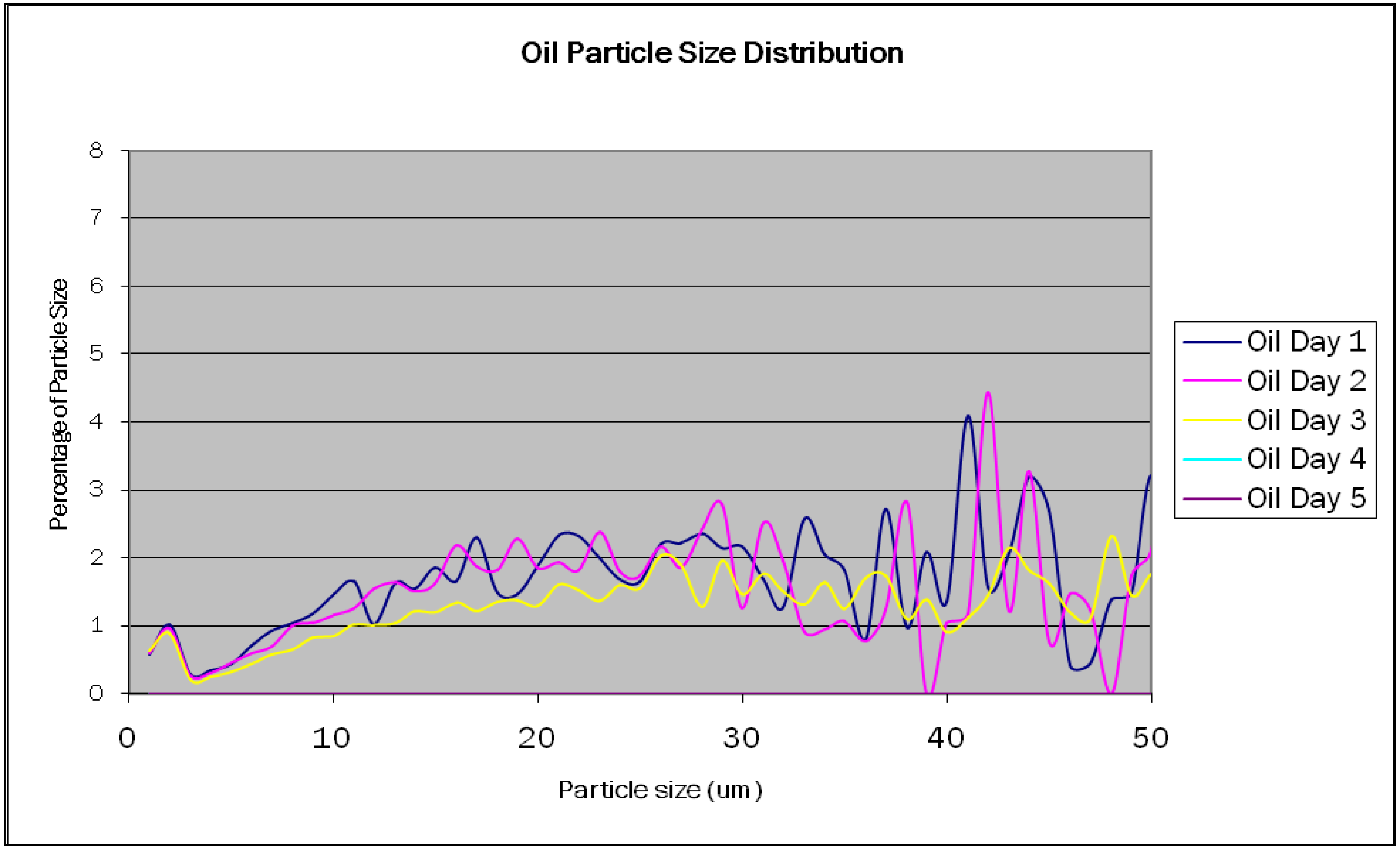


Figure O. Chamber 2

Water Samples at the outlet of each chamber collected for Client 1.

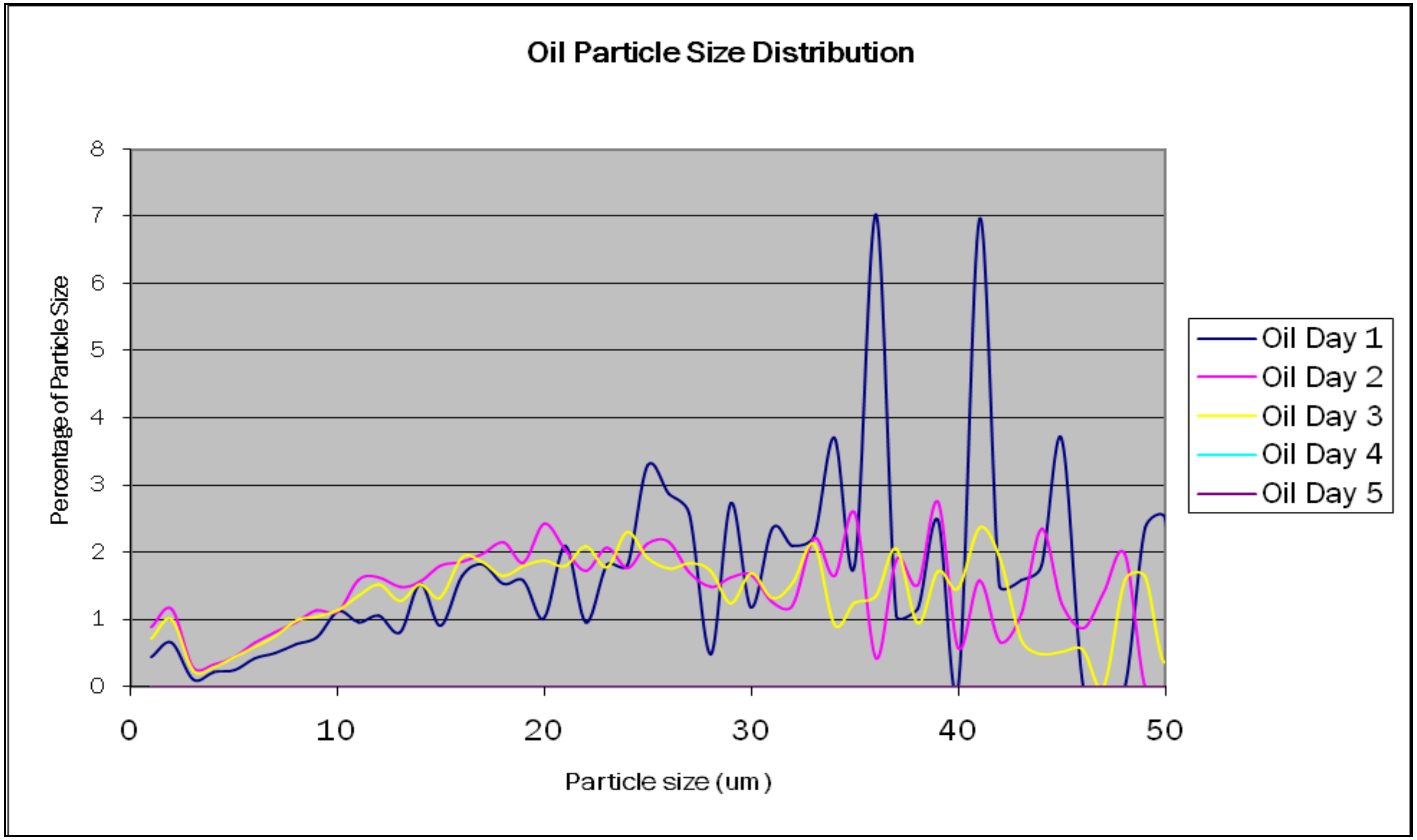


Figure P Chamber 3

Note: Spikes in the larger droplet range seems to be coalescing oil droplets getting detached from the sampling nozzle pipe attached on the wall of the GFT.

Water Samples at the outlet of each chamber collected for Client 1.

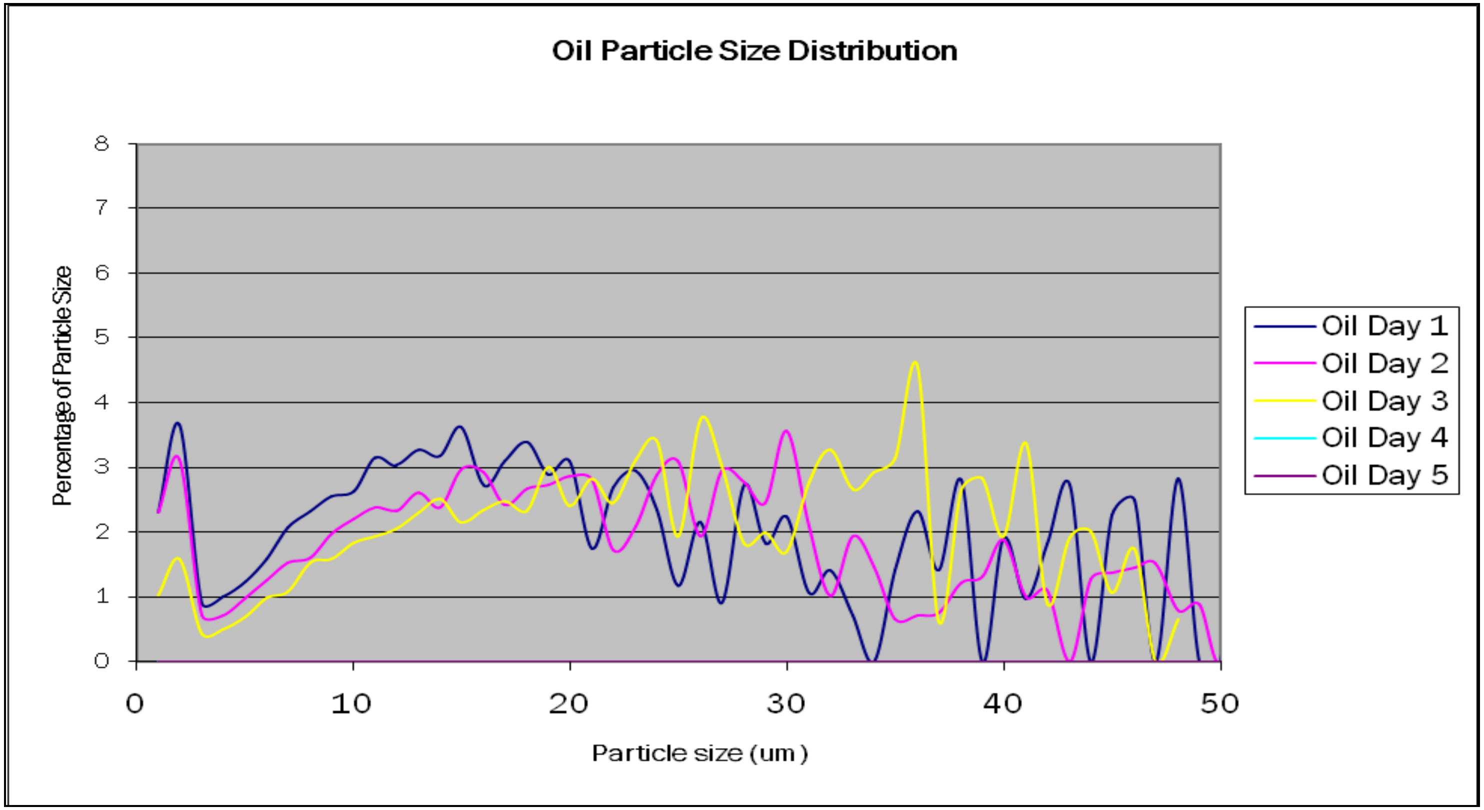


Figure Q Chamber 4

Conclusions:

I. The overall removal efficiency of a 2 Ch GFT and cumulative efficiency of 2nd Ch in a 4 Ch. GFT are similar. Hence addition of the 3rd and 4th chamber significantly improves performance**.**

II. Additional chambers help in containing upset. For more challenging water with upsets in flow and inlet oil the 4 chamber GFT is more preferable.

III. Sequential cleaning helps in improving overall efficiency. In the above case study, overall efficiency of a two chamber GFTs were at 83% to 86%; this is improved to 91% to 99% in case of the 4 chamber GFTs.

IV. The overall removal efficiency for each chamber in a 2 chamber or a 4 chamber GFT can be accurately predicted if the inlet concentrations and particle size distribution is well characterize.

V. Numerical and CFD models are useful at predicting performance and real world data confirms overall conclusions but also indicates that models can be likely improved upon (Calibrated)

Thank You!

Questions?