Improving Conventional Flotation Methods to Treat EOR Polymer Rich Produced Water

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OBJECTIVES

- Compare IGF and DGF to identify the *main criteria affecting the performance and functionality of flotation units* and *their accessories in different environments*
- Describe the effects and *benefits of using both IGF and DGF* at the same time
- *Verify the hypothesis* through three years of laboratory and field study

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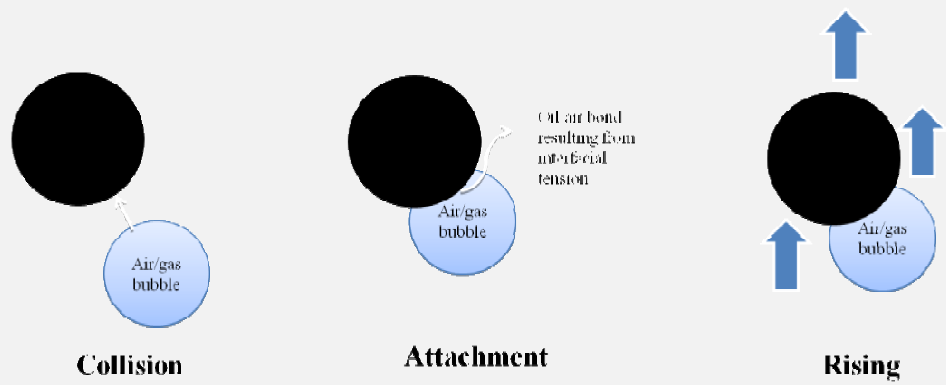
GAS FLOTATION: DYNAMICS

- The flotation process occurs in three steps:

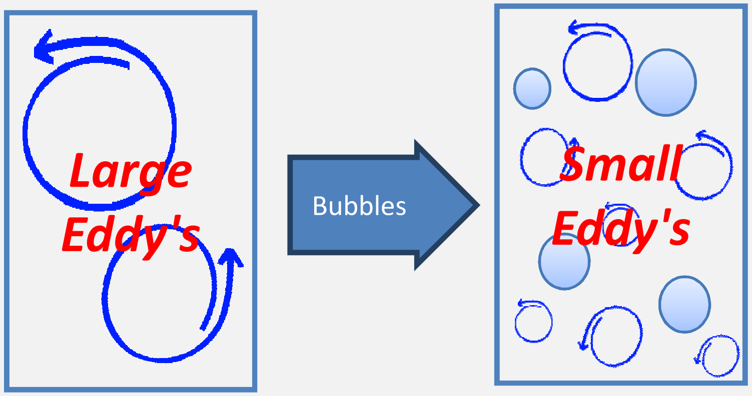


- Gas bubbles are the lightest fluid – *powerful buoyancy*

- Gas bubbles exchange upward momentum with surrounding media – *drag momentum exchange*

GAS FLOTATION: DYNAMICS

- Manipulation of turbulence motion – *Eddy's*
- Homogeneous flow
  - One phase
  - Eddies grow and create large swirl
- Heterogeneous flow
  - Multiple phases
  - Small eddy's are created

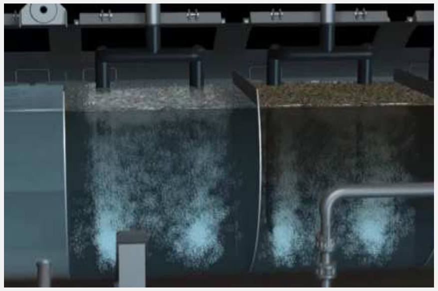


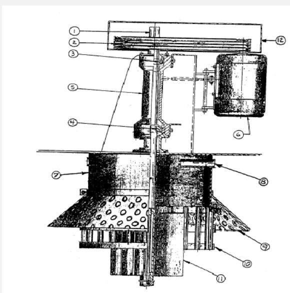
- Utilizing the same total turbulence, the introduction of gas bubbles increases collision – *higher efficiency in separation*

GAS FLOTATION: APPLICATION

- Flotation units, which operate with the assistance of gas in the flotation process, have been widely *used for the treatment of produced water both onshore and offshore*.
- Differing technologies are applied to Flotation units for *specific applications*.
- *Advantages and disadvantages of each arrangement + the requirements of the process = determine the choice of gas floatation mechanism*.
- These methods can be divided in two major categories:
    1. Induced Gas Flotation (IGF)
    2. Dissolved Gas Flotation (DGF).

Induced Gas Flotation Technology





- Eductor IGF (hydraulic):
  - gas is introduced into a slipstream of effluent
  - because the fluid must be recycled back into the system, this design effectively decreases the residence time of the fluid to be treated
- Impeller (mechanical):
  - utilizes an electric motor impeller
  - dependent on the application, mechanical units tend to be more efficient than hydraulic units
  - mechanical units are associated with maintenance difficulties and the emission of noxious vapors
- Sparger:
  - sparger tubes
  - plugging/ fouling of pores create non-uniformity and high pressure drop
  - limited with scale tendency of inorganic solutes

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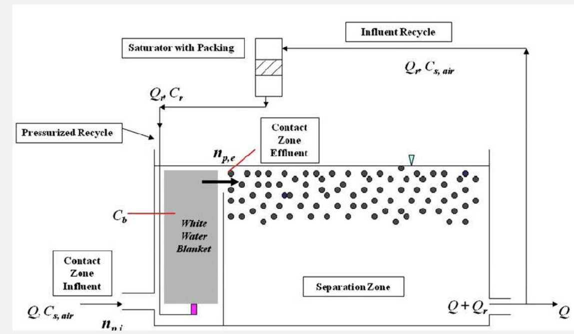
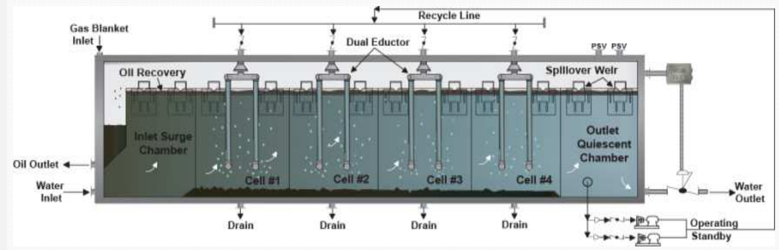
Dissolved Gas Flotation Technology

- Saturator Vessel:
  - gas is dissolved into the recycle flow by adding air under pressure in a vessel



- DGF Pump:
  - single pump is used to mix gas and recirculation water

FLOTATION TRADE-OFF



- Induced Gas Flotation (IGF), Eductor:
  - most common IGF design
  - simplicity of design
  - least number of operational issues

* *IGF efficiency is limited* by the minimum oil droplet size wherein smallest gas bubble can separate

- Dissolved Gas Flotation (DGF), Micro-Bubble Pump:
  - most common DGF method

* The *retention time* required to effectively remove the contaminates only using Micro-Bubbles *is higher* than IGF. However, the overall efficiency of the gas flotation is significantly more.

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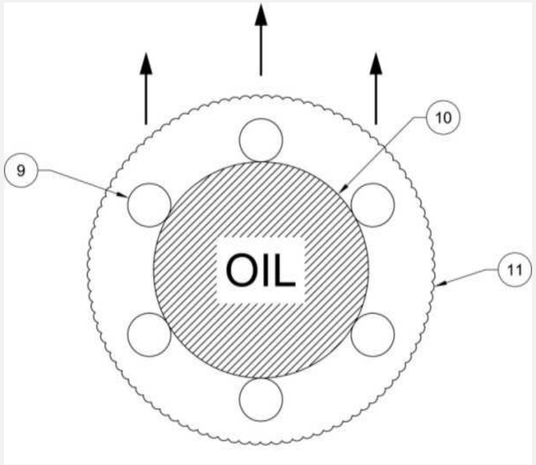
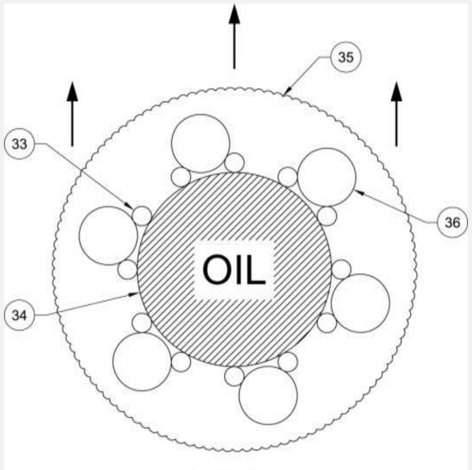
THEORY

- Shortcomings motivated investigation of combining both methods
- Early stage introduction of micro-bubbles will create an intermediate layer around oil droplets and micro-bubbles will lift the oil droplets by attaching to this layer





1- LITERATURE STUDY AND COMPUTATIONAL FLUID DYNAMICS

- A partial differential mathematical model was developed by Modification on O'Rooke's Collision Model through Stochastic Analysis to define the effect of gas bubble size on oil separation.
- The separation was modeled through Computational Fluid Dynamics (CFD)
- The simulation proved the followings:
  - I. The attachment of Oil droplets to gas bubbles are directly correlated to:
    - a. Gas to Oil diameter ratio: Smaller the ratio, more attachment of oil and gas bubbles
    - b. Interfacial Tension between Water/Oil, Oil/Gas, Gas/Water controls the attachment of oil droplets and gas bubbles.
  - II. Large Eddy's will break to smaller ones
  - III. Small gas bubbles cannot float oil droplets to surface in short retention time.

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2- LABORATORY TEST

- Different configuration was tested in controlled environment to optimize operating conditions (Gas Fraction and Operating Pressure)

MICRO-BUBBLES IN THE FORM OF WHITE CLOUD

TEST SETUP

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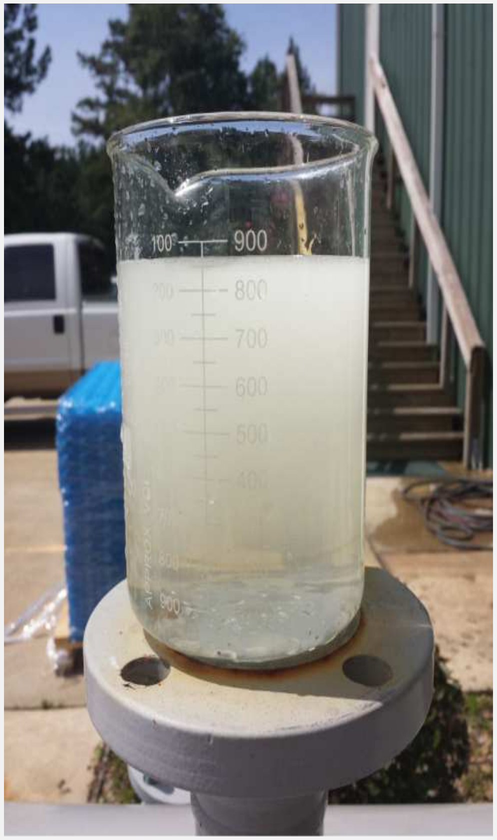
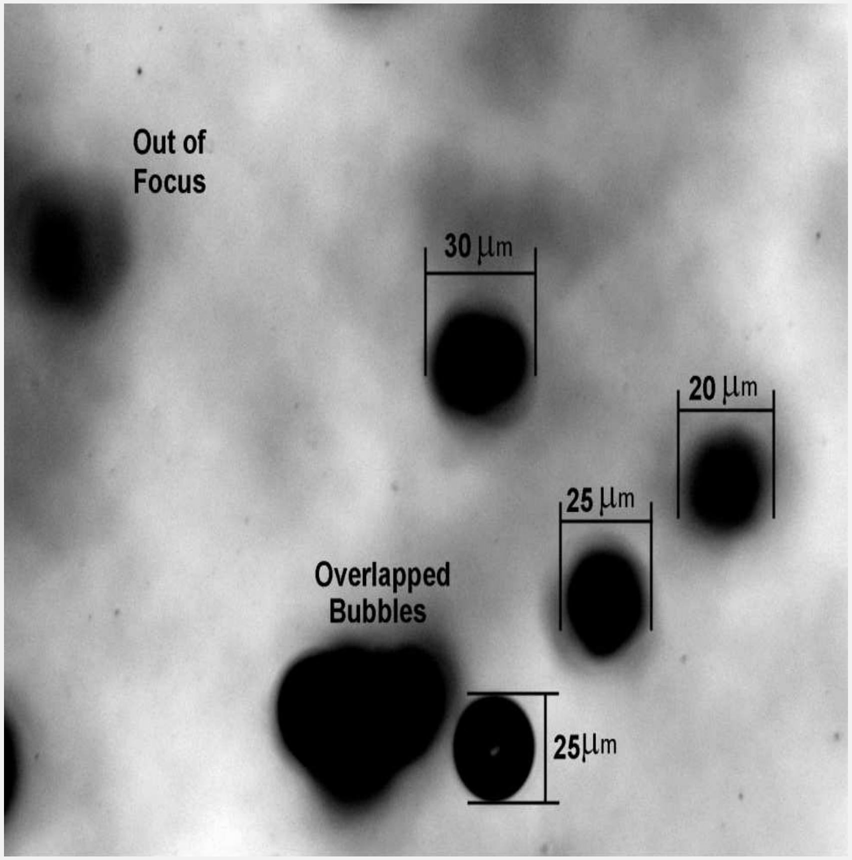
2- LABORATORY TEST

WATER SPECIMEN WITH MICRO BUBBLE



VIDEO MICROSCOPY OF MICRO-BUBBLES (FRESH WATER



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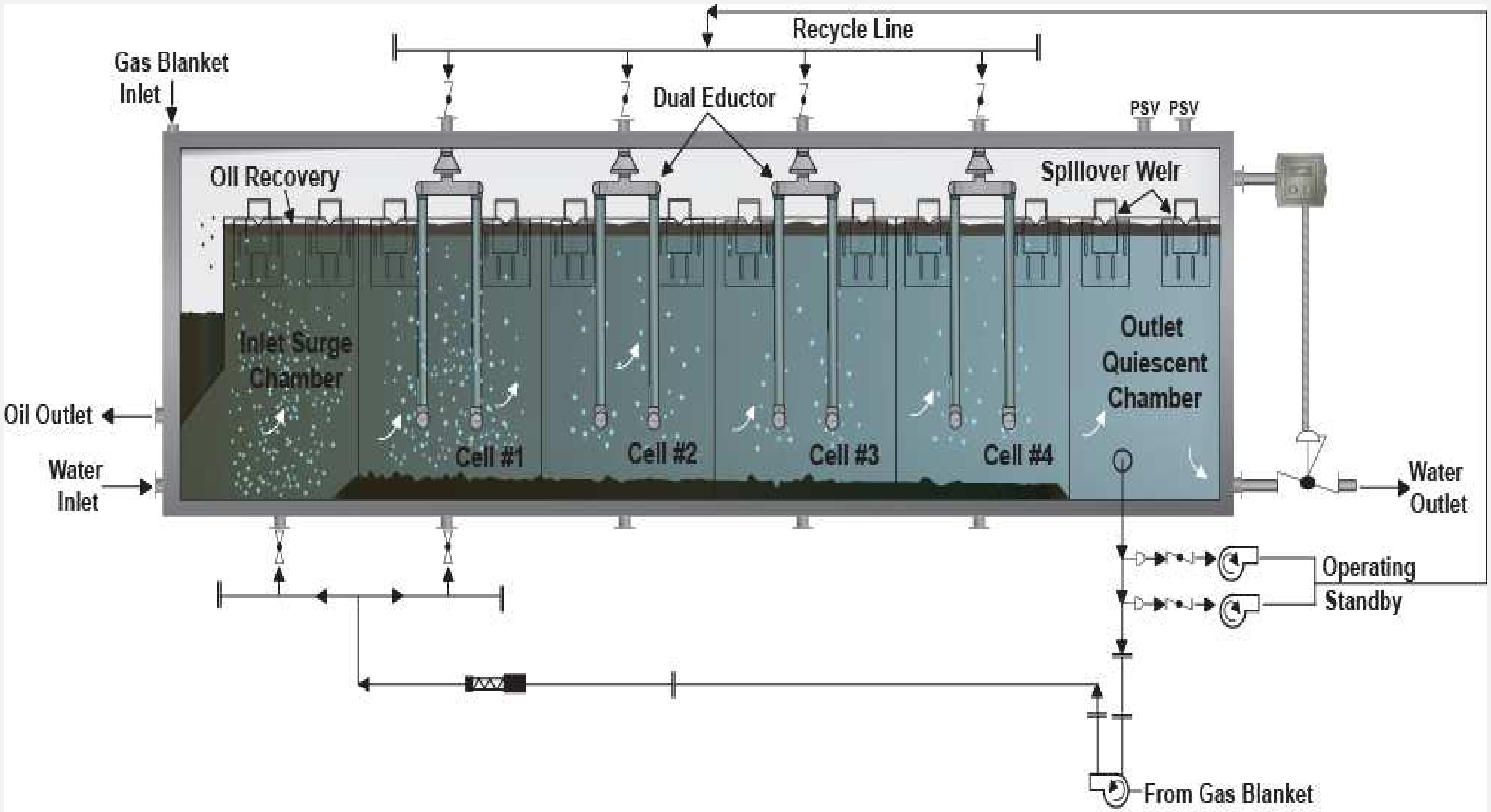
2- LABORATORY SETUP



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3.1- FIELD TEST 1: OMAN

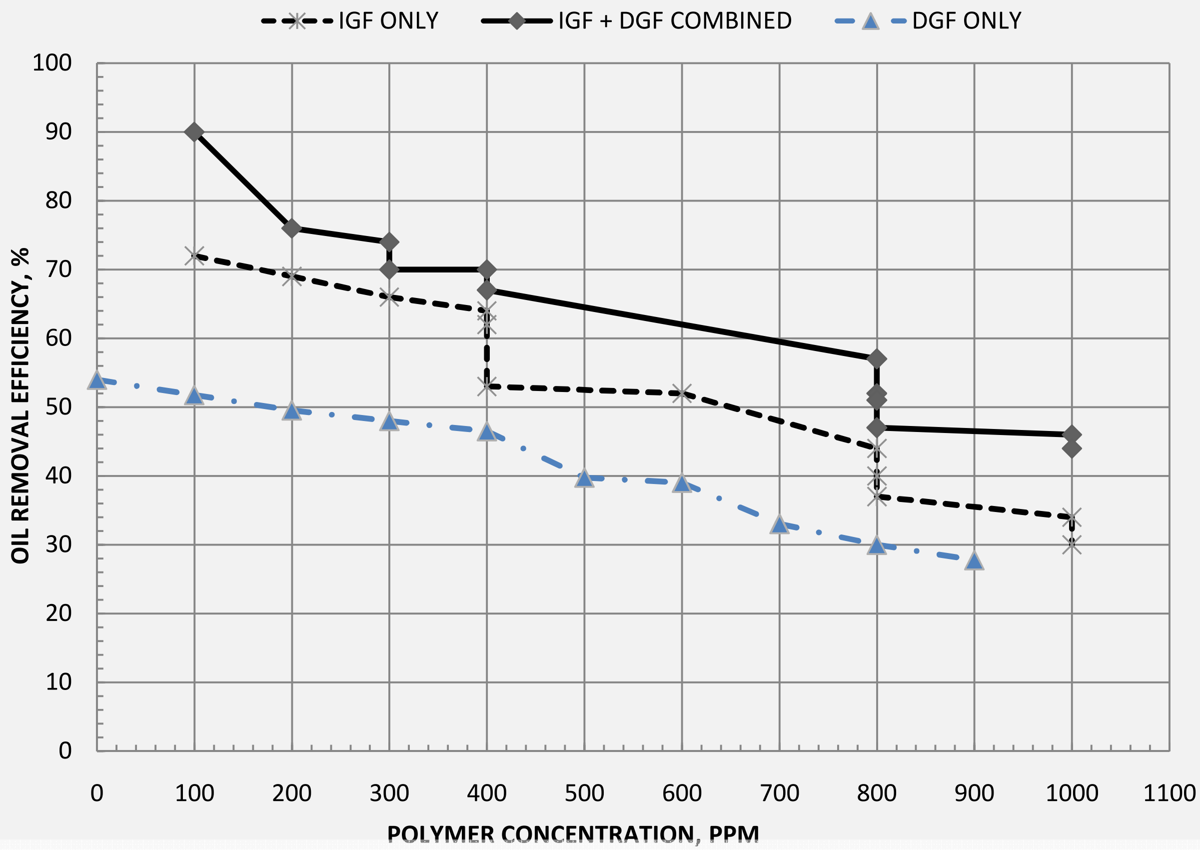
- ENVIRO-CELL EC-3 (hydraulic IGF) Eductors + Micro-Bubble Pump

- Advanced Sensors EX-100
  - inlet and outlet oil concentration
  - efficiency in different scenarios

- Oman (Field X) Enhanced Oil Recovery (EOR)
  - primary water flooding
  - secondary polymer flooding

3.1- RESULTS

- Comparison of IGF, DGF, IGF+DGF



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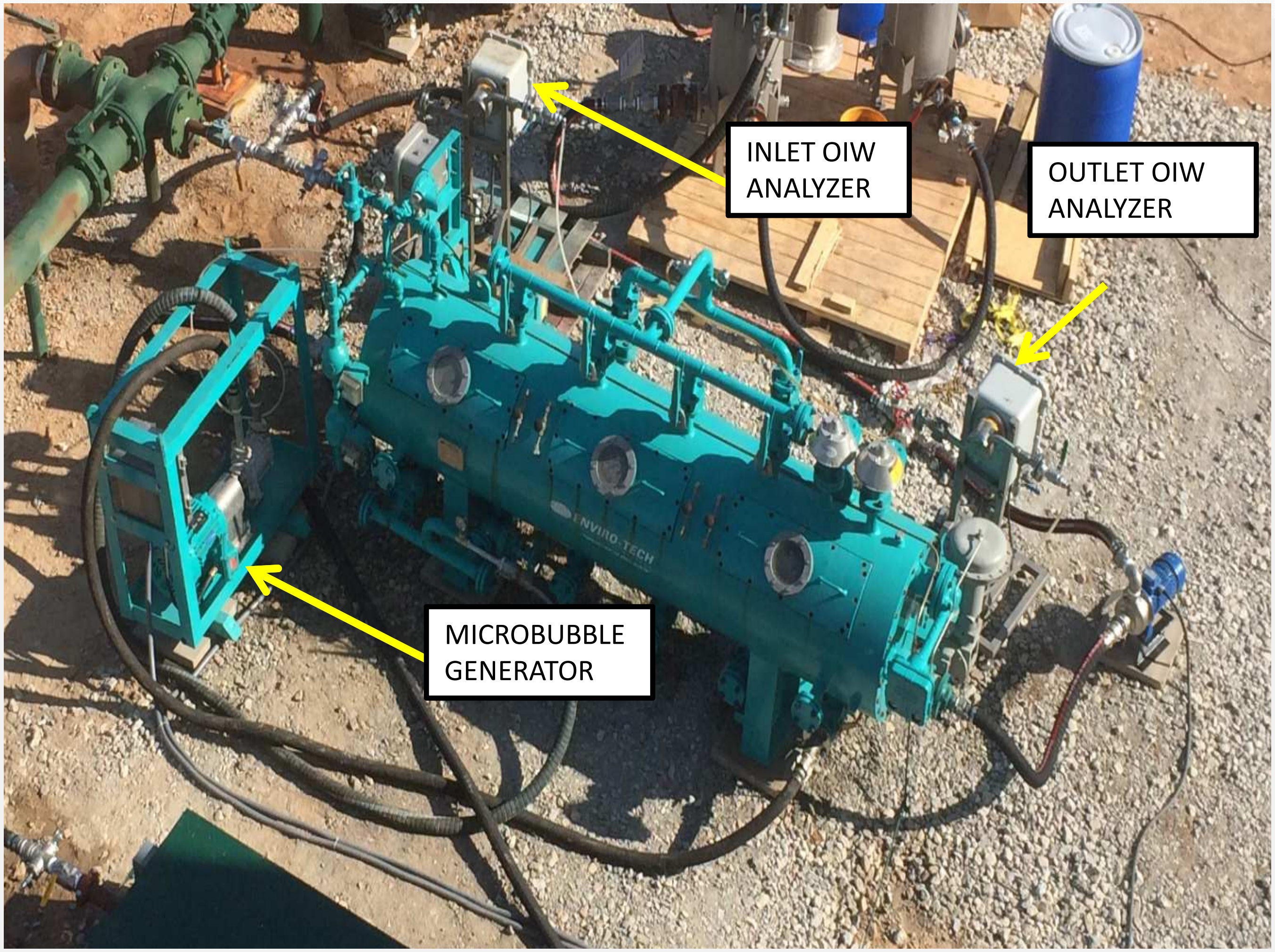
3.2- FIELD TEST 2: TEXAS, USA



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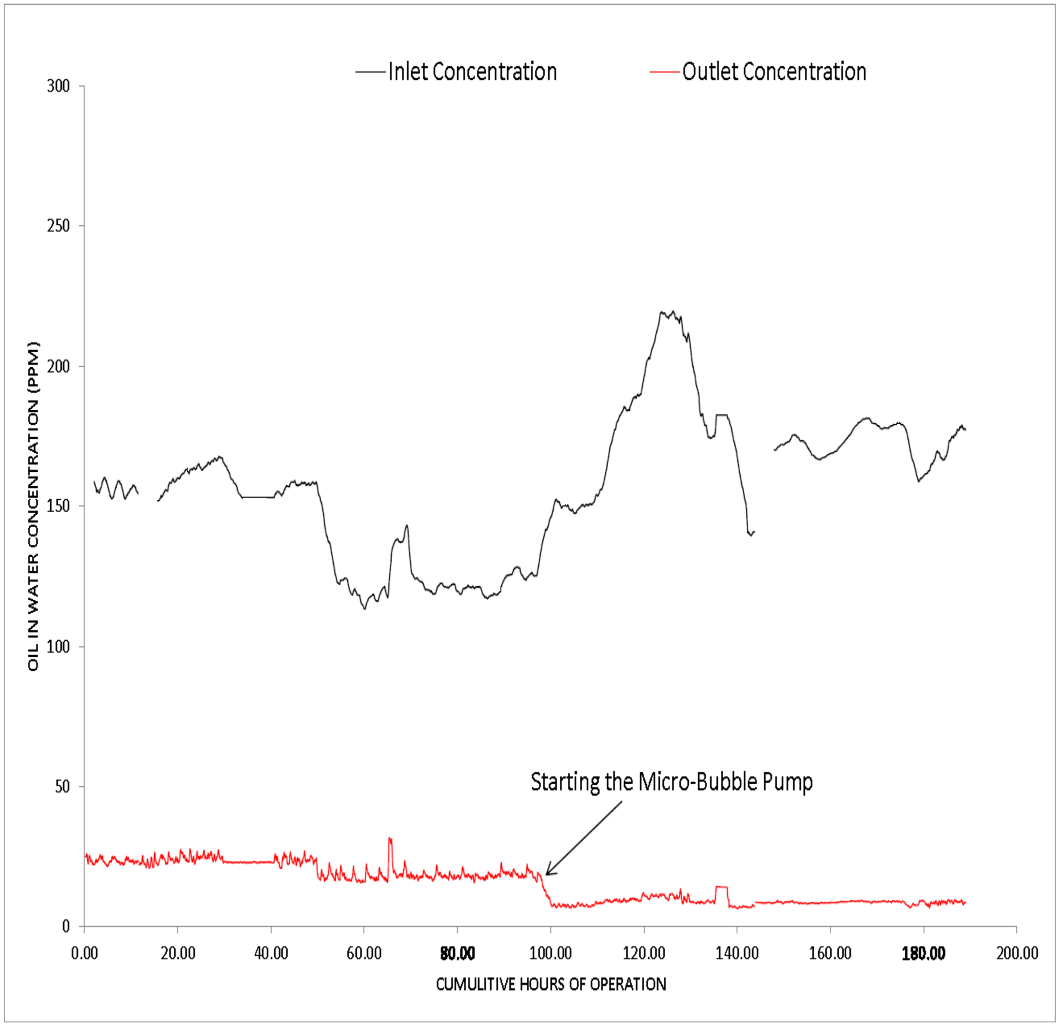

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3.3- FIELD TEST 3: COLORADO, USA

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3.3- FIELD TEST 3: COLORADO, USA

- The test currently in progress, and the data has not been compiled/analyzed yet.
- On average, the efficiency increased from 80% to 90%-95% by starting the DGF (Micro-Bubble) pump.

CONCLUSION

- IGF – efficiency is limited by size of oil droplet in polymer rich produced water
- DGF – bubbles not strong enough to meet retention time in polymer rich produced water
- PROVEN COMBINATION: by combining IGF and DGF in the first step the speed of rise is increased in polymer rich produced water conditions

Questions