

**COMSOL
CONFERENCE**
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Chemical Engineering Department

The Use of Finite Element Analysis in the Design of Oil-Water Separators

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Outlines

- Introduction
- Aim Of The Present Work
- Laboratory Work
- Modeling and Simulation
- Identification of The Flow Pattern
- Results and Discussion
- Conclusions
- Plans for future research

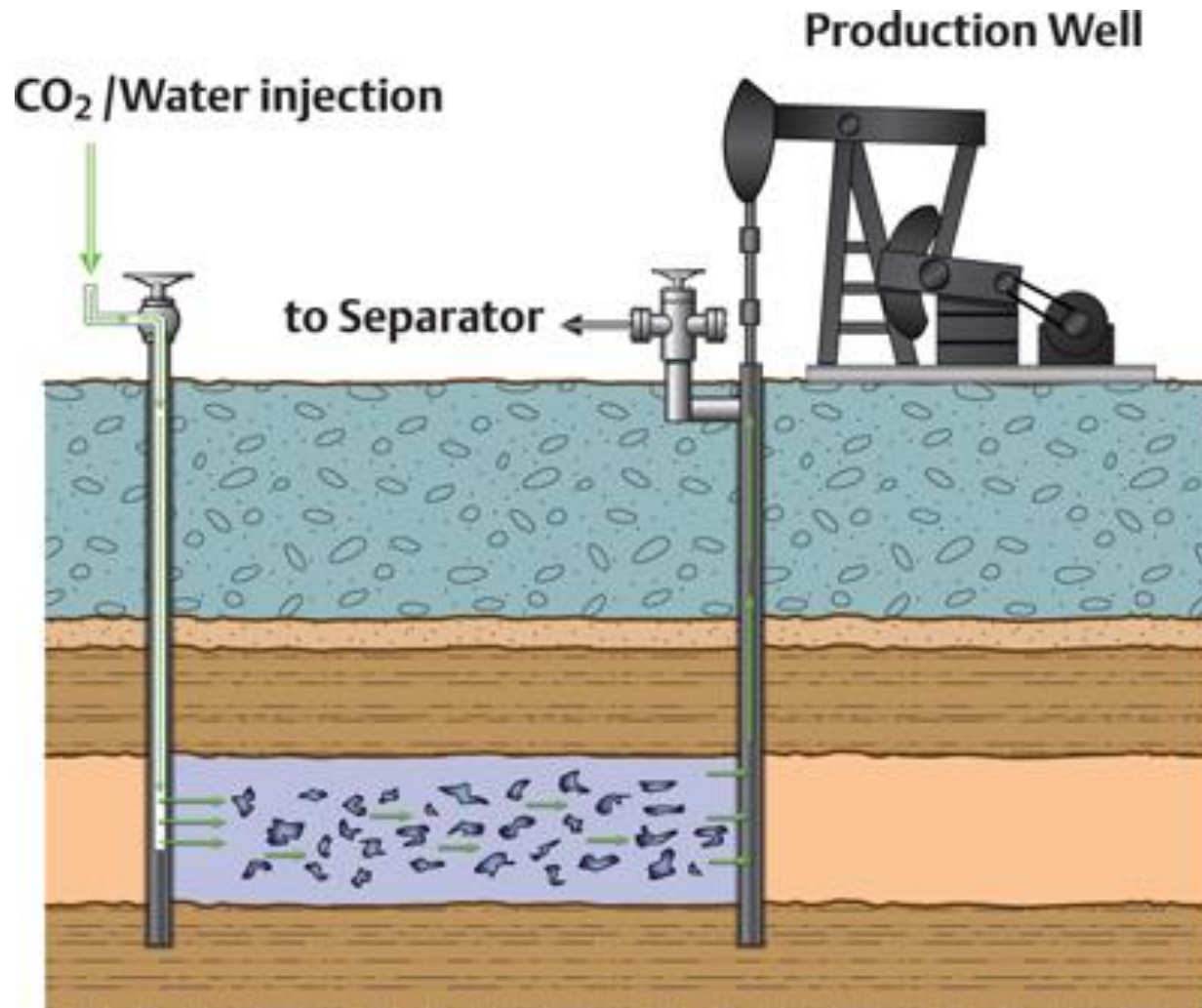
Introduction

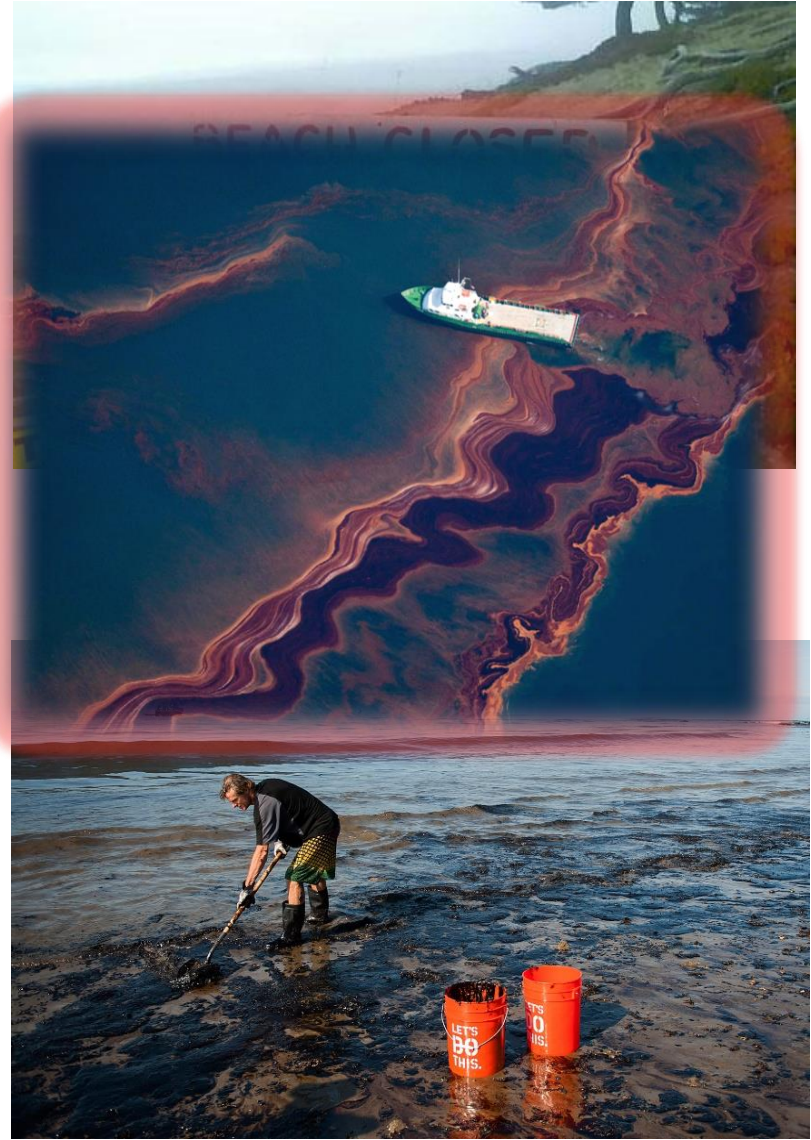
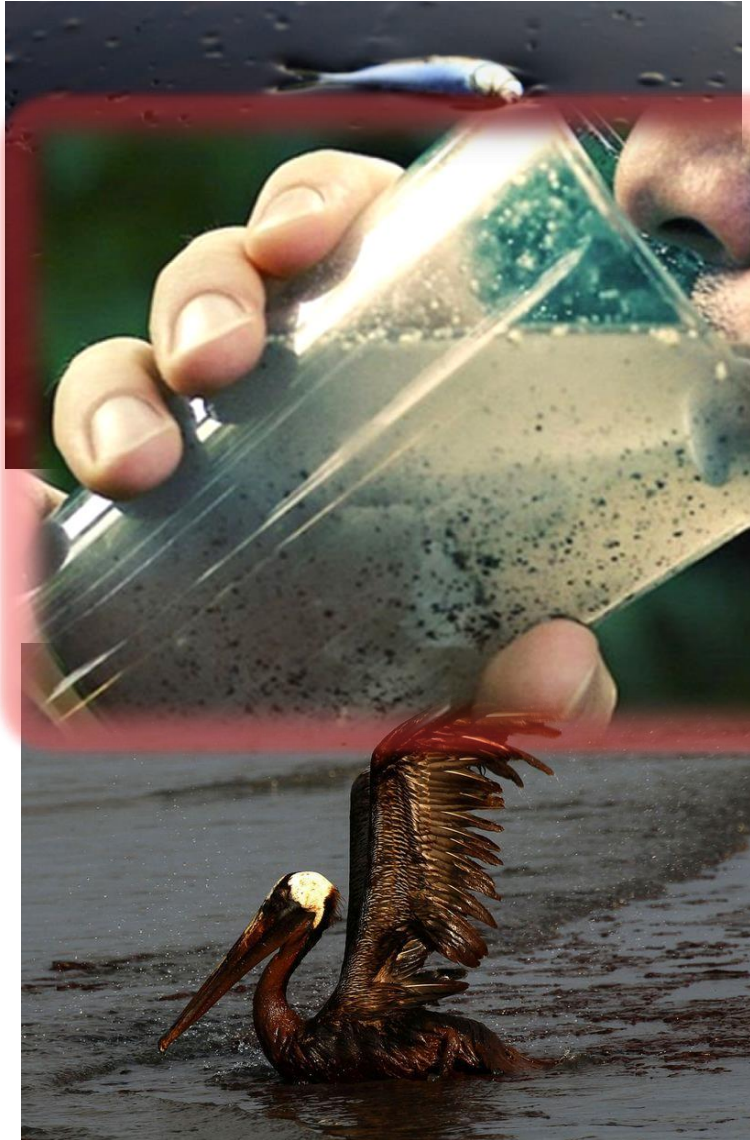
Common uses of oil-water separators

The oil-water mixture is usually regarded as a problematic mixture. Common troubles caused by the mixture are seen in:

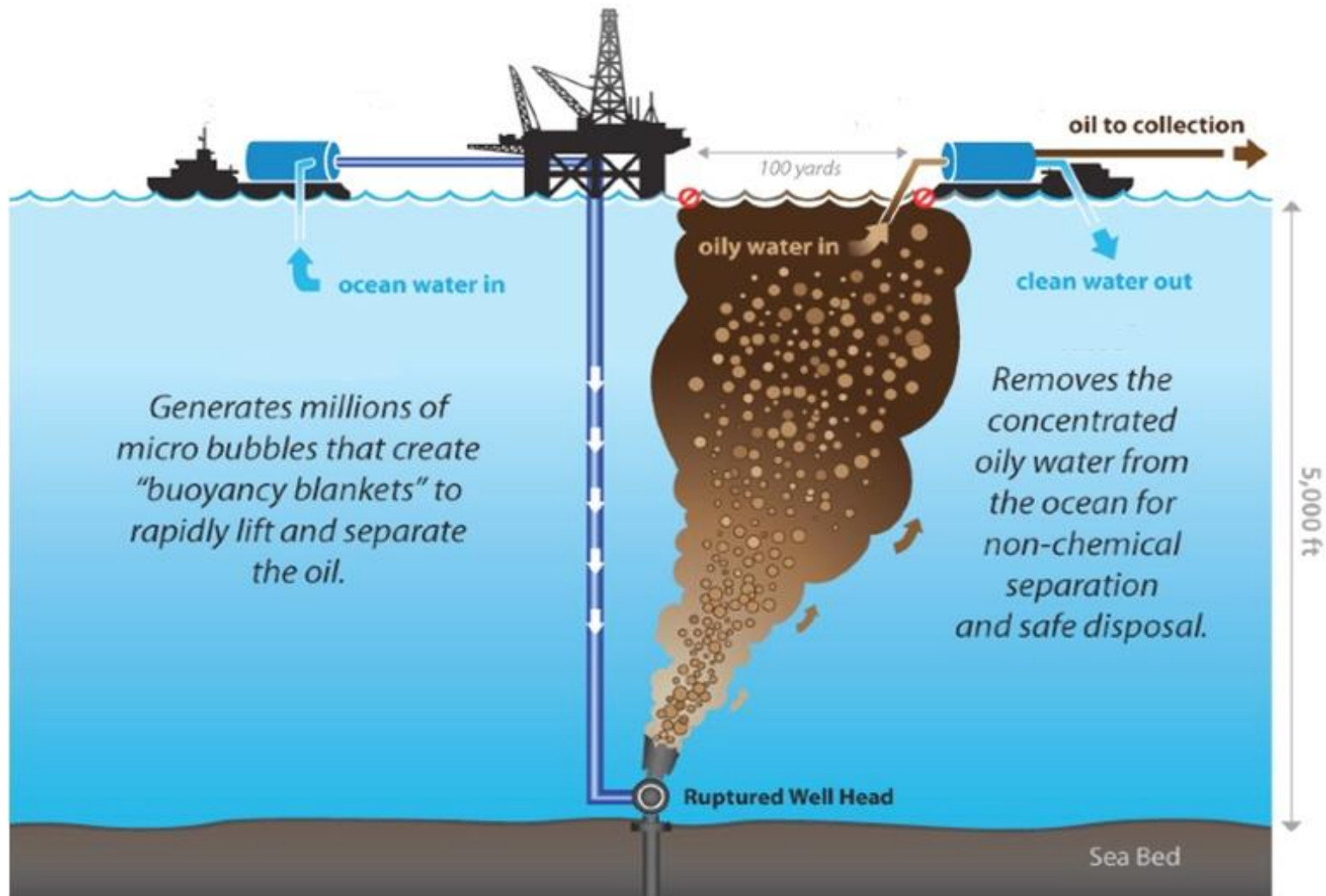
- Industrial applications.
- Environmental Problems & oil spills.
- Cost of pumping.
- Corrosion/Fire hazards.
- Storm water in industrial locations.

• Regular Water Injection in Oil/Gas production wells





- Oil water separators also used to clear water from oil spills.



Design of Oil-Water Separators

- The advances and modifications of separators took decades to be mastered through building prototypes and gathering results in order to develop the separators as seen today.

Types of Separators

Gravity based separators

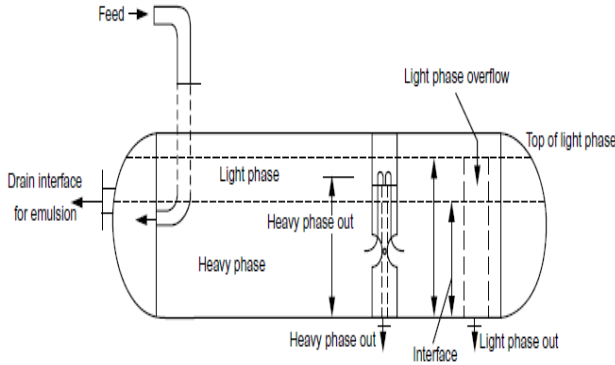
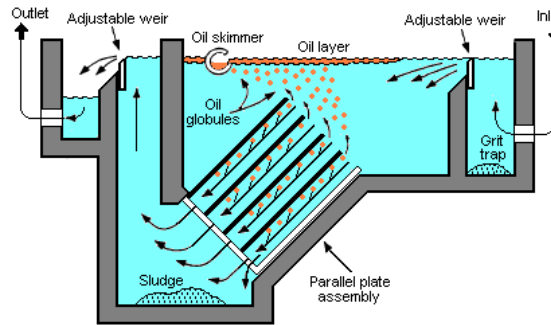
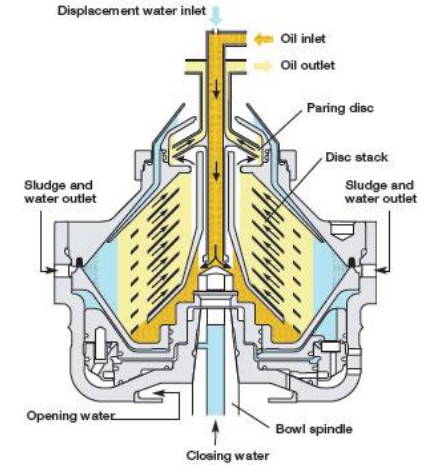


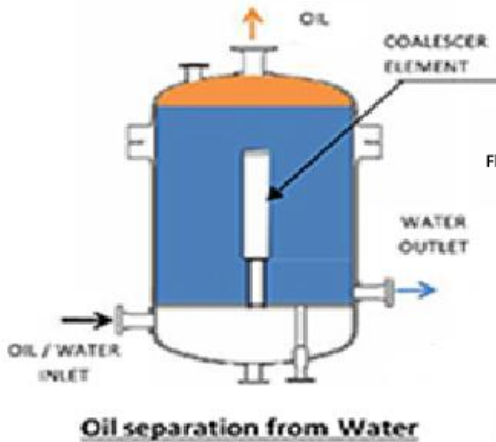
Plate coalescers



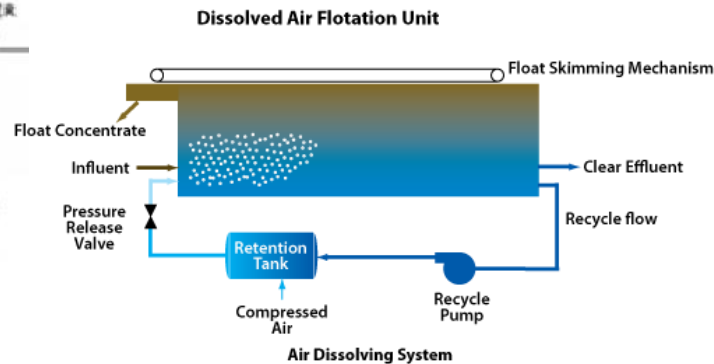
Centrifugal separators



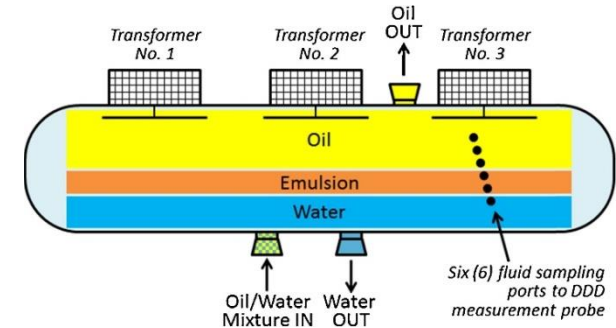
Filter separators



DAF

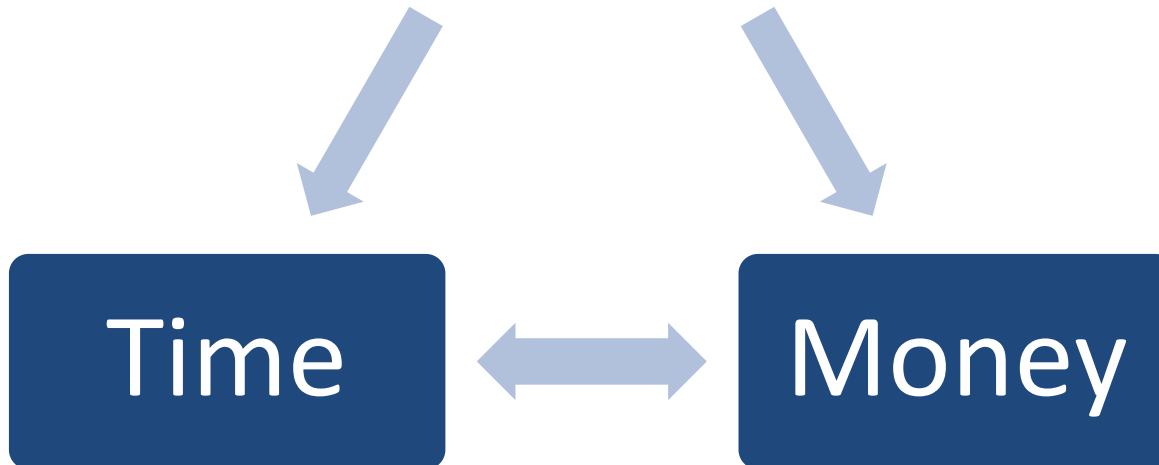


Electro-coalescence



Problem

- Choice of suitable Separator.
- Sizing of the Separator.
- Modification on existing Separators

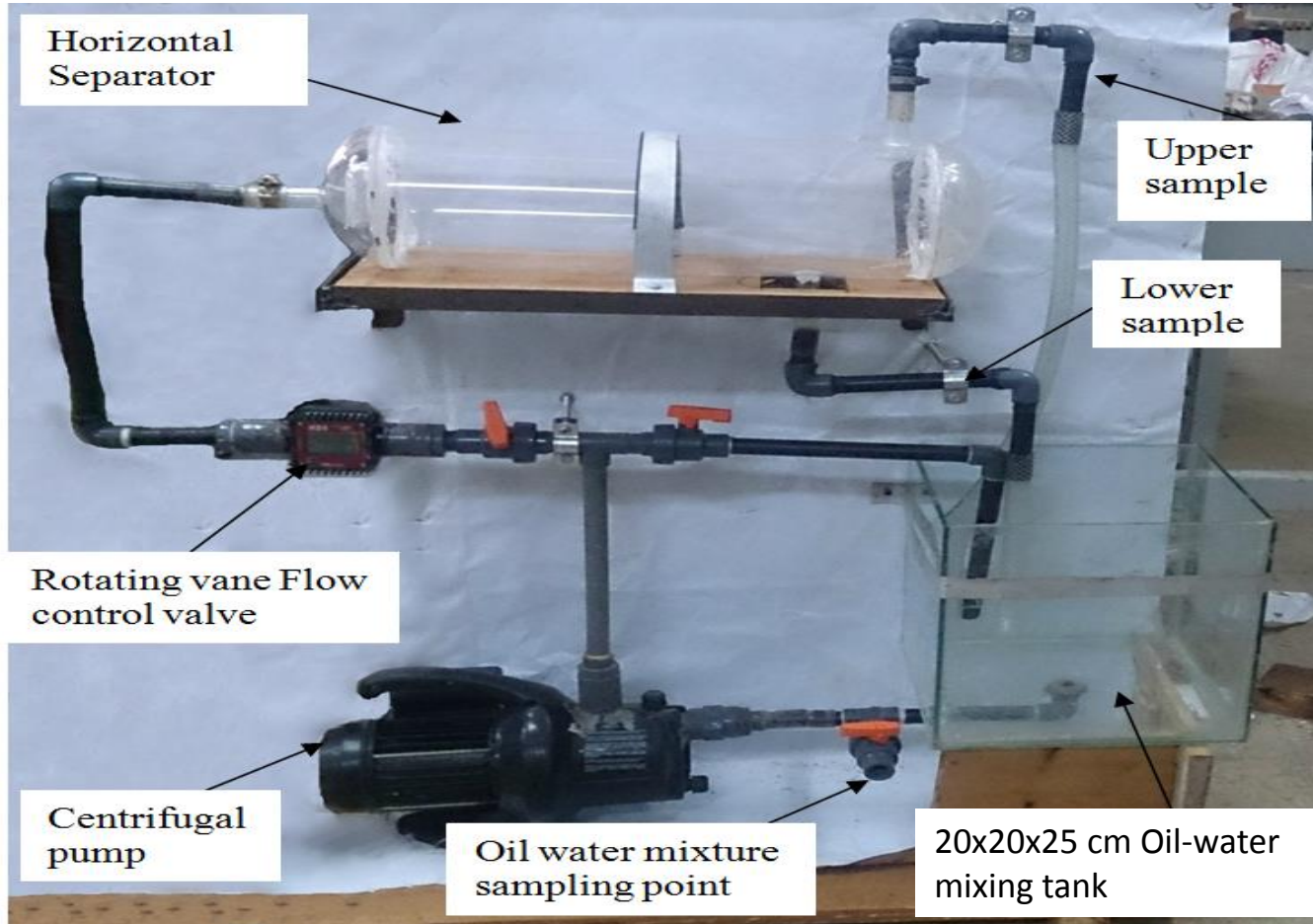


Aim of the work

- Testing the accuracy of Comsol multiphysics CFD simulations in the design of two phase oil-water in comparison to experimental results received from similar separator prototypes.
- Study the effect of different operational and design parameters on the efficiency of the separation process.
- Suggesting methods to enhance the separation efficiency.

Laboratory Work

Prototype



Measuring volumetric oil content of each of the gathered samples

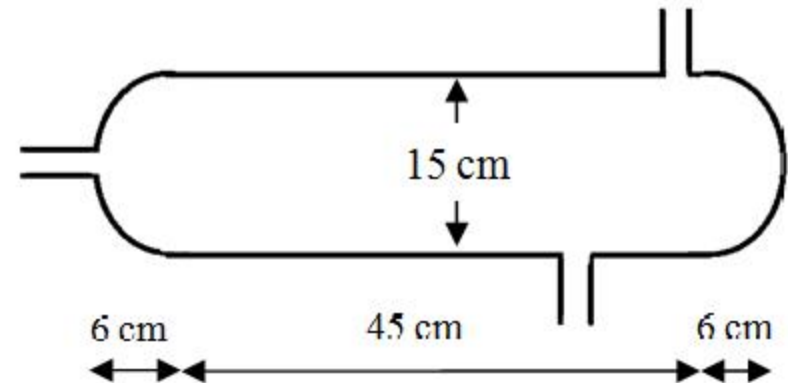


Variables Studied:

- i. Mixture inlet velocity (0.21, 0.42, 0.53, 0.64, 0.75, 0.86, 1.0 m/s)
- ii. Separator internal design
- iii. Baffle location inside the separator
- iv. Mixture inlet composition (oil vol. 10%, 20%, 30%)

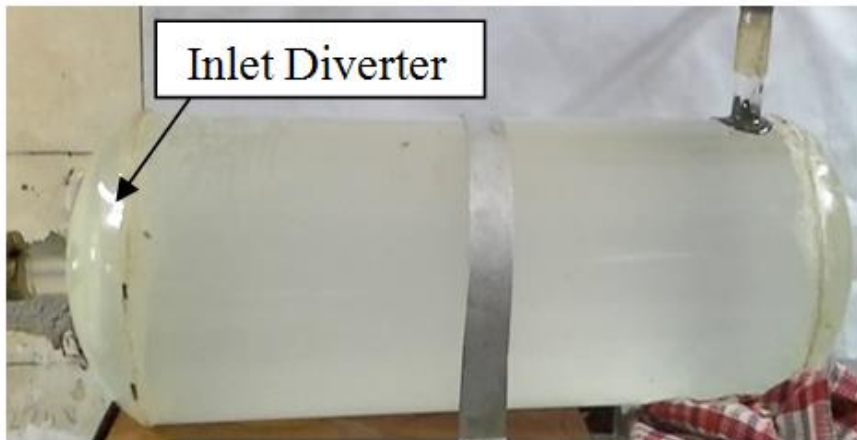
Separator internal design

a) Empty horizontal separator (no baffles or diverter)

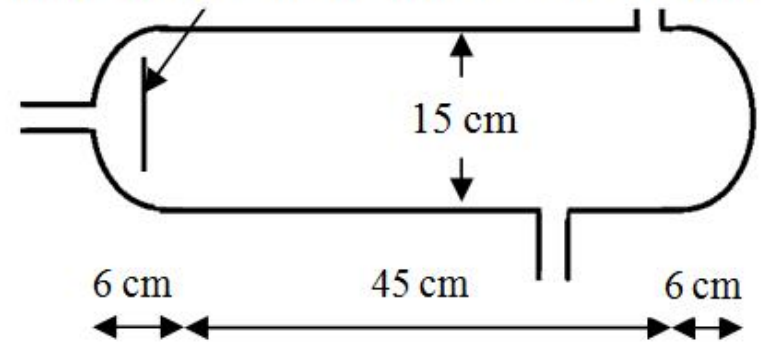


Separator internal design

b) Separator with inlet diverter

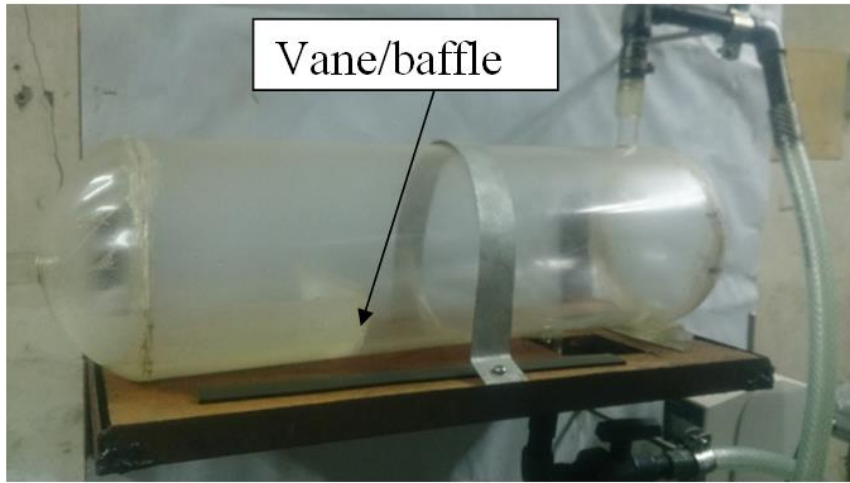


Inlet Diverter 4cm from the inlet nozzle

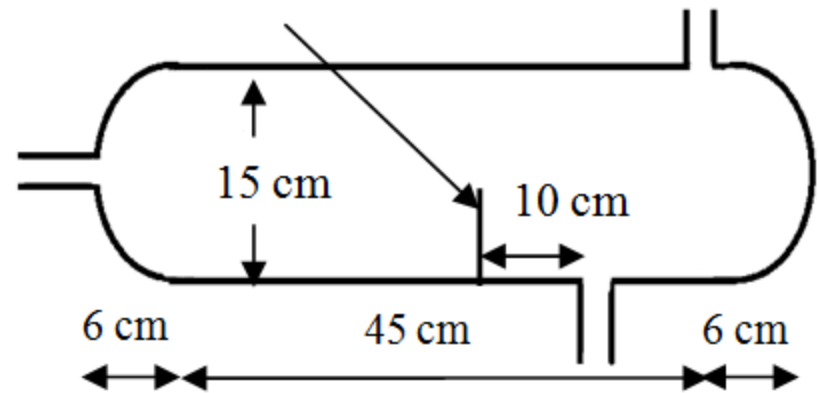


Separator internal design

c) Separator with bottom baffle

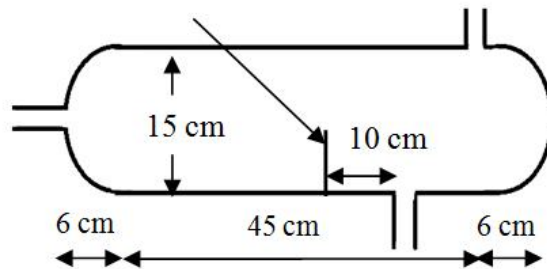


Baffle placed 10 cm ahead of the water outlet

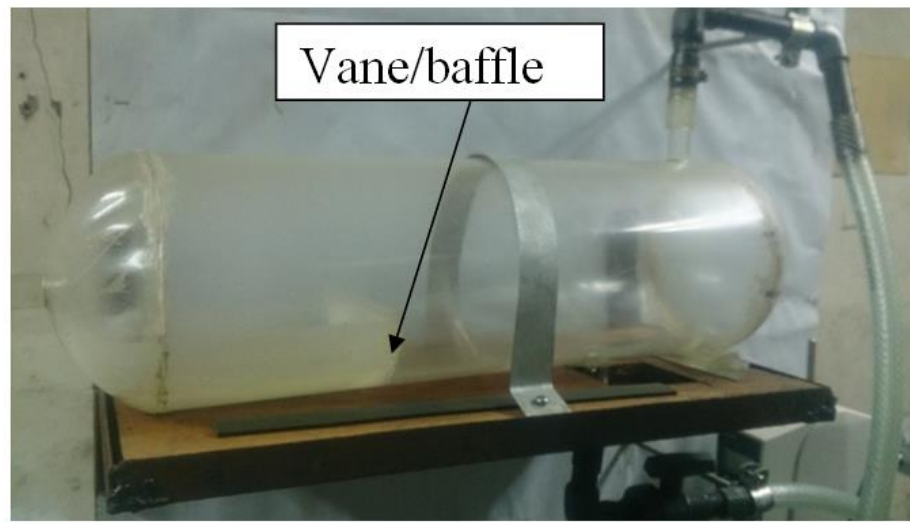
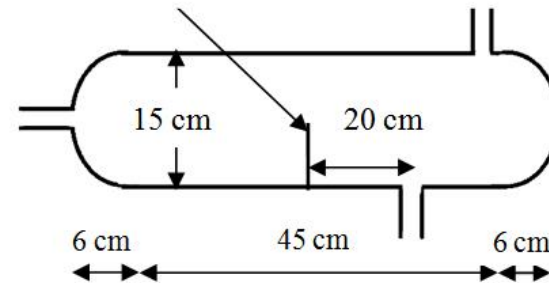


Bottom baffle location inside separator

Baffle placed 10 cm ahead of the water outlet



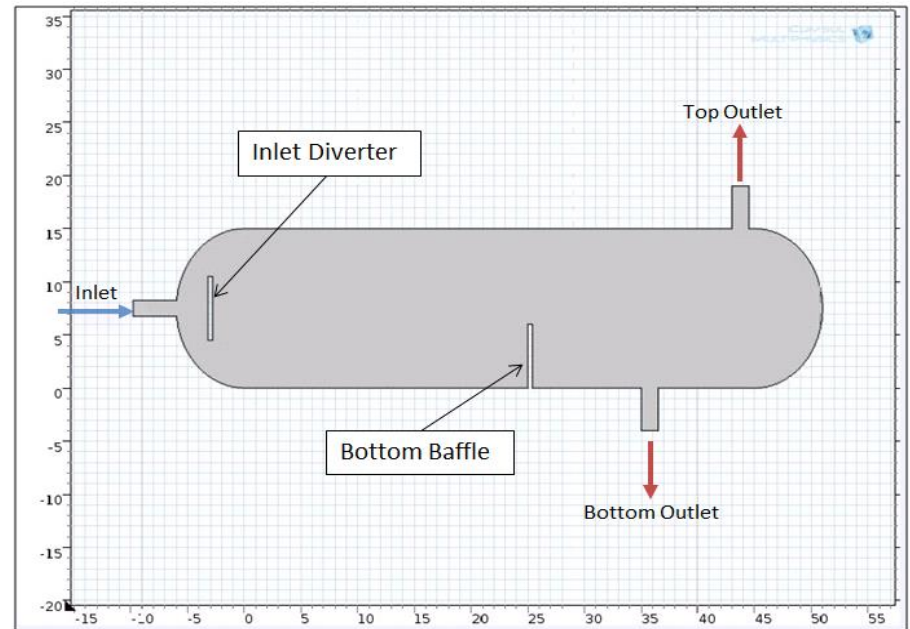
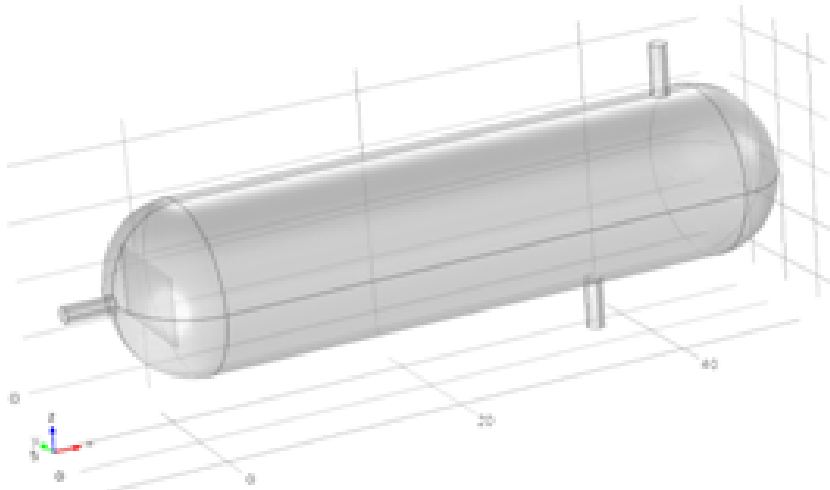
Baffle placed 20 cm ahead of the water outlet



Modeling and Simulation

Use of Comsol Multiphysics

- Geometric Design



Simplification of the 3D geometry to 2D

Use of Comsol multiphysics



- Based on Reynolds number calculations for studied flow rates ($Re > 4000$) and the presence of several obstacles in the system to be studied.
- The Turbulent Two-Phase Flow, Level Set interface was selected to track the separation between the two liquids.

$$Re = \frac{\rho u D}{\mu} \geq 4000$$

Turbulent Two-Phase Flow, Level Set

Principles and Governing Equations

- Mass is conserved
- Energy is conserved.
- Conservation of momentum by Combining between Navier-Stokes equation and Newton's second law ($F=ma$).

$$\underbrace{\rho \left(\frac{\partial \mathbf{u}}{\partial t} + \mathbf{u} \cdot \nabla \mathbf{u} \right)}_1 = \underbrace{-\nabla p}_2 + \underbrace{\nabla \cdot (\mu(\nabla \mathbf{u} + (\nabla \mathbf{u})^T) - \frac{2}{3}\mu(\nabla \cdot \mathbf{u})\mathbf{I})}_3 + \underbrace{\mathbf{F}}_4$$

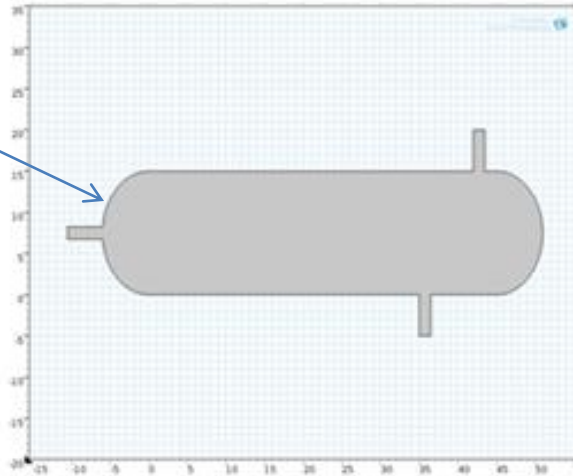
Where: \mathbf{u} is the fluid velocity, P is the fluid pressure, ρ is the fluid density, and μ is the fluid dynamic viscosity.

The different terms in the equation correspond to:

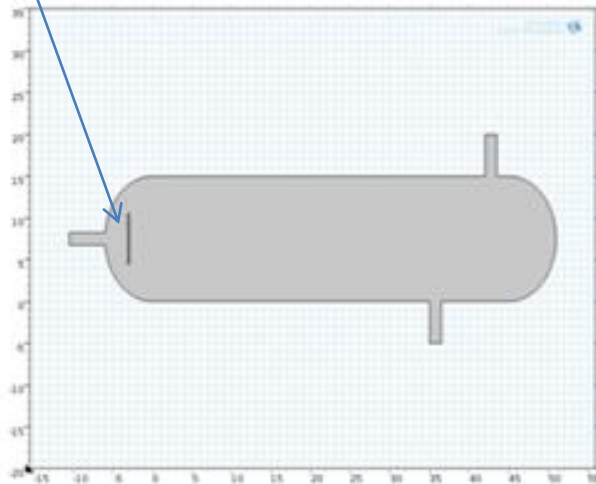
- 1) The inertial force.
- 2) Pressure forces.
- 3) Viscous forces.
- 4) External forces applied to the fluid.

Separator internal design

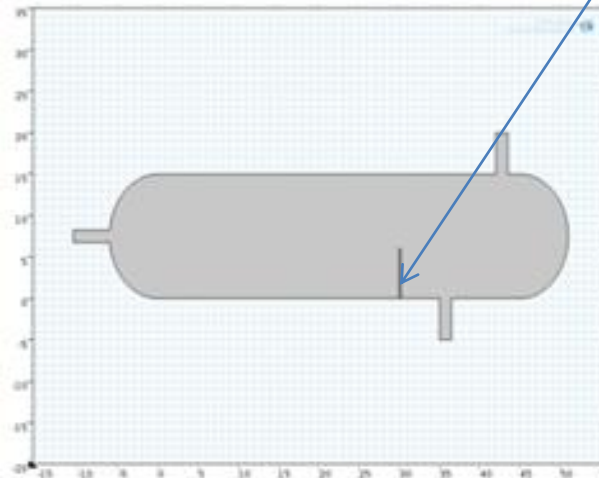
Empty Separator no
diverter or any baffles



Inlet Diverter

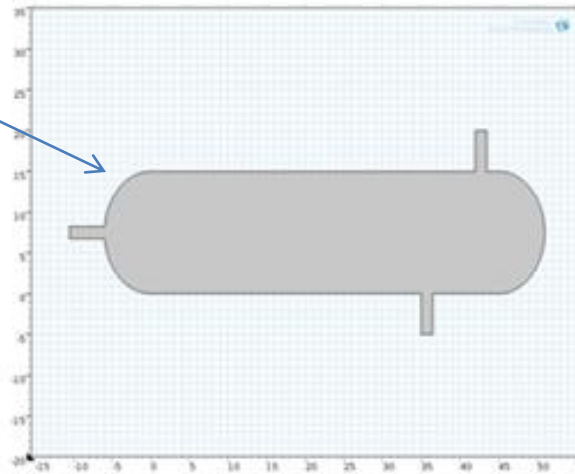


Baffle 10 cm ahead of
bottom outlet nozzle

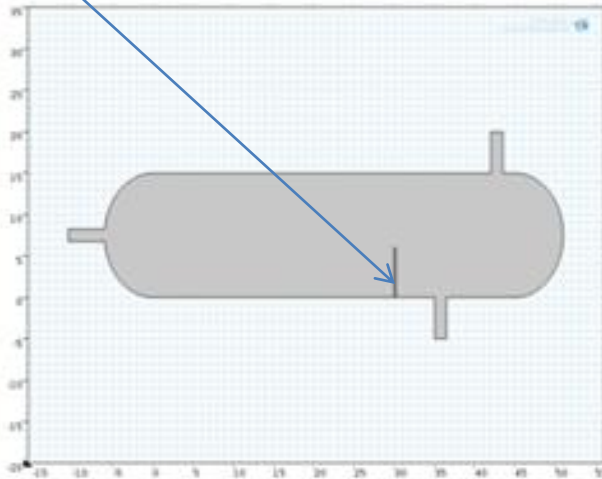


Bottom baffle location inside separator

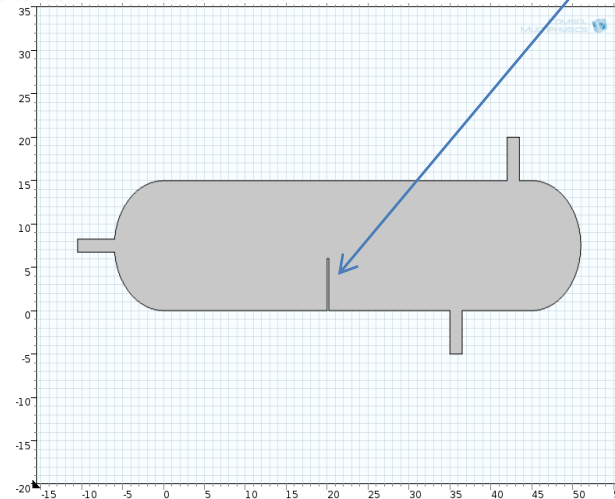
Empty Separator no
diverter or any baffles



Baffle 10 cm ahead of
bottom outlet nozzle

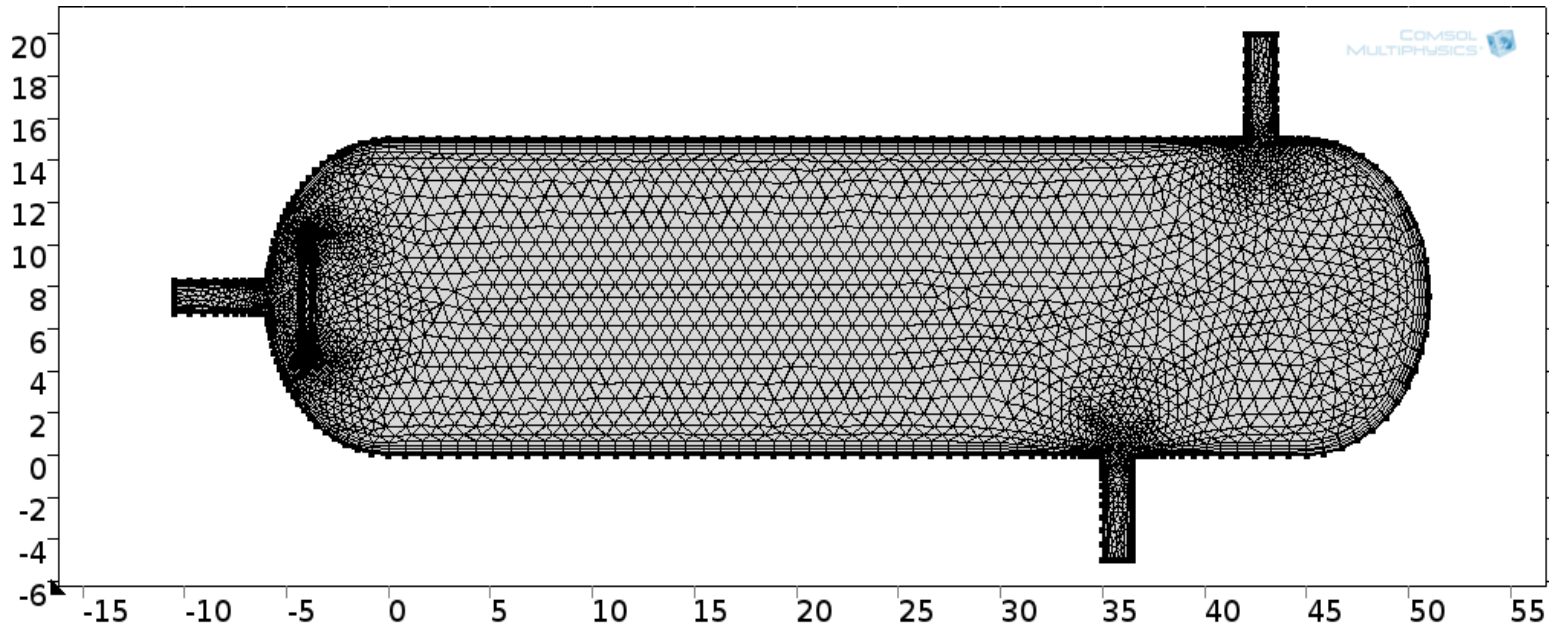


Baffle 20 cm ahead of
bottom outlet nozzle



Mesh Design

- Different mesh sizes were tested. The results showed that the size of the mesh is irrelevant. Thus, coarse mesh size was selected for the remaining simulations.

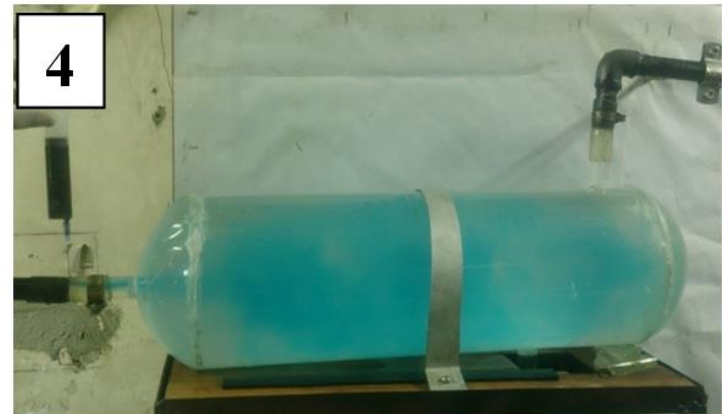
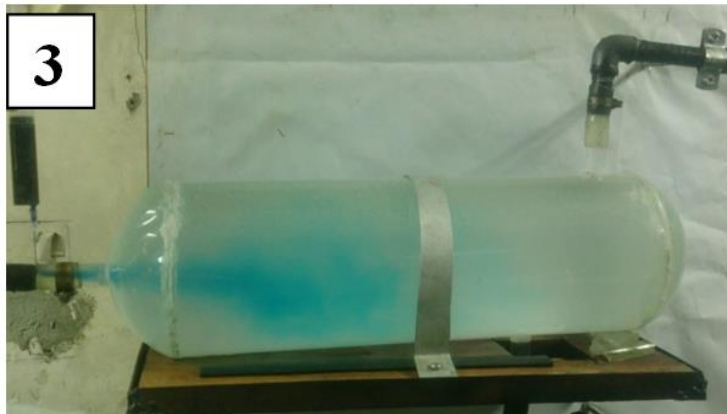
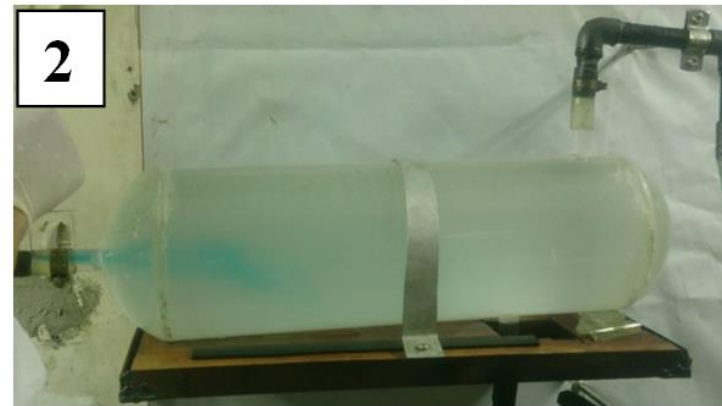
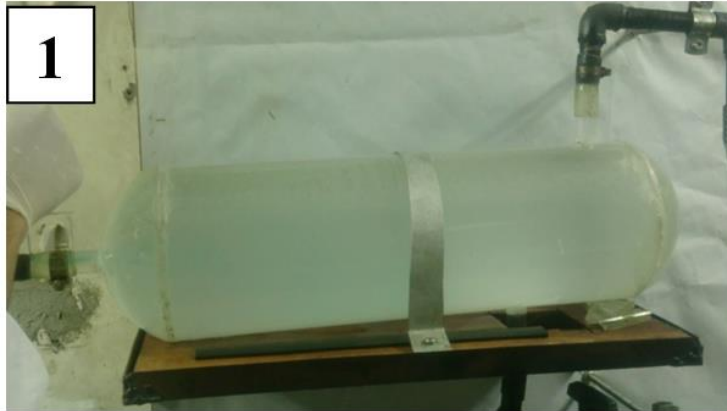


2D discretization of the separator to a coarse mesh size.

Identification of the flow pattern

Identification of the flow pattern

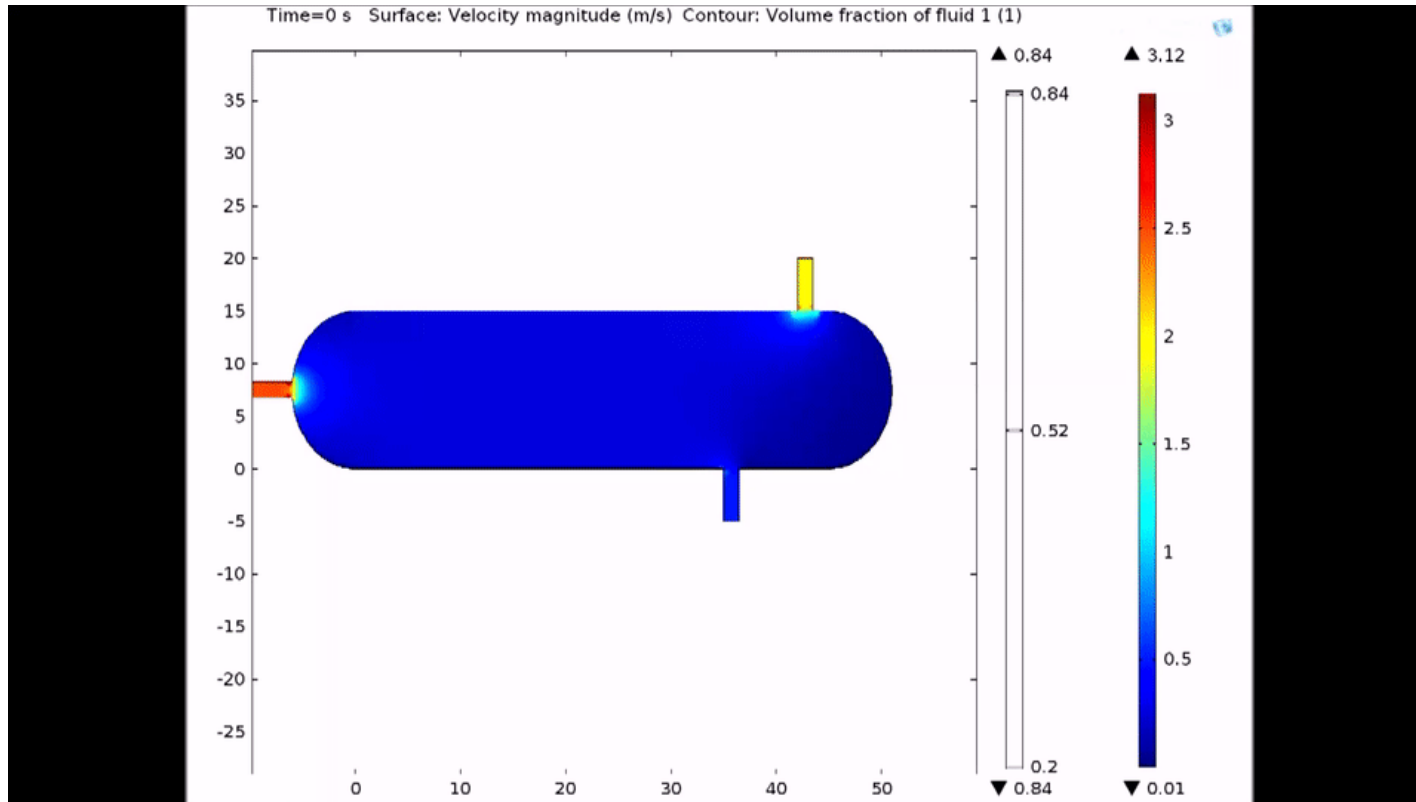
Tracer injection laboratory Experiments



Empty separator with no baffles

Identification of the flow pattern

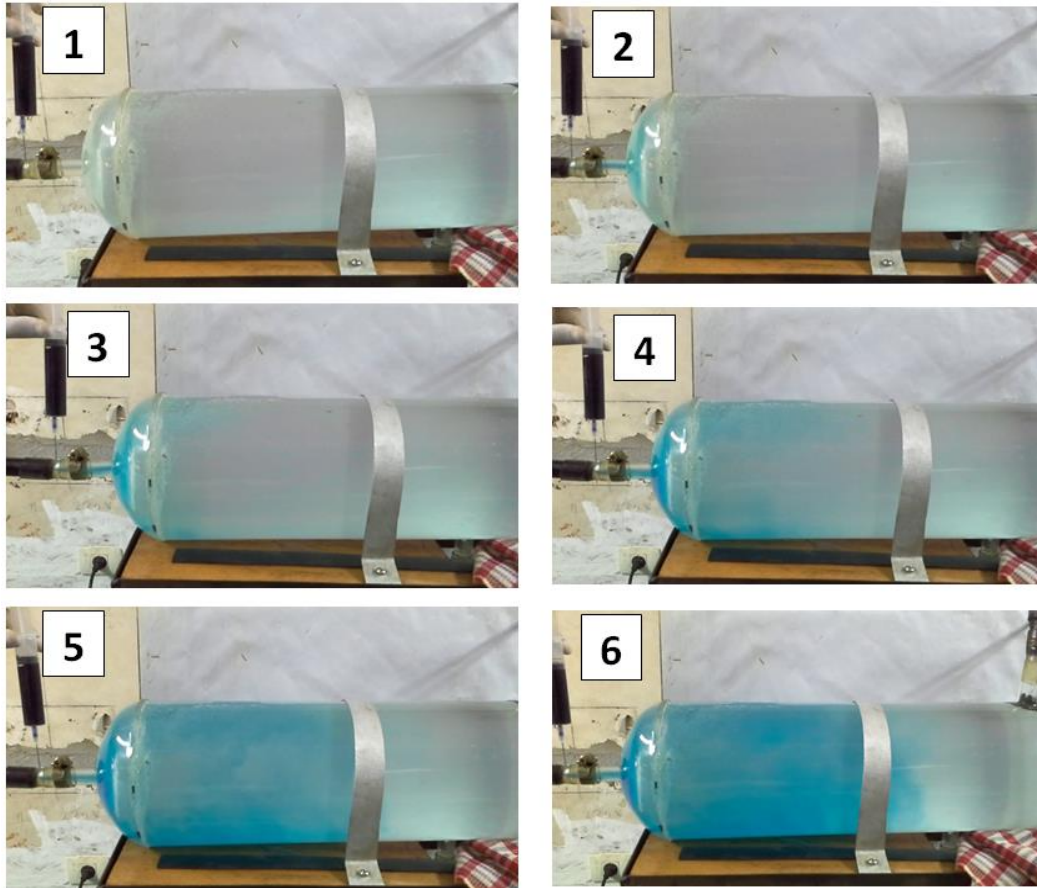
Modeling and simulation



Empty separator with no baffles

Identification of the flow pattern

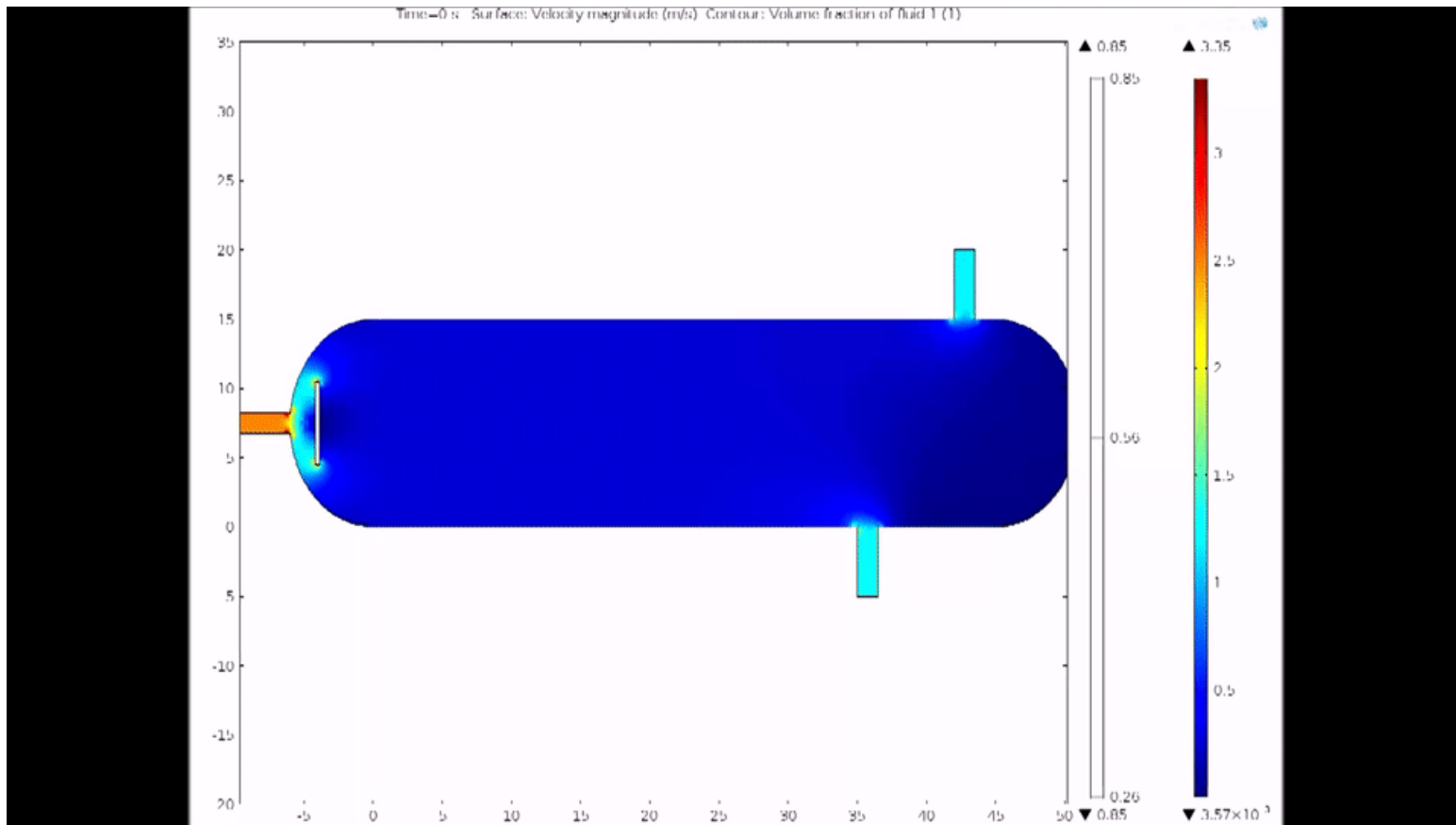
Tracer injection laboratory Experiments



Separator with inlet diverter

Identification of the flow pattern

Modeling and simulation



Separator with inlet diverter

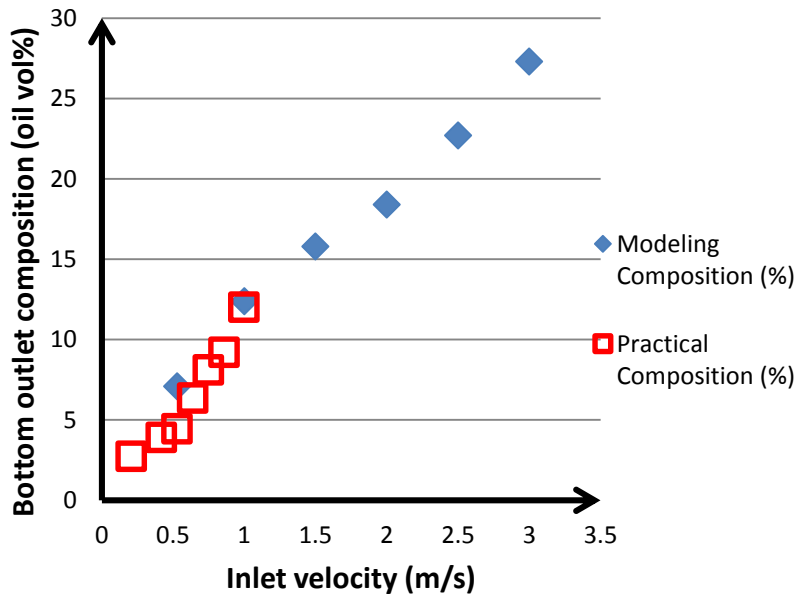
Results and Discussion

$$\% \text{ Reduction in oil composition by Volume} = \frac{\text{Oil Vol\% in the inlet mixture} - \text{Oil Vol\% in the bottom sample}}{\text{Oil Vol\% in the inlet mixture}}$$

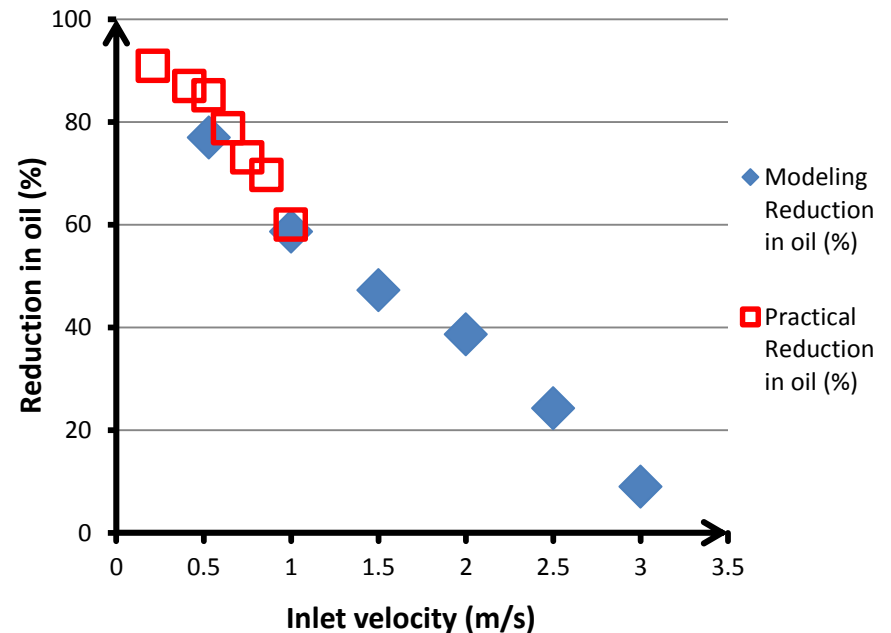
i. Effect of inlet velocity

- Using an inlet composition of 30% oil in water by volume in a separator with no baffles

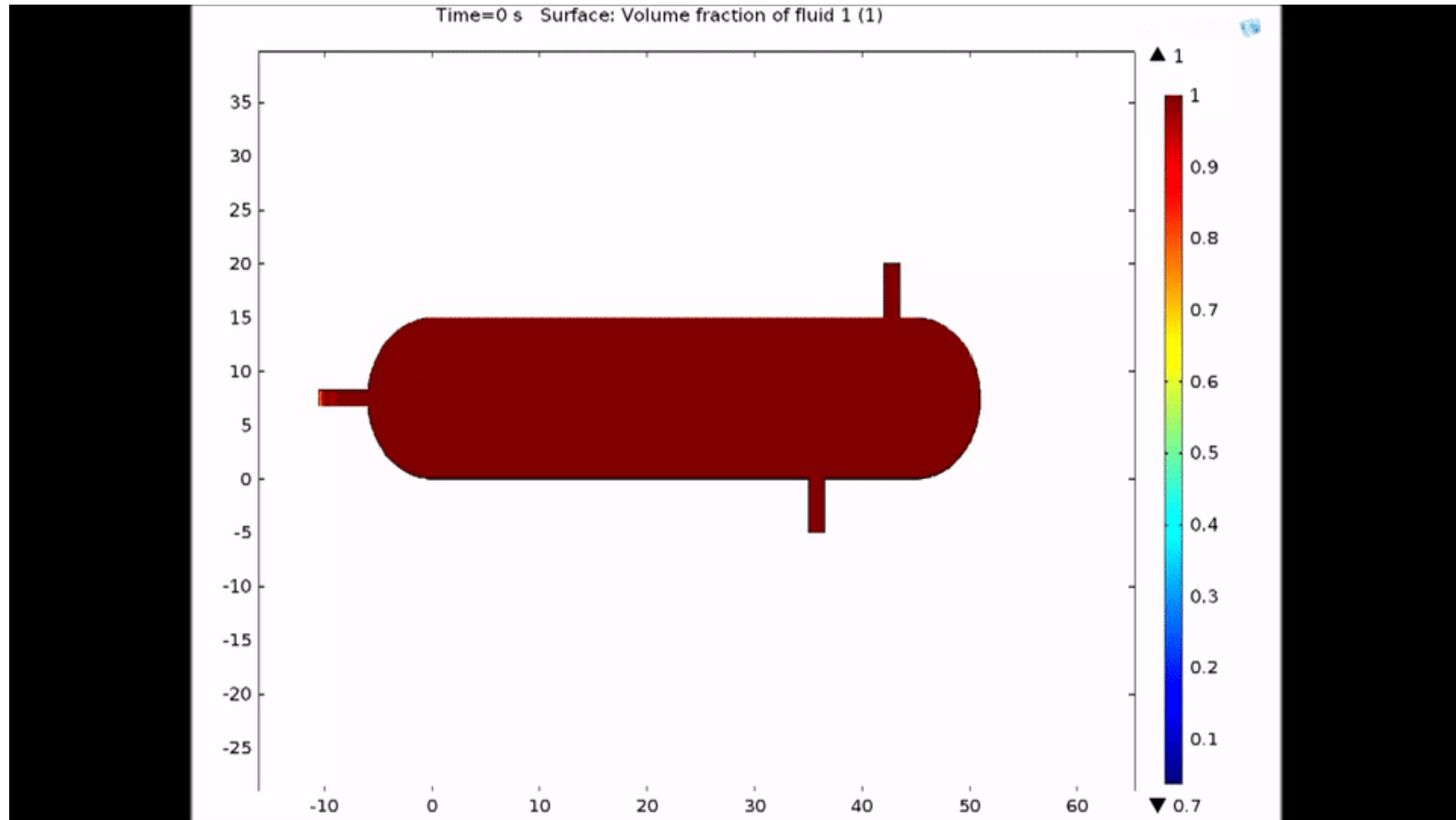
Bottom outlet oil% at different inlet velocities



Reduction in oil composition % at different inlet velocities

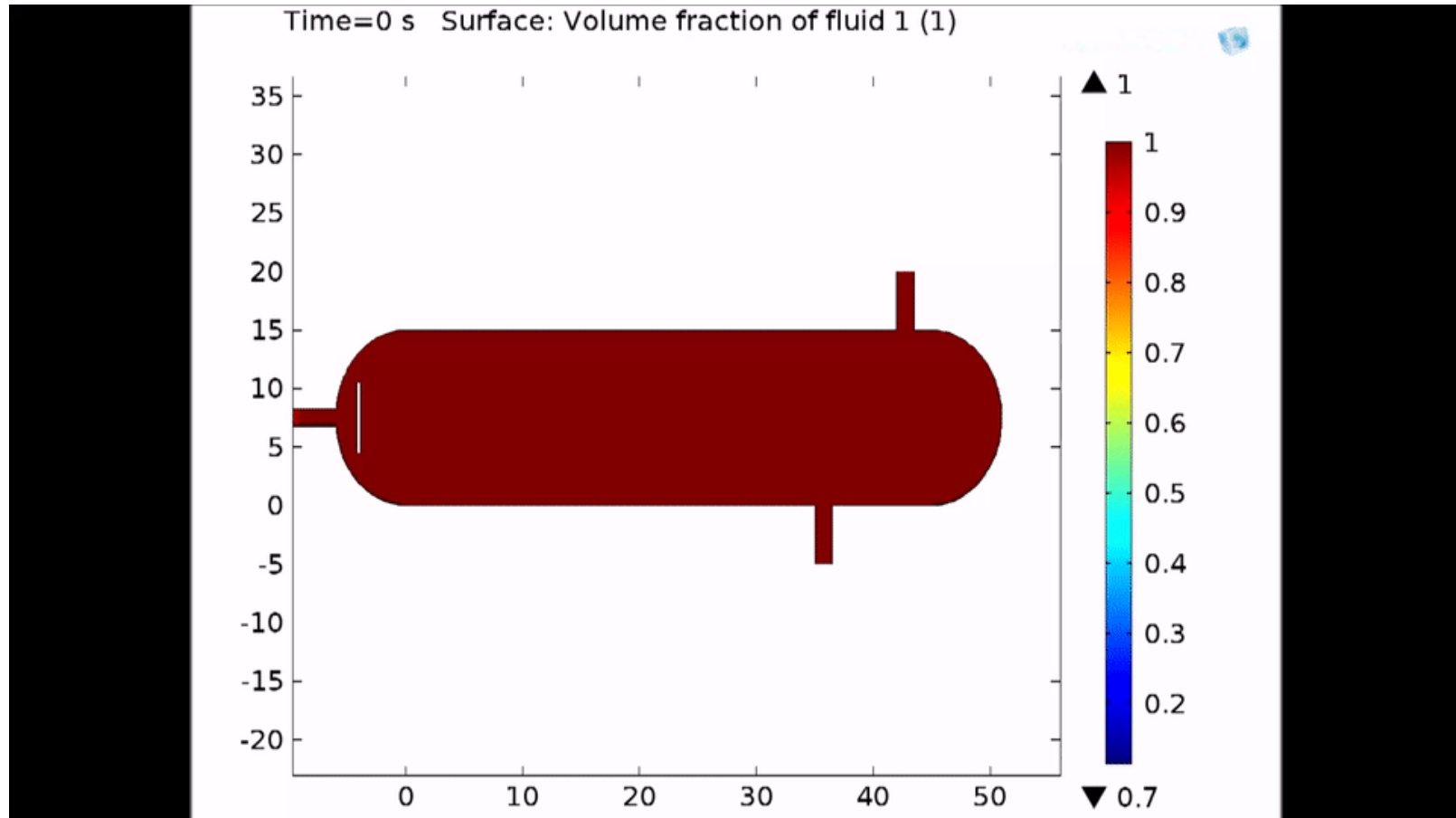


ii. Effect of separator internal design



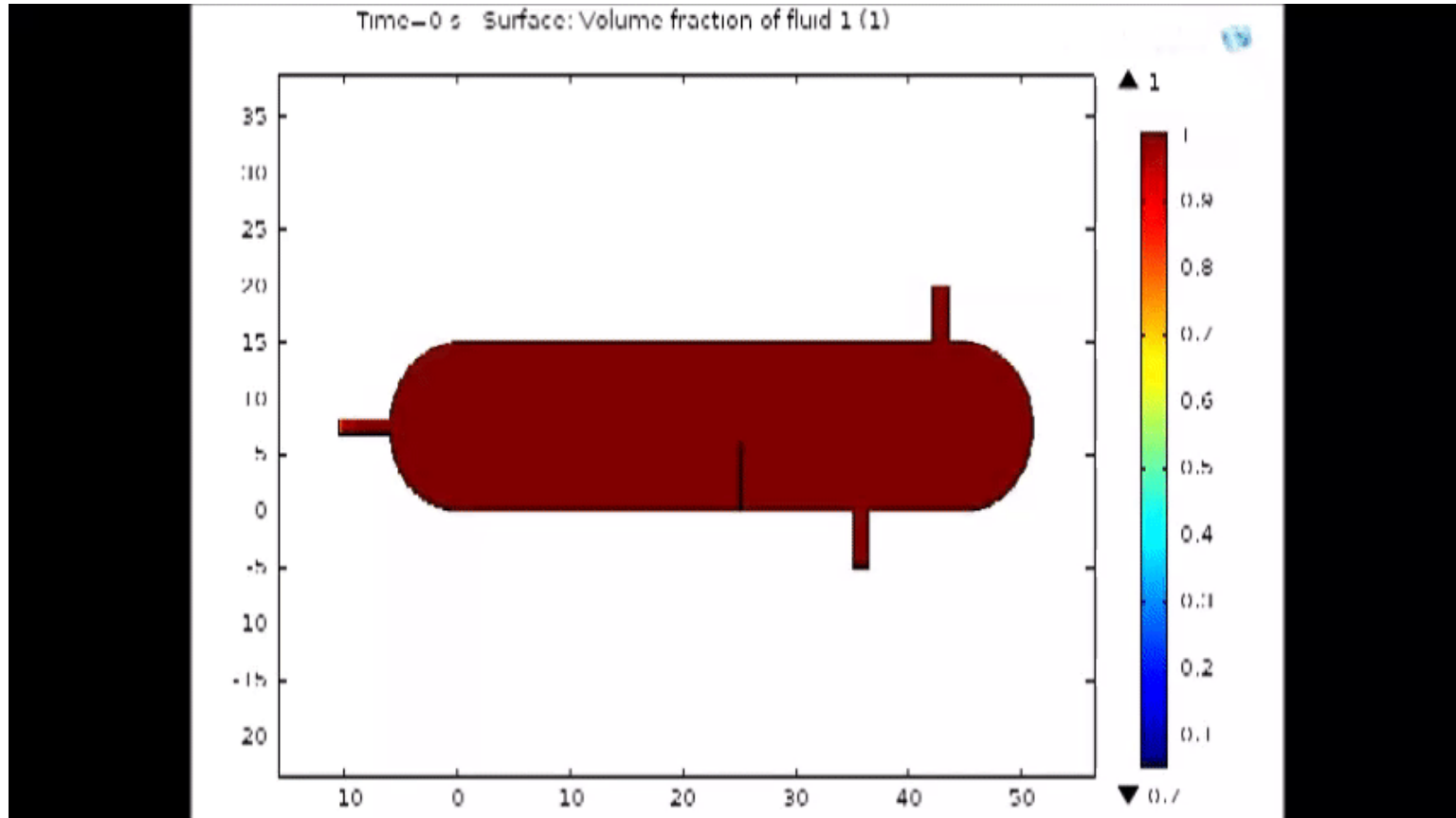
Empty separator with no diverter or any baffles

ii. Effect of separator internal design



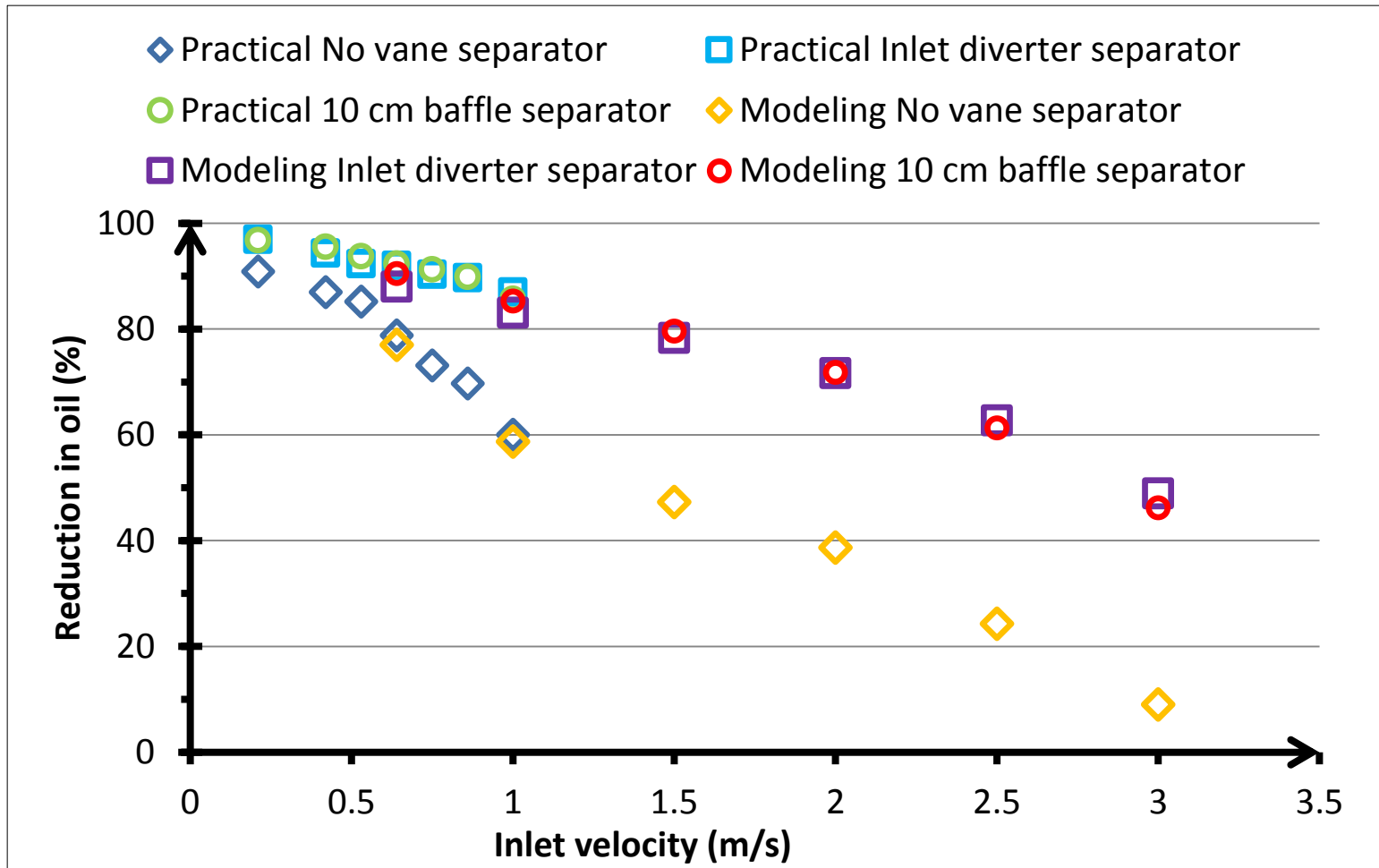
Separator with an inlet diverter

ii. Effect of separator internal design

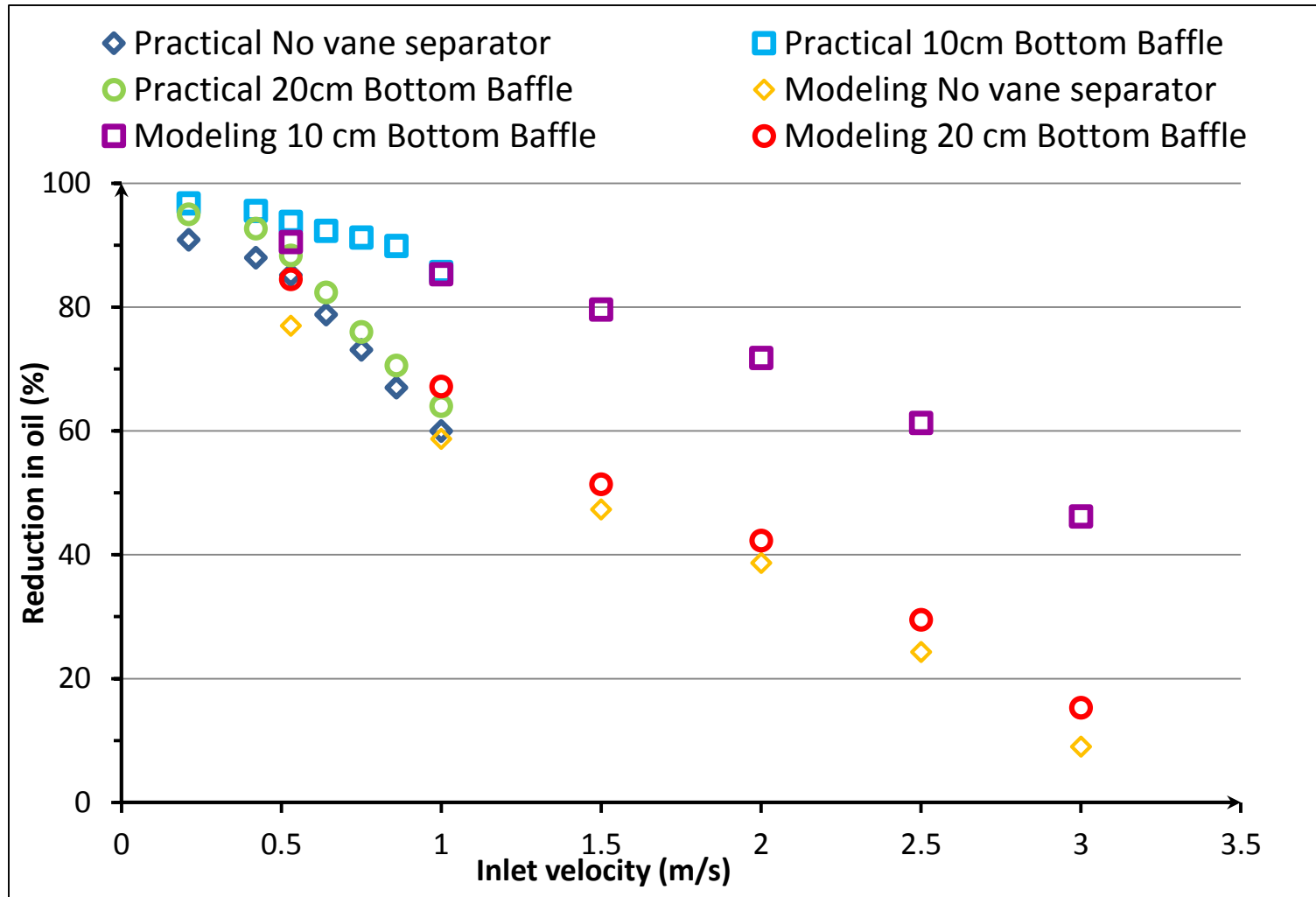


Separator with bottom baffle placed 10 cm ahead of
bottom outlet nozzle

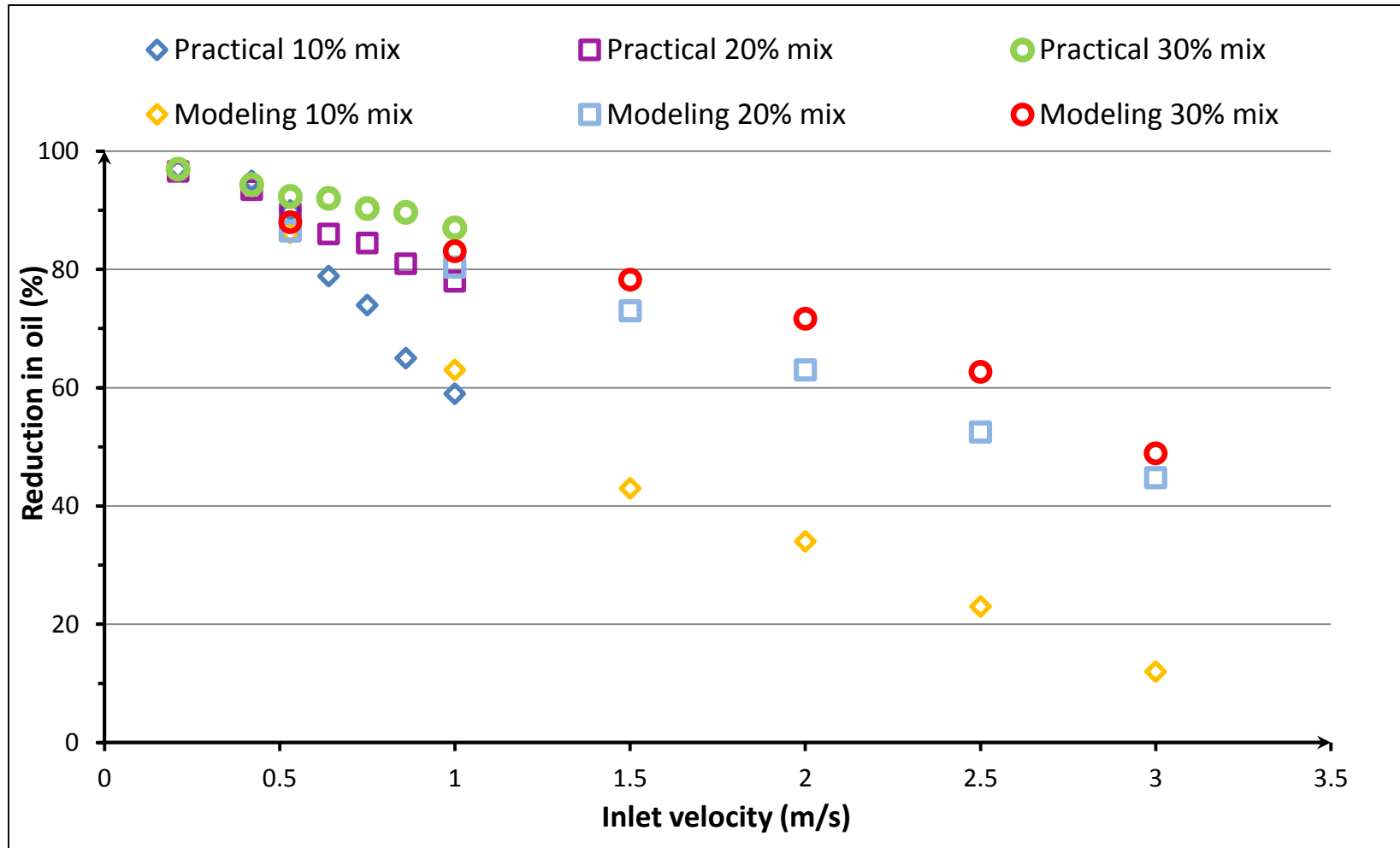
ii. Effect of separator internal design



iii. Effect of bottom baffle location



iv. Effect of inlet mixture composition



Conclusions and Recommendations

Conclusions & Recommendations

- Comsol multiphysics simulations could be used with great confidence to replace the old standard methods or building prototypes before assembling the final separator design.
- The Introduction of an inlet diverter or a baffle plays an important role in enhancing the separation process and offer a cheaper solution to increase the separation efficiency.
- The combination of the inlet velocity and the location of the baffle inside the separator has an important effect on the separation process.
- The mixtures with low oil contents need longer retention times than mixtures with high oil content in order to achieve a similar separation efficiency.

Plans for Future research

- Design of Liquid/Gas separators and their simulations using Comsol multiphysics.
- Design of Three phase (Gas, Oil and water) separators and slug catchers and their simulations using Comsol multiphysics and testing several variables that alter the separation process.
- Study accuracy of 3D simulation in comparison to the 2D simulations for similar separator designs.

Thank you.