



# Improving Conventional Flotation Methods to Treat EOR Polymer Rich Produced Water

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# OBJECTIVES

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Improving Conventional Flotation Methods to Treat EOR Polymer Rich Produced Water

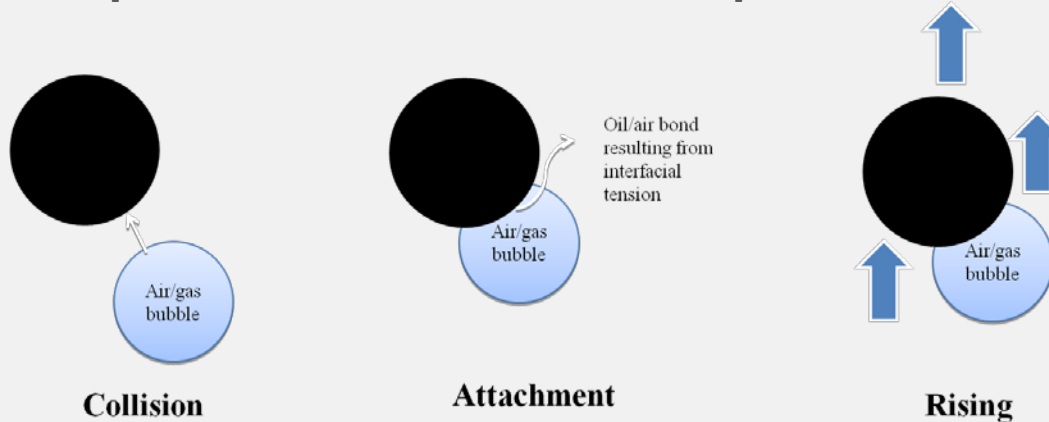
- Compare IGF and DGF to identify the main criteria affecting the performance and functionality of flotation units and their accessories in different environments
- Describe the effects and benefits of using both IGF and DGF at the same time
- Verify the hypothesis through three years of laboratory and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



# GAS FLOTATION: DYNAMICS

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- 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

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- **Manipulation of turbulence motion - Eddies**

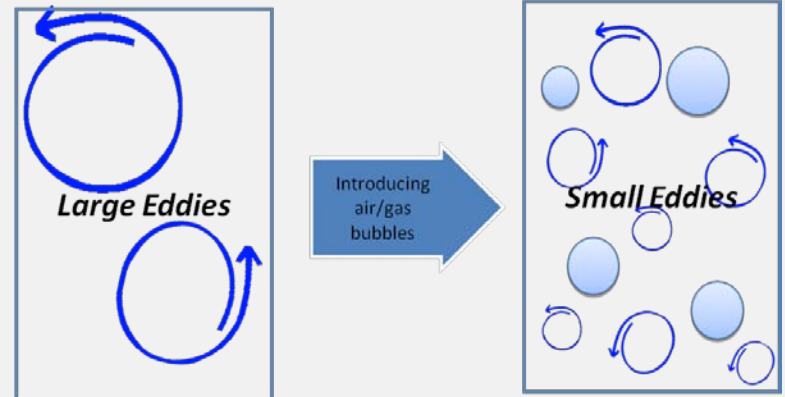
- **Homogeneous flow**

- One phase
- Eddies grow and create large swirl

- **Heterogeneous flow**

- Multiple phases
- Small eddies are created

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



# GAS FLOTATION: APPLICATION

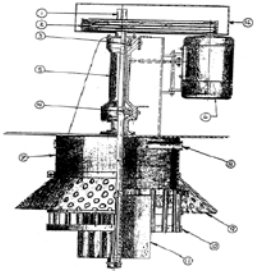
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Improving Conventional Flotation Methods to Treat EOR Polymer Rich Produced Water

- 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

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- **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

# Dissolved Gas Flotation Technology

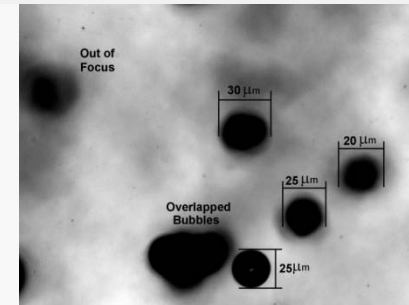
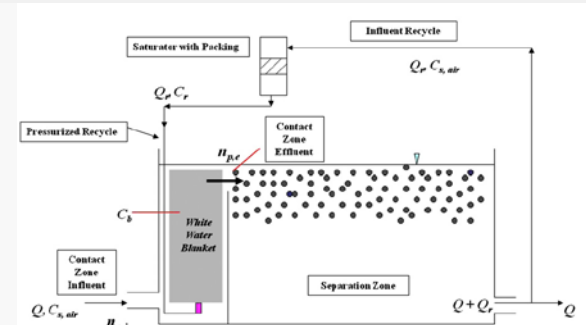
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- **Saturator Vessel:**

- 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



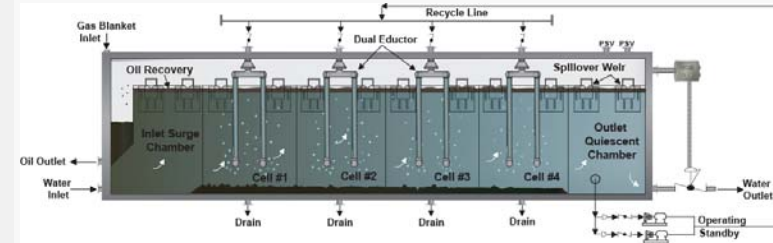
# FLOTATION TRADE-OFF

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- **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 contaminants only using Micro-Bubbles is higher than IGF. However, the overall efficiency of the gas flotation is significantly more.

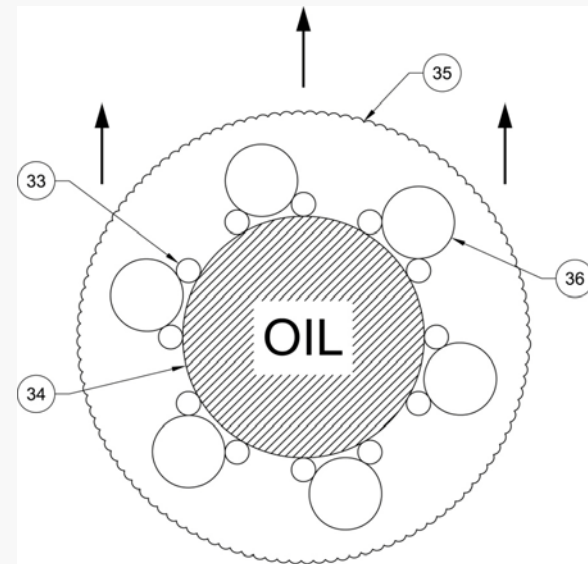
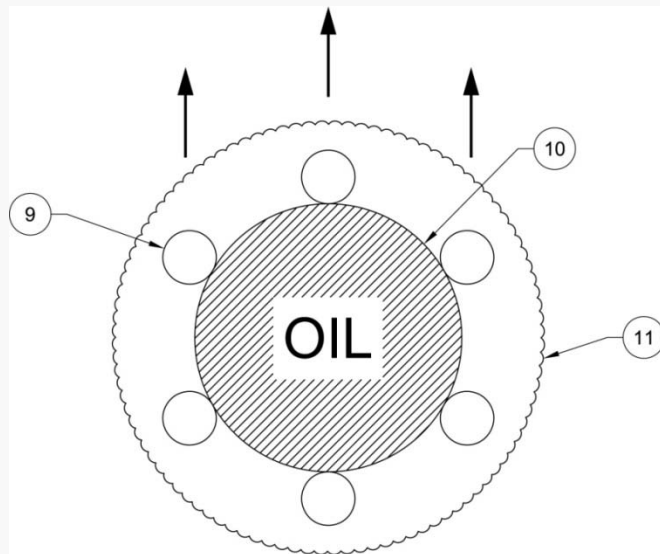




# THEORY

## Improving Conventional Flotation Methods to Treat EOR Polymer Rich Produced Water

- 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



# FIELD TEST

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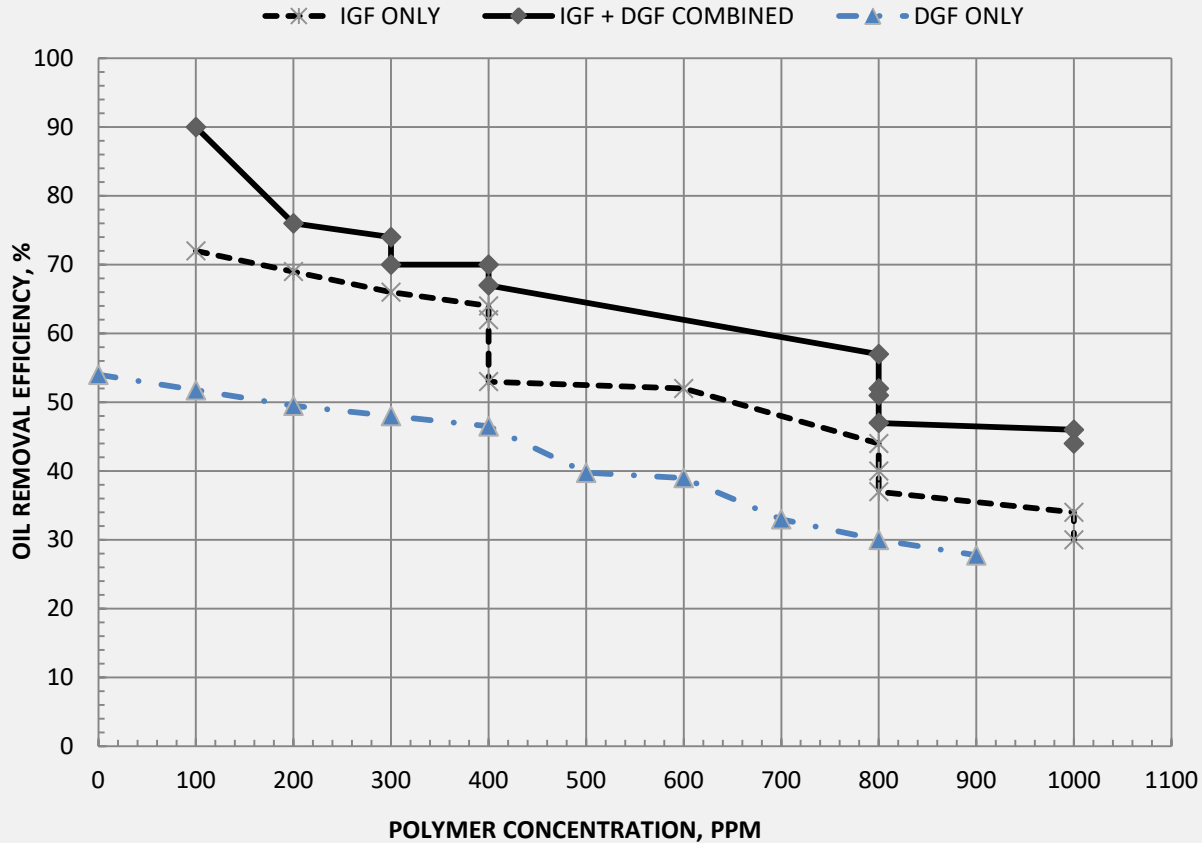
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- **ENVIRO-CELL EC-3 (hydraulic IGF) Eductors + Micro-Bubble Pump**
- **Advanced Sensors EX-100**
  - inlet and outlet oil concentration
  - efficiency in different scenarios
  
- **Oman (Field X) Enhanced Oil Recovery (EOR)**
  - primary water flooding
  - secondary polymer flooding

# RESULTS

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- **Comparison of IGF, DGF, IGF+DGF**



# CONCLUSION

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- **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 and efficiency of the system is increased in polymer rich produced water conditions